Lecture Notes in Networks and Systems 695

Xin-She Yang
R. Simon Sherratt
Nilanjan Dey
Amit Joshi *Editors*

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Lecture Notes in Networks and Systems

Volume 695

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Preface

The Eighth International Congress on Information and Communication Technology will be held during 20–23 February 2023, in a hybrid mode, physical at London, UK and digital platform: Zoom. ICICT 2023 was organised by Global Knowledge Research Foundation and managed by G. R. Scholastic LLP. The associated partners were Springer and InterYIT IFIP. The conference will provide a useful and wide platform both for display of the latest research and for exchange of research results and thoughts. The participants of the conference will be from almost every part of the world, with backgrounds of either academia or industry, allowing a real multinational multicultural exchange of experiences and ideas.

A great pool of more than 1300 papers were received for this conference from across 113 countries among which around 361 papers were accepted and will be presented physically at London and digital platform Zoom during the four days. Due to the overwhelming response, we had to drop many papers in the hierarchy of the quality. Total 46 technical sessions will be organised in parallel in four days along with a few keynotes and panel discussions in hybrid mode. The conference will be involved in deep discussion and issues which will be intended to solve at global levels. New technologies will be proposed, experiences will be shared, and future solutions for design infrastructure for ICT will also be discussed. The final papers will be published in four volumes of proceedings by Springer LNNS Series. Over the years, this congress has been organised and conceptualised with collective efforts of a large number of individuals. I would like to thank each of the committee members and the reviewers for their excellent work in reviewing the papers. Grateful acknowledgements are extended to the team of Global Knowledge Research Foundation for their valuable efforts and support.

I look forward to welcoming you to the 8th Edition of this ICICT Congress 2023.

Amit Joshi, Ph.D.
Organising Secretary, ICICT 2023
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Editors and Contributors

About the Editors

Xin-She Yang obtained his D.Phil. in Applied Mathematics from the University of Oxford. He then worked at Cambridge University and National Physical Laboratory (UK) as a Senior Research Scientist. Now he is Reader at Middlesex University London, Fellow of the Institute of Mathematics and its Application (IMA) and a Book Series co-editor of the *Springer Tracts in Nature-Inspired Computing*. He was also the IEEE Computational Intelligence Society task force chair for Business Intelligence and Knowledge Management (2015–2020). He has published more than 25 books and more than 400 peer-reviewed research publications with over 78,600 citations, and he has been on the prestigious list of highly cited researchers (Web of Sciences) for seven consecutive years (2016–2022).

R. Simon Sherratt was born near Liverpool, England, in 1969. He is currently a Professor of Biosensors at the Department of Biomedical Engineering, University of Reading, UK. His main research area is signal processing and personal communications in consumer devices, focusing on wearable devices and health care. Professor Sherratt received the 1st place IEEE Chester Sall Memorial Award in 2006, the 2nd place in 2016 and the 3rd place in 2017.

Nilanjan Dey is an Associate Professor at the Department of Computer Science and Engineering, Techno International New Town, India. He is Editor-in-Chief of the *International Journal of Ambient Computing and Intelligence*; a Series co-editor of *Springer Tracts in Nature-Inspired Computing* (STNIC), *Data-Intensive Research* (DIR), Springer Nature; and a Series co-editor of *Advances in Ubiquitous Sensing Applications for Healthcare*, Elsevier. He is a fellow of IETE and a Senior Member of IEEE.

Amit Joshi is currently the Director of Global Knowledge Research Foundation, also an Entrepreneur and Researcher who has completed his Masters and research in

the areas of cloud computing and cryptography in medical imaging. Dr. Joshi has an experience of around 10 years in academic and industry in prestigious organisations. Dr. Joshi is an active member of ACM, IEEE, CSI, AMIE, IACSIT-Singapore, IDES, ACEEE, NPA and many other professional societies. Currently, Dr. Joshi is the International Chair of InterYIT at International Federation of Information Processing (IFIP, Austria). He has presented and published more than 50 papers in national and international journals/conferences of IEEE and ACM. Dr. Joshi has also edited more than 40 books which are published by Springer, ACM and other reputed publishers. Dr. Joshi has also organised more than 50 national and international conferences and programs in association with ACM, Springer, IEEE to name a few across different countries including India, UK, Europe, USA, Canada, Thailand, Egypt and many more.

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Knowledge Management in Integrated Media for Public Relation on Innovative Thai Cuisine to Global Market Project

Nattaphon Rampai, Narong Sompong, Cherdpong Kheerajit, and Sarinya Paisarnsombat

Abstract Thai cuisine to global market is the one of important projects to drive economic sector in Thailand, especially in gastronomy food promoting activity. This research aims to (1) study knowledge in Thai cuisine innovation to global market research projects for public relations through integrated media technology, (2) investigate the tourists' Thai food media exposure behavior, and (3) study satisfaction's audiences toward the Thai food integrated media. The participants were 130 chefs and tourists in Republic of China and United States of America. Methodology included qualitative and quantitative research methods. The results showed that the contents for public relations though integrated media technology from the 16 research projects could be categorized into three groups: (1) Thai innovation for health concern and elders, (2) Thai herbs and Thai food business, and (3) Thai food lunch for students. In case of the media exposure behavior, there were the differences among the various audiences that depend on the digital technology platforms such as mobile application and website database engaged to the laws and environment context of media using and the characteristics of the audiences. The overall satisfactions toward the integrated media of the audiences in both countries were at high level. The audiences in both countries had satisfaction in using convenient and the clarity of contents at the very high level. The research exhibited the suitable integrated media for public relations of Thai food to the target audients in both countries.

Keywords Integrated media · Knowledge management · Media exposure

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1 Introduction

Thai cuisine to global market is the one of strategic plan to drives economic both locally and nationally. Thailand is an agricultural country, in which agricultural products have been domestically consumed and exported to global market. Many of Thai food innovations that produced and promoted through Thai food media campaign [1]. The National Research Council of Thailand (NRCT) has supported the research project on Thai Food to Global since 2002. This research focuses on knowledge management on health benefit and nutrition of Thailand, which is corresponding to one of the Thai Government's policies on promoting Thai food to world [2], including a variety of food and cultural knowledge. Food gastronomy and tourism strategy should be enhanced to value of nature, tradition, culture, and history that related to Thai food service personnel, especially in the raw material production system to the world market [3]. Thai chefs can set menus for tourists who will receive useful knowledge to help them providing the authentic gastronomy food and rearrange to the customers. Thus, most of the research focus on strategic planning for public relations of Thai food in other countries such as suitability of integrated media and channel for different age target group, type of media specified for target group, and media assessment, which are necessary to achieve a goal of public relations of Thai food to global market [4], especially, in Thai food for tourism and the sustainable economy. Thai food has the uniqueness in taste and is dominant differing from the other countries in the world and could be a part of cultural identities accumulation since the ancient time [5]. Thailand's strategic plan focuses on the sustainable tourism that contributed to compete among the Asian Economic Community (AEC) countries. The creation of new knowledge is a spiraling process of interactions between explicit and tacit knowledge [6]. A knowledge management in integrated media for public relations on innovative Thai cuisine to global market project would be useful for stakeholders who could be collecting, learning, and sharing the Thai cuisine knowledge through website, video, mobile application, and printed media with AR technology [7]. Therefore, this research would find out and manage the knowledge on innovative Thai cuisine for tourists and the business sectors to global market.

2 Objectives

This research aims to (1) study knowledge in Thai cuisine innovation to global market research projects for public relations through integrated media technology, (2) investigate the tourists' Thai food media exposure behavior, and (3) study satisfaction toward the Thai food integrated media of the audiences in Republic of China and the United States of America.

3 Methodology

3.1 Population and Samples

The samples of this study were 130 foreign tourists in China and the United States of America; researchers use accidental random samplings to identify into two groups: 100 tourists at the Lu One Tower in Shanghai, Republic of China, and 30 tourists at International Culinary School (ICC) in New York City, United States of America; in this research, we called participants.

3.2 Research Tools

There were three research tools which have been developed for the study including (1) media exposure behavior of media consumers questionnaire using five-level rating score (1.00 = strongly disagree, 2.00 = disagree, 3.00 = moderate, 4.00 = agree, 5.00 = strongly agree), (2) integrated media for public relations of Thai food innovation including integrated media: mobile application, website database, video and printed media with AR technology, and (3) media consumer satisfaction survey, with four-level rating score (0.0–0.99 = low, 1.00–1.99 = moderate, 2.00–2.99 = high, 3.00–4.00 = very high), on the integrated media.

3.3 Research Procedure

1. First stage: Researchers study the knowledge of Thai food technology from 16 research projects on Thai food to global market by using knowledge management: KM process composed of five steps to manipulate: step 1—explore and capture; step 2—identify and organize; step 3—exchange and apply; step 4—transfer and share, and step 5—collect and store [7]. There projects were reviewed and verified by the focus group consisted of 13 experts in engaged fields, then, the integrated media had been developed using the verify knowledge. In this stage, appropriate media were identified and selected to integrate with the proper activities and events including integrated media: mobile application, website database, video and printed media with AR technology based on their needs and purposes. After that all of media prototype had been tested to the foreign tourists who were the target audiences in Thailand at the Nongnooch Tropical Garden in Pattaya, Chonburi and Phuket Province. There were 249 tourists participated in the try-out stage, and the revision of the media was implemented and used in the next stage.
2. Second stage: The integrated media was applied for knowledge transfer as the public relations on Thai food in China and the United Stated of America. The

target audiences composed of 130 chefs and tourists' participants who interested in Thai food cooking and attended the "Thai Food Festival" in both countries. They had participated in the Thai food cooking accompanying with media exposure to each media. Accidental random samplings method was used to identify the participants into two groups: 100 tourists at the Lu One Tower in Shanghai, Republic of China, and 30 tourists at International Culinary School (ICC) in New York City, United States of America.

3. Finally, at the third stage, researcher evaluated their satisfaction of the target audiences by using the questionnaires. The instruments were Thai food innovation integrated media: mobile application, website database, video and printed media with AR technology, media exposure behavior on public relations media of Thai food to global market questionnaires, and audience's satisfaction in both countries.

3.4 Data and Statistical Analysis

Descriptive statistical analysis including percentage, average, and standard deviation (S.D.) was used to analyze data collected from the survey on the media exposure behavior. Analysis of the public relations was performed using a four-level rating score media consumer satisfaction survey. Descriptive statistical analysis (i.e., percentage, average, and standard deviation: S.D.) was used for data analysis.

4 Results

4.1. The knowledge in Thai cuisine shows transforming the knowledge from tacit knowledge to the explicit knowledge on Thai food innovation from every research project granted by the NRCT research projects using an in-depth interview with principal investigation of the 16 projects on Thai food to global market, followed by knowledge identification and content analysis. As a result, the content can be categorized into two groups: (1) Thai food innovation for health concern and elders and (2) Thai herbs and Thai food business. The content was published into four types of online media including (1) website database contains content on project information, Thai food recipe, nutrition of Thai vegetable and herbs, and product from Thai food innovation; (2) Mobile application presents Thai food recipe and cooking instruction and introduces Thai food restaurant in other countries and Thai food innovation product; (3) Motion infographic video illustrates Thai food business model, Thai food cooking demonstration, and introduction to Thai food innovation; (4) Infographic with augmented reality (AR) and E-book for public relations of Thai food, including documents, and recipe book especially in infographic on nutritional fact of Thai food products (Figs. 1, 2, 3 and 4).

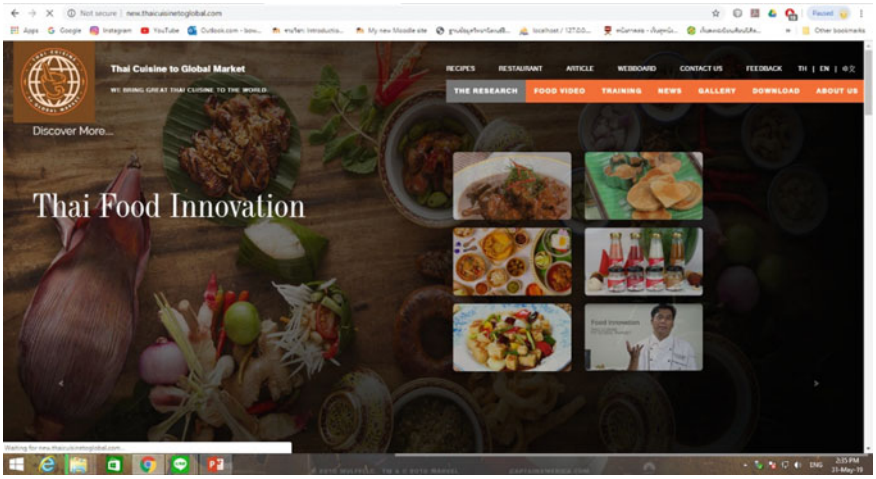

Fig. 1 Website database

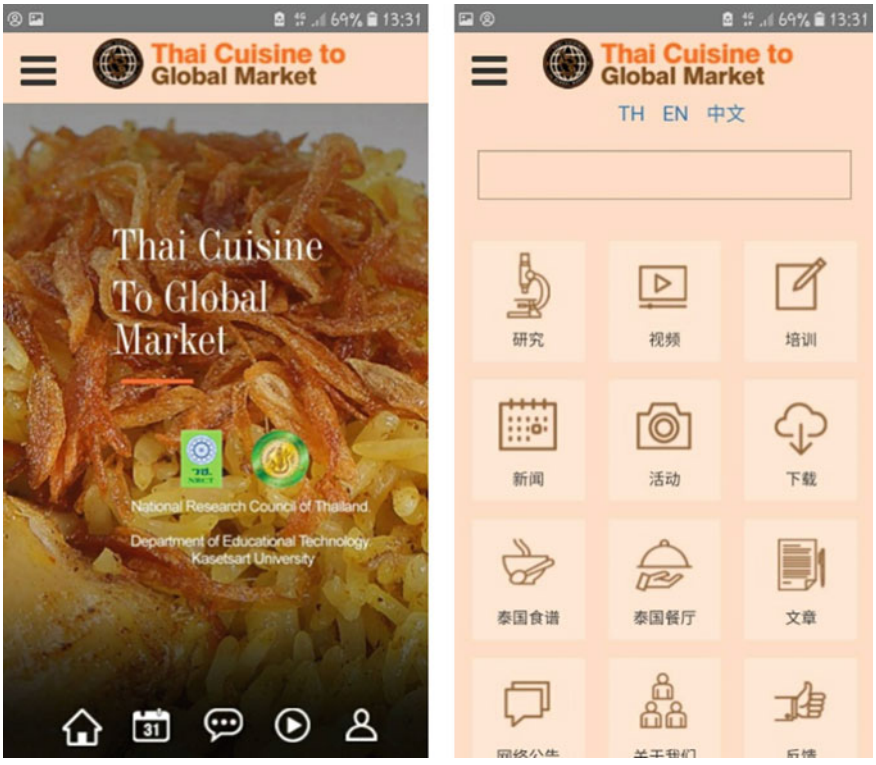

Fig. 2 Mobile application

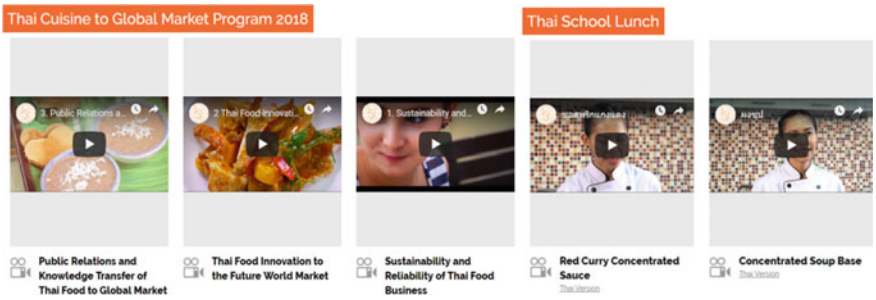

Fig. 3 Motion infographic video

Fig. 4 Infographic with augmented reality (AR) and E-book

4.2. Thai food media exposure behavior of the tourists: The study of the needs in Thai food information and contents of 249 Chinese tourists and other foreigners showed that they mostly needed Thai food information from the mobile phone application, tablet, and iPad that might be easier to let them access to various applications and social media such as Facebook and YouTube more than the non-mobile media; however in case of Chinese tourist, they needed the special local platform that were Baidu Web browser and Search Engine, Youku video online, WeChat, and WhatsApp. Chinese tourists like to search about Thai food innovation following vegetables and herbs, but the other foreign tourists needed authentic Thai cuisine and nutrients information. They mostly tried to find out contents on Thai food menu, ingredients, and Thai recipes through website. From their media exposure behavior of the target audiences in global market, they suggested that because of the language problem of Chinese tourists, the media presentation should be provided in English and Chinese version on every media and onsite display exhibition in China and other countries. Moreover, Thai agency should give the information on Thai street food to foreign tourists as well. In addition, five experts suggested about Thai food to global market depending on audience's behavior as follows.

(1) Thai food public relation format and Thai food knowledge transfer: The big issues should be handled on "Thai Food for Health" or "Thai medical food" because the trend of people in the world was interested in healthy food consumption, nutrition value, and food aging extension. Presentation format was in modernized online media and keeps it interesting.
(2) Thai food public relation strategies to global market: The tourism activities should open for tasting Thai food in Thai food festival, inbound and outbound tourism; this was giving direct experience and good attitude in Thai food. The activities included to invite the representative cooperation from mass media, blogger, influencer, and Website on Thai cuisine and Gastronomy. Government agency such as commercial consulate and private business sector of hotel and chef association . Lastly, all integrated media should be translated and delivered in Thai, English and Chinese language version.
(3) Integrated media application for public relation and knowledge transfer to global market: The media contents should be concise and suitable which is emphasizing the ingredients' value and product usefulness from Thai food consuming. Every digital and printed material should put QR and AR code which the audience could be accessible to every type of media by themselves through smart phone. Infographic was updated and suitable for research presentation. Video should have the content compact and shortage 3–5 min which the audiences were accessible through website and applications.

4.3. Satisfaction toward the Thai Food integrated media of the audiences in Republic of China and the United States of America: After the integrated media had been developed and testing at Nong Nooch Tropical Garden in Pattaya, Chonburi, and the Blue Elephant Restaurant in Phuket Province, the researchers had implemented the media prototype on Thai food Festival at International Culinary School (ICC) in New York City, USA, during March 26–28, 2019, and The Essence of Thainess at Lu One Tower Shopping Center, Shanghai, Republic of China, during April 16–23, 2019. The respondents composed of 30 people in New York and 100 people in Shanghai.

In Table 1, the result indicated the satisfaction of American audiences toward the integrated media when they had learned from each media almost at very high level in every issues. Otherwise, the result indicated the satisfaction of Chinese audiences toward the integrated media when they had learned from each media almost at very high level in every issues. Anyway, in case of database, website in computer graphic issue and application in easy access to the information issues have the highest rank.

In Table 2, the result indicated the satisfaction of American audiences toward the content of integrated media in case of clarity of the content, interest of the content and suitable content when they had learned from each media almost at very high level in every issues, respectively. In media application issues, the audiences satisfied mostly on the very high level. In each item, there were media that can be publicized for public relations, easy access to media, and its application, and media can be used as reference and overall integration of the media, respectively. Otherwise, the satisfaction of Chinese tourists toward the contents in case of clarity of content issue

Table 1 Satisfaction of American and Chinese tourists toward the integrated media on innovative Thai food

Assessment topics	American (n = 30)		Chinese (n = 100)		Meaning
	$\overline{x}$	S.D	$\overline{x}$	S.D	
1. Video					
– Interests of sound and computer	3.67	0.65	3.17	0.52	Very high/very high
– Presentation technique	3.59	0.66	2.96	0.72	Very high/high
Database website					
– Easy access to the information	3.66	0.57	3.10	0.54	Very high/very high
– Computer graphic	3.59	0.62	3.25	0.75	Very high/very high
Printed media (AR)					
– Computer graphic	3.59	0.58	3.04	0.60	Very high/very high
– Suitable content and picture	3.59	0.67	3.02	0.65	Very high/very high
Application					
– Easy access to the information	3.63	0.57	3.25	0.63	Very high
– Suitable content in each menu	3.55	0.70	2.75	0.82	Very high/high

Table 2 Satisfaction of American and Chinese tourists toward the contents and media application of integrated media on innovative Thai food

Assessment topics	American ($n = 30$)		Chinese ($n = 100$)		Meaning
	$\overline{x}$	S.D	$\overline{x}$	S.D	
2. Contents					
– Clarity of the content	3.64	0.53	3.33	0.59	Very high/very high
– Interest of the content	3.63	0.57	3.27	0.63	Very high/very high
– Suitable content	3.61	0.67	3.18	0.52	Very high/very high
– Suitable content sequence	2.79	0.62	3.02	0.65	High/very high
3. Media application					
– Media can be publicized for public relations of Thai food	3.36	0.51	3.34	0.54	Very high/very high
– Easy access to media and its application	3.50	0.82	3.27	0.61	Very high/very high
– Media can be used as reference for Thai food research	3.14	0.59	3.10	0.67	Very high/very high
– Overall integration of the media	3.08	0.61	3.02	0.69	Very high/very high

was the highest rank at very high level. And the media application indicated that overall integration of the media has the highest rank.

5 Conclusion and Discussion

1. Knowledge management process in Thai cuisine: As a result, the content can be categorized into two groups: (1) Thai food innovation for health concern and elders and (2) Thai herbs and Thai food business. The content was published into four types of online media including (1) database website contains content on project information, Thai food recipe, nutrition of Thai vegetable and herbs, and product from Thai food innovation, (2) motion infographic video illustrates Thai food business model, Thai food cooking demonstration, and introduction to Thai food innovation, (3) application presents Thai food recipe and cooking instruction, introduces Thai food restaurant in other countries and Thai food innovation product, and (4) infographic with augmented reality (AR) and E-book for public relations of Thai food, documents, and recipe book as well as infographic on nutritional fact of Thai food products by using knowledge management: KM process [4].
2. Thai food media exposure behavior of the tourists showed that they mostly needed Thai food information from the mobile phone application, tablet, and iPad that might be easier to let them access to various applications and social media such as Facebook and YouTube more than the non-mobile media; however

in case of Chinese tourist, they needed the special local platform that were Baidu Web browser and Search Engine, Youku video online, WeChat, and WhatsApp. Chinese tourists like to search about Thai food innovation following vegetables and herbs, but the other foreign tourists needed authentic Thai cuisine and nutrients information. They mostly tried to find out contents on Thai food menu, ingredients, and Thai recipes though website. The big issues should be handled on "Thai Food for Health" or "Thai medical food", and the tourism activities should open for tasting Thai food in Thai food festival, inbound and outbound tourism, this was giving direct experience and good attitude in Thai food, and finally the media contents should be concise and suitable which is emphasizing the ingredients' value and product usefulness from Thai food consumption [1].

3. Satisfaction toward the Thai food integrated media of the audiences in Republic of China and the United States of America: The result indicated the satisfaction of American audiences toward the integrated media when they had learned from each media almost at very high level in every issues. In media application issues, the audiences satisfied mostly on the very high level. In each item, there were integrated media that can be publicized for public relations, easy access to media, and its application, and media can be used as reference and overall integration of the media, respectively [2].

6 Recommendations

6.1. Benefits from the research can promote and consist of Thai food recipe, nutrition of Thai vegetable and herbs, and products.

6.2. Exchange and sharing community reflect on guideline ideas between the local and global sector with a focus on participate and collaborate with local knowledge that can be used to search for food knowledge in online community.

6.3. Tourism can take advantage of Thai food business model, Thai food cooking demonstration, and introduction to Thai food innovation through the integrated media technology.

6.4. Thai food business sector can use the guidelines to integrated media to enhance public relations platform for tourists that using the knowledge management: KM process to integrate media package with appropriated and meet the needs of tourists.

6.5. Relevant Thai food agencies should design and produce the digital contents that contained in the integrated media in terms of digital contents which is always interesting and appropriate use of public relations network.

6.6. Government sector and policy makers should make a policy and budgets to promote long-term development plans of gastronomy food for tourists with the community, according to the policy maker.

6.7. Policy maker should be promoting the strategic application of integrated media by using based on KM process as the content-based for media production and development.

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Emotion Recognition Using Electroencephalogram Signals and a 1D Local Binary Pattern for an ML-Classification-Based Approach

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Abstract Machine learning techniques provide low complexity in classification algorithms and feature analysis. In the emotion recognition area, these techniques have reduced their impact with the development of deep learning. Taking advantage of low-cost machine learning models, in this study, we introduce a novel method for emotion recognition using electroencephalographic signals and a local binary pattern to extract the periodicity of a signal and apply a feature extraction algorithm. Five emotions are classified with a support vector machine using a feature matrix reduced using a minimum redundancy maximum relevance algorithm, obtaining the first, homogeneity, and spectral roll-off as the best emotion descriptors. The resulting model is evaluated using accuracy, recall, precision, and F1-score for 10-cross-validation folders. Achieved results are compared with the existing literature showing high performance in the machine learning approaches.

Keywords Emotion recognition · Electroencephalogram · LBP · MRMR · SVM

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1 Introduction

Emotions are a fundamental research topic on digital signals and image processing for developing models based on artificial intelligence (AI). Authors in [17] established the term "affective computing" as a reference to emotion processing based on interpreting and recognizing human affective environments.

Two of the most popular approaches in the emotion recognition (ER) area using EEG signals are based on the development of models for the classification of primitive and discrete emotions. Primitive emotions are based on the valence and arousal classification [19] for emotion levels, whereas in [7], authors establish that emotions can be expressed as mutually orthogonal vectors of valence and arousal. Valence is the affect in response to stimuli, and arousal is the component of the degree of stimuli reaction. Studies on a positive, negative, and neutral (PNN) emotion classification are recently proposed as an alternative to the primitive and discrete emotion classification by inferring a global advantage, using a ternary classification method [18]. There are approaches to discrete ER ("happy", "sad", among others) prediction or classification using different signal processing methods and classification algorithms [9]. Some methodologies propose the Fourier transform [1, 2], wavelet transform [3, 11], and empirical mode decomposition [4, 15] as kernel, then a feature extraction algorithm is performed. Our approach analyzes and processes EEG signals for discrete emotion classification by applying a periodicity extraction algorithm. The classification task is developed through a machine learning-based algorithm with 10-cross-validation folders. Section 2 describes the state-of-the-art applied to emotion recognition. Section 3 presents the methodology implemented for EEG signal processing, followed by a description of the obtained results in Sect. 4. Section 5 is a discussion, and Sect. 6 presents the conclusions of this study.

2 State-of-the-Art

The ER area has shown different research approaches proposing a wide variety of AI methodologies. Classical ML algorithms have achieved competitive results compared to DL methods. For instance, in [4], a support vector machine (SVM) is used to classify two features, differential entropy (DE) and mutual information (MI), calculated from the EEG filtered signals by the intensive multivariate empirical mode decomposition (iMEMD) for SEED and DEAP datasets. For the SEED dataset, a ternary classification achieved 96.3%, while the DEAP model achieved 81.1% accuracy for four classes. In addition, in [8], an SVM is employed to achieve a ternary classification, with a flexible analytic wavelet transform (FAWT) to extract information potential features in EEGs from fusion SEED and DEAP datasets, achieving 90.48% accuracy. The SVM has been widely used in the classification of discrete and primitive emotions. In [9], a discrete wavelet transform combined with empirical mode decomposition (DWT-EMD) performs the signal processing. Some models for primitive emotions are presented in [13, 15]. For primitive emotions, in [15], the

DEAP dataset is used achieving an accuracy of 86.46% and 84.90%. In [13], a power spectrum (PS) feature extraction method based on the short-time Fourier transform (STFT) is developed for positive and negative emotions, achieving an accuracy of 86.63%.

Some methodologies have been developed applying the LBP [16] idea for signal processing, defining the 1D-LBP. In [10], feature extraction from wavelet decomposition coefficients by the LBP-EEG is used for an epilepsy diagnosis. This epilepsy recognition model presents a binary classification method where a normal or epilepsy event is presented in EEG signals. Similarly, in [6], a subject-independent method using a 1D-CNN is proposed. The technique applies a feature extraction and reduction to the 1D-LBP and 1D local ternary pattern (1D-LTP). The patterns are used to classify the ECG audio signals for multiclass abnormal heart disease and normal and abnormal heart conditions. This approach achieved 91.66% for the multiclass and 91.78% for the binary model, respectively. A binary human recognition (HR) classification method is developed in [12] for the movement measures to detect if subjects are female or male. Eight different subjects, four women and four men perform a set of 19 different movement trials, collecting the signals from a triaxial gyroscope, accelerometer, and magnetometer sensors. A 1D-LBP algorithm is applied to acquired signals, and an 88.46% accuracy rate is achieved with a K-nearest neighbors (KNNs) algorithm. Thus, it can be concluded that algorithms based on LBP applied to physiological or non-physiological signals show high performance in AI models.

Considering the non-stationary behavior of EEG signals as a challenge in classifying ML-based algorithms, this research proposes a human emotion classification using the SEED-V dataset for five emotions. An LBP and classical ML algorithms are applied to EEG signals acquired from 62-channels for 16 subjects that perform three times the emotional stimuli. In the following sections, the proposed methods and results are described.

3 Methodology

This paper's approach aims to classify human emotions using EEG signals from the SEED-V dataset. Each EEG signal is processed by LBP. Then, feature extraction is applied to the LBP-EGG signals to obtain a classification model. A general diagram is shown in Fig. 1. The prediction plot is used for illustrative purposes only.

The SEED-V dataset [14] records the bioelectrical encephalographic data from 16 test subjects based on emotional stimuli measured three times per subject. Each subject is stimulated with 15 experimental movie clips resulting from five different emotions in three experiments. Electroencephalographic activity is acquired and stored by an electrode headband, placed on the scalp surface, instrumented with 62 electrode channels under the 10–20 system configuration. The simulated emotions are "happy", "sad", "disgust", "neutral", and "angry". Summarizing the total number of EEG signals available in the dataset is 44, 640, from 16 test subjects, 3 repetitions per subject, 15 stimuli, and 62 electrode channels at a sampling period 1000 Hz.

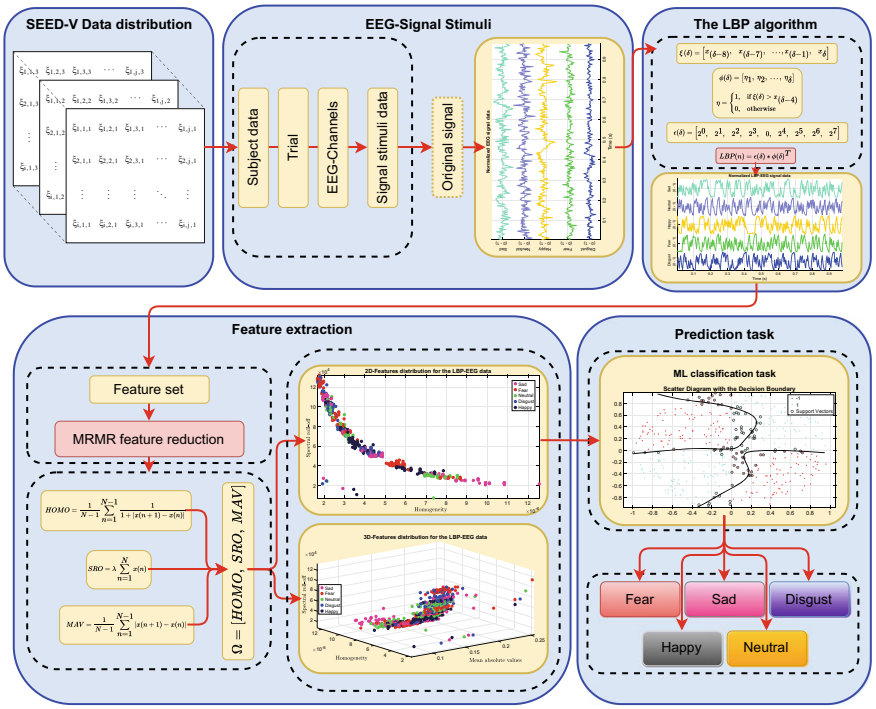

Fig. 1 General methodology in our approach

3.1 1D Local Binary Pattern Algorithm

The non-stationary behavior of EEG signals requires deeper processing to achieve an accuracy rate to compete with the AI models in the state-of-the-art, where some superior ones exceed 90% accuracy by performing feature extraction. In our approach, an LBP-EEG is proposed to compute, from the EEG signal vector $x(n)$ of length N, a data vector that models the periodicity of the original signal, where $n = [1,\ 2,\ \ldots,\ N]$. First, a sliding window of size $\delta = 9$ is used, yielding $\xi(\delta)$ as shown in (1). The next equations compute the first case where $\xi\ (\delta) = \left[x_{(\delta-8)},\ \ldots,\ x_{(\delta)}\right] = \left[x_{(1)},\ \ldots,\ x_{(9)}\right]$. For the second case $\xi\ (\delta) = \left[x_{(2)},\ \ldots,\ x_{(10)}\right]$, and so on.

$$\xi\ (\delta) = \left[x_{(\delta-8)},\ x_{(\delta-7)},\ \ldots,\ x_{(\delta-1)},\ x_{\delta}\right] \tag{1}$$

The mid-value, $x_{(\delta-4)}$, from vector $\xi\ (\delta)$ is used as threshold for all the coefficients in $\xi\ (\delta)$, resulting the function $\phi\ (\delta)$ defined in (2), according to (3).

$$\phi\ (\delta) = \left[\eta_1,\ \eta_2,\ \ldots,\ \eta_{\delta}\right] \tag{2}$$

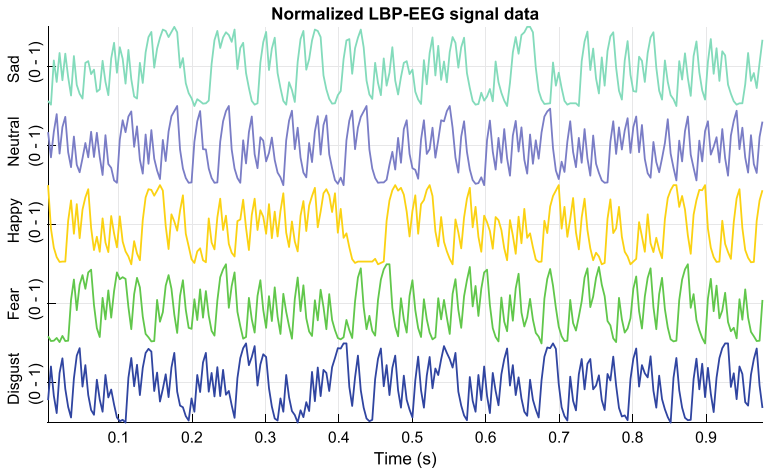

Fig. 2 EEG data periodicity using the LBP algorithm

$$\eta = \begin{cases} 1, & \text{if } \xi(n_\delta) > x_{n+(\delta-4)} \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

Then, a vector $\epsilon\ (\delta)$ is declared in (4) as an 8-bit chain code, appending a central zero value, to achieve an inner product with the $\phi\ (\delta)$ as in (5). Finally, the LBP(n) pattern will be a vector with the same length as $x(n)$. The 1D LBP algorithm obtains the periodicity values that characterize five emotions in EEG signals. Figure 2 shows the normalized LBP-EEG signals for one second.

$$\epsilon\ (\delta) = \left[2^0,\ 2^1,\ 2^2,\ 2^3,\ 0,\ 2^4,\ 2^5,\ 2^6,\ 2^7\right] \tag{4}$$

$$\text{LBP}(n) = \epsilon\ (\delta) * \phi\ (\delta)^T \tag{5}$$

For each EEG signal in the SEED-V dataset, a feature extraction algorithm using 13 statistical and time-frequency features as proposed in [1] and [20]. Table 1 shows the equations per feature, yielding a feature matrix with a size of [44640 × 13]. Once the feature matrix is computed, a maximum relevance minimum redundancy (MRMR) algorithm [5] is applied for a feature selection achieving a score vector where the highest coefficient yields the most relevant feature.

Table 1 Statistical and time-frequency features applied to LBP-EEG signals

Statistical feature set			
(1) Mean	$\mu = \frac{1}{N}\sum_{n=1}^{N} x\,(n)$	(2) Variance	$\sigma = \frac{1}{N}\sum_{n=1}^{N}(x\,(n)-\mu)^2$
(3) Skewness	$\gamma = \frac{1}{N\sigma^{3/2}}\sum_{n=1}^{N}(x\,(n)-\mu)^3$	(4) Kurtosis	$\kappa = \frac{1}{N\sigma^{2}}\sum_{n=1}^{N}(x\,(n)-\mu)^4$
(5) Sum of the logarithmic amplitudes	$\text{SLA} = \sum_{n=1}^{N}\log(\lvert x(n)\rvert)$	(6) Median absolute deviation	$\text{MAD} = \frac{1}{N}\sum_{n=1}^{N}\lvert x\,(n)-\mu\rvert$
(7) Root mean square value	$\text{RMSV} = \sqrt{\frac{\sum_{n=1}^{N} x(n)}{N}}$	(8) Mean absolute values	$\text{MAV} = \frac{1}{N-1}\sum_{n=1}^{N}\lvert x(n+1)-x(n)\rvert$
Time-frecuency feature set			
(9) Flatness	$\text{FLS} = N\frac{\prod_{n=1}^{N}(\lvert x(n)\rvert)^{\frac{1}{N}}}{\sum_{n=1}^{N}(\lvert x(n)\rvert)^{\frac{1}{N}}}$	(10) Spectral roll-off	$\text{SRO} = \lambda\sum_{n=1}^{N} x(n),\ \lambda = 0.85$
(11) Normalized Renyi entropy	$\text{NRE} = \frac{1}{1-v}\log_2\sum_{n=1}^{N}\left(\frac{x(n)}{N\mu}\right)^{v},\ v = 3$	(12) Energy concentration	$\text{EC} = \left(\sum_{n=1}^{N}\sqrt{\lvert x(n)\rvert}\right)^2$
(13) Homogeneity	$\text{HOMO} = \frac{1}{N-1}\sum_{n=1}^{N}\frac{1}{1+\lvert x(n+1)-x(n)\rvert}$		

4 Results

From the 16 subjects, 3 trails per subject, 15 stimuli movie clips, and 62 electrode channels, 44640 EEG signal vectors are collected. From all these signals, an extensive number of windows are analyzed for the LBP-EEG. A 1D LBP algorithm is applied per EEG signal, obtaining a new set of signals called LBP-EEG. All the tests and results in this work are performed in a PC with an Intel Core i7-3660X (3.30 GHz) and 32 Gb RAM. The signal processing and feature extraction task achieved ≈ 150 minutes for 117, 738, 240 processing LBP windows on parallel computing using six digital cores. The feature extraction presented in Table 1 is computed per LBP-EEG signal followed by an MRMR feature selection. The MRMR algorithm computes a score vector with each target class's relevant information per feature. The resulting score vector is shown in (6)

$$\begin{aligned}\zeta = [&0.0127,\ 0.0317,\ 0.4815,\ 0.2728,\ 0.000,\ 0.0313,\ 0.0127,\ 0.7026,\\ &0.000,\ 0.5401,\ 0.4770,\ 0.4846,\ 0.9834]\end{aligned} \tag{6}$$

where only the top three relevant features are considered to test the following ML training and validation. The feature with the higher score is homogeneity (HOMO), 0.9834, followed by the mean absolute values (MAV) with an MRMR score of 0.7026. In the third place, the spectral roll-off (SRO) yields an score of 0.5401. By the use of those three features, an Ω matrix with a size of $[44640 \times 3]$ is achieved and

used as input to an ML model. Different ML-based models (tree, KNN, ensemble, and SVM) are used as a descriptor for five discrete emotions: "happy", "sad", "fear", "neutral", and "disgust". Four algorithms are used to classify the features arising from the LBP-EEG signals, as shown in Table 2. Training shown in Table 2 is performed from 10-cross-validation folders at 50 epochs. The metrics evaluate the mean of training performed per folder. The training results shown in Table 2 highlight the ensemble model as the most accurate, achieving 89%. In (6), it can be noticed that homogeneity is the highest MRMR index, with a 0.9834 score. Based on this score, it is inferred that this metric can be used to obtain an optimal and accurate result. Therefore, the classification task is performed using only homogeneity. The results achieved are shown in Table 3. In this table, the KNN model is shown as the most accurate.

5 Discussion

EEG signals show high complexity as input data to a classification algorithm. To avoid artifacts, it is recommended to preprocess the signals and then apply a domain transformation with a feature extraction technique. In this work, we show the results obtained by applying a preprocessing LBP algorithm to a set of EEG signals to extract statistical and time-frequency features. A feature selection algorithm achieves the dimensionality reduction and cleans our original dataset to not-relevant descriptors for ER. Thus, the homogeneity feature is enough to describe the behavior of LBP-EEG signals.

As shown in Table 3, the KNN and SVM present an important improvement in accuracy rate with an increase of around 13%. In comparison with the models shown in Table 2, the mean absolute values and spectral roll-off feature vectors add a conflict of learning, reducing the accuracy of the model. In addition, the rest of the models trained with homogeneity showed that the "fear" class is the best-predicted class, in contrast, "sad" is the lowest and is mainly misclassified as the "neutral" class. Table 4 shows the ER's top results using EEG data input. The main advantages of our work are the use of an image analysis algorithm applied for EEG signals processing and avoiding frequency splint band of the WD method, IMD, or the Butterworth filtering. The advantage of this work, compared to the two previously approaches [2, 3], is the complexity reduction of the EEG signal processing algorithm. In the previous works, we computed the spectrogram and scalogram images. These images suggest a high-computational resource consumption, in contrast to the LBP preprocessing shown in this work. Furthermore, the implementation of multiple ML architectures for classification, in contrast to the complexity of DL-based architectures, is an improvement. Finally, in the spatial distribution of the homogeneity, the mean absolute values and spectral roll-off features show a simple, two-dimensional behavior, as shown in Fig. 2. In contrast, the features obtained by a CNN architecture are highly complex to interpret and suggest only quantitative analysis.

Table 2 Machine learning validation with the MRMR features for the LBP-EEG

Tree							**KNN**						
Confusion matrix													
	Happy	Sad	Fear	Neutral	Disgust	Total		Happy	Sad	Fear	Neutral	Disgust	Total
Happy	**7896**	482	31	472	47	8928	Happy	**6566**	1121	176	668	397	8928
Sad	511	**6990**	43	977	407	8928	Sad	977	**5515**	577	1466	393	8928
Fear	41	43	**8755**	60	29	8928	Fear	183	379	**7830**	378	158	8928
Neutral	439	843	52	**7549**	45	8928	Neutral	491	1466	324	**6455**	192	8928
Disgust	46	483	32	37	**8330**	8928	Disgust	333	596	104	217	**7678**	8928
Evaluation metrics (%)													
	Happy	Sad	Fear	Neutral	Disgust	μ		Happy	Sad	Fear	Neutral	Disgust	μ
Precision	88.44	78.29	98.06	84.55	93.30	88.53	Precision	73.54	61.77	87.70	72.30	86.00	76.26
Recall	88.39	79.06	98.23	83.00	94.04	88.54	Recall	76.80	60.76	86.89	70.29	87.07	76.36
F1-score	88.42	78.68	98.14	83.77	93.67	88.54	F1-score	75.13	61.26	87.30	71.28	86.53	76.30
μ_{acc}	88.50						μ_{acc}	76.30					
Ensemble							**SVM**						
Confusion matrix													
	Happy	Sad	Fear	Neutral	Disgust	Total		Happy	Sad	Fear	Neutral	Disgust	Total
Happy	**7960**	467	23	444	34	8928	Happy	**6566**	1121	176	668	397	8928
Sad	493	**7048**	40	944	403	8928	Sad	977	**5515**	577	1466	393	8928
Fear	35	29	**8783**	58	23	8928	Fear	183	379	**7830**	378	158	8928
Neutral	418	872	45	**7552**	41	8928	Neutral	491	1466	324	**6455**	192	8928
Disgust	31	441	20	38	**8398**	8928	Disgust	333	596	104	217	**7678**	8928
Evaluation metrics (%)													
	Happy	Sad	Fear	Neutral	Disgust	μ		Happy	Sad	Fear	Neutral	Disgust	μ
Precision	89.16	78.94	98.38	84.59	94.06	89.03	Precision	73.54	61.77	87.70	72.30	86.00	76.26
Recall	89.07	79.58	98.56	83.58	94.37	89.03	Recall	76.80	60.76	86.89	70.29	87.07	76.36
F1-score	89.11	79.26	98.47	84.08	94.22	89.03	F1-score	75.13	61.26	87.30	71.28	86.53	76.30
μ_{acc}	89.00						μ_{acc}	76.30					

Table 3 Validation from trained models using homogeneity for the LBP-EEG

Tree							**KNN**						
Confusion matrix													
	Happy	Sad	Fear	Neutral	Disgust	Total		Happy	Sad	Fear	Neutral	Disgust	Total
Happy	**7834**	597	18	469	10	8928	Happy	**7862**	585	10	465	6	8928
Sad	403	**6910**	36	1257	322	8928	Sad	384	**6967**	7	1254	316	8928
Fear	14	27	**8853**	16	18	8928	Fear	8	11	**8880**	7	22	8928
Neutral	406	528	23	**7955**	16	8928	Neutral	406	514	13	**7986**	9	8928
Disgust	20	566	8	21	**8313**	8928	Disgust	8	561	3	8	**8348**	8928
Evaluation metrics (%)													
	Happy	Sad	Fear	Neutral	Disgust	μ		Happy	Sad	Fear	Neutral	Disgust	μ
Precision	87.75	77.40	99.16	89.10	93.11	89.30	Precision	88.06	78.04	99.46	89.45	93.50	89.70
Recall	90.28	80.09	99.05	81.86	95.78	89.41	Recall	90.70	80.66	99.63	82.16	95.94	89.82
F1-score	89.00	78.72	99.10	85.33	94.43	89.32	F1-score	89.36	79.32	99.55	85.65	94.71	89.72
μ_{acc}	89.30						μ_{acc}	89.70					
Ensemble							**SVM**						
Confusion matrix													
	Happy	Sad	Fear	Neutral	Disgust	Total		Happy	Sad	Fear	Neutral	Disgust	Total
Happy	**7861**	589	12	459	7	8928	Happy	**7861**	590	8	458	11	8928
Sad	389	**6958**	9	1256	316	8928	Sad	395	**6943**	9	1262	319	8928
Fear	11	10	**8883**	9	15	8928	Fear	27	11	**8872**	11	7	8928
Neutral	408	523	15	**7975**	7	8928	Neutral	413	528	20	**7958**	9	8928
Disgust	9	562	4	10	**8343**	8928	Disgust	36	558	4	7	**8322**	8928
Evaluation metrics (%)													
	Happy	Sad	Fear	Neutral	Disgust	μ		Happy	Sad	Fear	Neutral	Disgust	μ
Precision	88.05	77.93	99.50	89.33	93.45	89.65	Precision	88.05	77.77	99.37	89.14	93.22	89.51
Recall	90.59	80.51	99.55	82.14	96.03	89.76	Recall	90.03	80.45	99.54	82.08	96.01	89.62
F1-score	89.30	79.20	99.52	85.58	94.72	89.67	F1-score	89.03	79.09	99.46	85.46	94.60	89.52
μ_{acc}	89.65						μ_{acc}	89.50					

Table 4 Comparison of ER approaches

Author and year	Dataset	Feature extraction	Number of classes	Classifier	Accuracy (%)
Liu et al. (2018) [13]	Custom dataset	PS	Binary class	SVM (SLDA)	86.63
Ji et al. (2019) [9]	BCI competition	Approx. entropy	Multiclass	SVM	85.71
Gupta et al. (2019) [8]	SEED & DEAP fusion dataset	Information potential	Ternary class	SVM	90.48
Liu et al. (2019) [15]	DEAP	SC & LZC	Binary class	SVM	86.46, 84.90, per dim
Asghar et al. (2021) [4]	SEED & DEAP	DE & MI	Ternary & multiclass	SVM	96.3, 81.1 per dataset
Our approach (2022)	SEED-V	Homogeneity	Multiclass	Tree, SVM, ensemble and KNN	89.30, 89.50, 89.65, and 89.70 per classifier

6 Conclusions

The proposed model is an automatic technique for emotion recognition using EEG signals and LBP. This algorithm classifies five emotions with an accuracy rate of 89.7%, being "fear" the best-predicted class with an F1-score of 99.55%. In contrast, "sad" shows the lowest F1-score with a 79.32%. In future work, we will implement a channel selection algorithm to reduce the dimensionality of the feature matrix. In addition, an LBP-EEG change domain will be discussed to improve the accuracy of the model prediction.

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Error Performance of Relay-Assisted Free-Space Optical Communication Links Over Atmospheric Turbulence Channels

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Abstract Free-space optical (FSO) communication has regained substantial research interests in the recent decade and is well reckoned as a viable alternative which is highly complementary/integrable with existing radio frequency (RF) solutions, such as the 5G wireless networks. Unpredictable weather conditions severely impair the link availability and performance of the FSO system. The presence of atmospheric loss and turbulence-induced optical scintillation within the communication channel causes attenuation and random fluctuation of the received optical signals, thereby limiting the link distance and impairing the error performance. Multi-hop relaying technique can be adopted in the FSO system for improving the channel gain and mitigating the turbulence-induced channel fading. In this paper, we examine the bit error rate (BER) performances of FSO systems operating in the single-input single-output (SISO) and multi-hop relay-based configurations. The BER analysis is carried out using MATLAB simulation, whereby weather-dependent parameters and turbulence strength values for different weather scenarios such as clear air, light fog, and haze are considered here. Next, the aperture-averaging phenomenon caused by the receiver aperture dimension is jointly investigated with the relay-assisted multi-hop relaying technique. From our study, it is evident that the SISO FSO configuration is vulnerable to system outage, which can be effectively mitigated with the introduction of relay terminals. Our findings conclude that the relay-assisted multi-hop FSO system with aperture averaging is a feasible approach toward reducing the BER performance with minimum power requirement.

Keywords Free-space optical (FSO) communication · Optical relaying · Atmospheric turbulence · Bit error rate (BER)

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1 Introduction

Atmospheric loss and turbulence effects are responsible for the inferior performance of free-space optical (FSO) communication systems at the time of sending data using optical lasers. In this overall procedure, initially the information as a form of electrical signal generated from the source is modulated and then converted to optical form by driver circuit [1]. Atmospheric channel through which the optical beam passes faces a lot of challenges as a form of atmospheric attenuation. In the receiver part, optical signal data are converted to electrical form through a photodetector [2] again which can be amplified or processed. Although having some limitations, today FSO is a time-demanding technology for some of its excellent features. However, in recent times, this less costly, cableless, low-powered with no licensing and tariff, extensive linked, and radio frequency interference immunizing technology with various interfaces support is encouraging service providers to make their investment [3]. Despite the major advantages of FSO, its widespread use for long-range links has been hampered in different weather conditions by its disappointing performance due to turbulence effects like scintillation, absorption, scattering, attenuation, etc.

Different turbulence reducing techniques have been examined in several literatures including channel modeling, modulation schemes, relaying and diversity techniques, hybrid systems, etc. To the best of our knowledge [4], for FSO communications, equipping the serial relays with buffers targeted an outage analysis by not addressing the limitations of determining the overall ergodic capacity of this optical system. In an article [5], a simulation was performed considering wavelength division multiplexing (WDM) serial relay aided FSO model for improving path loss and fading effects only for haze and rain. In a study [6], a grouping optimization technique has been proposed for FSO decode forward (DF) multi-hop systems, where laser links were blocked as the relay nodes were not properly optimized in their location path. In a paper [7], asymptotic outage probability was analyzed and lessened through the selection of a weighted relay considering an optimal weight factor.

The objective of this research work is to optimize the performance of relay-assisted FSO communication systems under different weather conditions. The analysis and performance testing method used here is simulation study, which is carried out using MATLAB by considering turbulence effects, atmospheric losses, and channel effect. In terms of quantifying performance, bit error rate (BER) is analyzed. On top of that, performance enhancement is justified by a relay-assisted FSO system. The overall performance of the proposed system has been analyzed in terms of the relay node optimization for BER vs. consumed optical power considering clear weather, haze, fog, and rainy conditions at a 12 km link distance, and the effects of changing aperture diameter were observed for clear weather and light fog conditions at 8 and 3 km link distances. In all cases, as the number of relays increases, consumed optical power gradually requires less with an average BER of 10^{-9} or less and yields impressive results when aperture diameters are changed with relays. It is pretty evident, among the observations, that the performance can be optimized for triple-hop FSO communication links under clear weather at 12 km link distance, for an

aperture dimension $D = 150$ mm, where consumed power is reduced to -20 dB and an overall enhancement 38 dB as compared to the SISO transmission link at $D = 20$ mm.

The rest of the paper of our relay-based study is arranged followed by Sect. 2, where a system model is introduced considering scintillation, atmospheric loss, pointing errors as well as FSO transmission schemes with the assistance of relay-based multi-hop channels. Parameters for simulation, particularly BER quantization, are derived in Sect. 3. In Sect. 4, the MATLAB simulation results for BER analysis under different weather conditions for SISO and relay-assisted transmission links are presented and discussed. Finally, our conclusions are given in Sect. 5.

2 System Description

2.1 System Model

Figure 1 illustrates the general layout for an FSO communication system operating in the single-input single-output (SISO) configuration and intensity modulation with direct detection (IM/DD) scheme. Assuming non-return-to-zero on–off keying (NRZ-OOK) modulation [8], the transmitted data (at the source) are modulated onto the instantaneous laser beam intensity and propagated along the atmospheric turbulent channel with beam extinction and geometric loss. The optical signals are focused onto a photodetector using a receiving lens, thereby producing photocurrents (at the destination) according to the received optical intensities.

At the destination, the received electrical signal y can be modeled by the relation [9–11]:

$$y = h\gamma x + n_0; \tag{1}$$

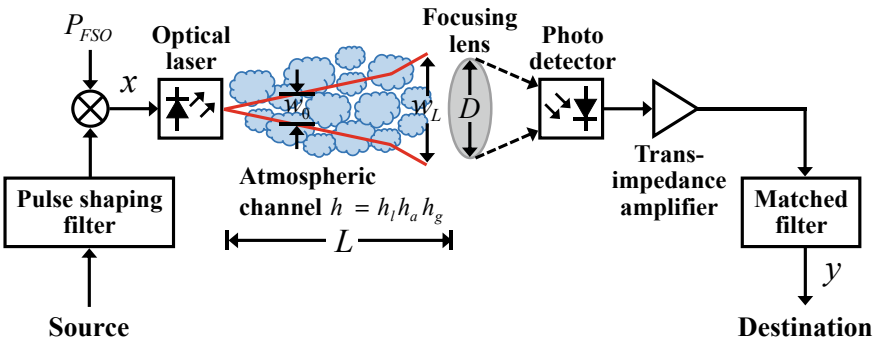

Fig. 1 Block diagram depicting the construction of an FSO communication system with single-input single-output configuration

where $x_o \in \{0, 2P_{\text{FSO}}\}$ denotes the transmitted optical signal, P_{FSO} is the average transmit optical power, h refers to the channel state, and γ is the photodetector responsivity. The n_0 resembles the additive white Gaussian noise (AWGN) having a mean of zero and variance of σ_0^2.

The channel state h describes the random fluctuations of the optical intensities contributed by propagation path loss, geometric loss, and atmospheric turbulence and is given by [12]

$$h = h_l h_g h_a \,. \tag{2}$$

The term h_l corresponds to the attenuation factor due to beam extinction, which is caused by scattering and absorption of atmospheric particulates. On the other hand, h_g and h_a account for the beam spreading and optical scintillation effects, respectively.

Considering OOK-modulated signal propagating through a non-ergodic slow-fading channel, the electrical signal-to-noise ratio (SNR) at the receiver is [13, 14]

$$\Gamma = \frac{2P_{\text{FSO}}^2 \gamma^2 h^2}{\sigma_0^2} \,. \tag{3}$$

Figure 2 illustrates the configuration of a relay-assisted multi-hop FSO communication system, where the modulated light beam is transmitted from the optical transmitter (source) to the optical receiver (destination) via intermediate optical terminals known as relays. An amplify-and-forward relaying scheme is considered [15, 16]. With the placement of relay nodes R_i (where $i = 1, 2, \ldots (N-1)$) separated by equal distance [19], the modulated signal propagates through N channels/hops before arriving at the destination. The end-to-end SNR of the channel-dependent N-hop FSO propagation link is given by

$$\Gamma_{\text{eq}} = \left[\prod_{i=1}^{N} \left(1 + \frac{1}{\Gamma_i} \right) - 1 \right]^{-1} ; \tag{4}$$

where Γ_i denotes the SNR of the nth hop and is given by

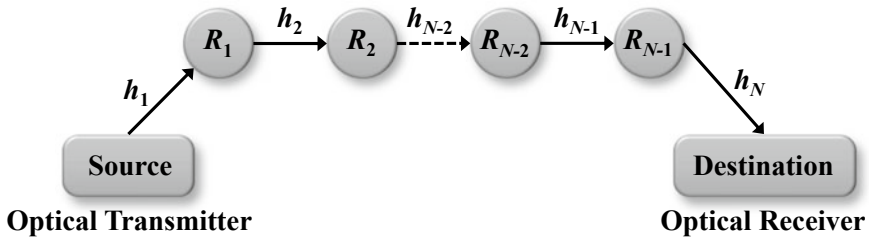

Fig. 2 Configuration of a relay-assisted N-hop FSO communication system

$$\Gamma_i = \frac{2P_{\mathrm{FSO}}^2 \gamma^2 h_i^2}{\sigma_{0,i}^2}. \tag{5}$$

2.2 Channel Model

Atmospheric Loss. It is mainly contributed by scattering and absorption, which is well modeled by the Beers–Lambert law [9, 17] given by

$$h_l = e^{-\sigma L}; \tag{6}$$

where σ is an attenuation coefficient affected by the wavelength and weather parameters and L denotes the link distance.

Applying the visibility data for different weather scenarios, the attenuation coefficient σ can be predicted using the following relations [8]. For clear and foggy weather,

$$\sigma = \frac{3.91}{V}\left(\frac{\lambda}{550}\right)^{-q}; \tag{7}$$

and for rainfall conditions:

$$\sigma = \frac{2.9}{V}; \tag{8}$$

where λ is the laser wavelength, V resembles the link visibility, and q represents a parameter dependent on the visibility and particle size distribution.

Turbulence-Induced Optical Scintillation. The log-normal distribution is applied in our analysis to model the randomly fading optical irradiance signals caused by weak-to-moderate turbulences. The probability density function (pdf) of the irradiance intensity in the turbulence channel is given by

$$f_{h_a}(h_a) = \frac{1}{h_a \sigma_I(D)\sqrt{2\pi}} \exp\left\{-\frac{\left[\ln(h_a) + \frac{1}{2}\sigma_I^2(D)\right]^2}{2\sigma_I^2(D)}\right\}. \tag{9}$$

For an optical receiver with an aperture dimension D, the scintillation index can be determined from the relation:

$$\sigma_I^2(D) = A_g \times \sigma_I^2(0); \tag{10}$$

where A_G denotes the aperture-averaging factor and $\sigma_I^2(0)$ is the point-received (with $D \sim 0$) scintillation index given by

$$\sigma_I^2(0) \cong 4.42\sigma_R^2\Lambda_L^{5/6}\frac{\rho^2}{w_L^2} + 3.86\sigma_R^2\Big\{0.4\Big[(1+2\Theta_L)^2 + 4\Lambda_L^2\Big]^{5/12} \times \cos\left[\frac{5}{6}\tan^{-1}\left(\frac{1+2\Theta_L}{2\Lambda_L}\right)\right] - \frac{11}{16}\Lambda_L^{5/6}\Big\}. \tag{11}$$

The Rytov variance for a plane wave is

$$\sigma_R^2 = 1.23C_n^2\big(2\pi/\lambda\big)^{7/6}L^{11/6}; \tag{12}$$

where C_n^2 is a parameter relevant to the index of refraction structure, which quantifies the atmospheric turbulence strength. This indicator is taken as constant for a horizontal path FSO link. At the receiver, the optical beam parameters are defined as

$$\Theta_L = 1 + \frac{L}{F_L} \text{ and } \Lambda_L = \frac{\lambda L}{\pi w_L^2}; \tag{13}$$

The corresponding beam width at link distance L is

$$w_L = w_0\sqrt{\Theta_n + \zeta\Lambda_n^2}; \tag{14}$$

where w_0 is the transmitter beam width. The resultant phase front radius of curvature is given by

$$F_L = \frac{L\big(\Theta_n^2 + \zeta\Lambda_n^2\big)}{\varphi\Lambda_n - \zeta\Lambda_n^2 - \Theta_n^2}, \text{ with } \varphi \equiv \frac{\Theta_n}{\Lambda_n} - \frac{\Lambda_n w_0^2}{\rho_0^2}. \tag{15}$$

The normalized components are given by

$$\Theta_n = 1 - \frac{L}{F_0} \text{ and } \Lambda_n = \frac{\lambda L}{\pi w_0^2}; \tag{16}$$

where F_0 is the transmitter phase front radius of curvature. The global coherence parameter is

$$\zeta = \zeta_s + \frac{2w_0^2}{\rho_0^2}; \tag{17}$$

where ζ_s is the beam coherence and the coherence length of a spherical wave is given by

$$\rho_0 = \left[0.55C_n^2\left(\frac{2\pi}{\lambda}\right)^2 L\right]^{-3/5}. \tag{18}$$

The aperture-averaging factor is given by

$$A_G = \frac{\sigma_I^2(0)}{\sigma_I^2(0)} = \frac{16}{\pi}\int_0^1 x\mathrm{d}x \exp\left\{\frac{-D^2x^2}{\rho_0^2}\left(2 + \frac{\rho_0^2}{w_0^2\Lambda_n^2} - \frac{\rho_0^2\varphi^2}{w_L^2}\right)\right\} \times \left[\cos^{-1}(x) - x\sqrt{1-x^2}\right]; \tag{19}$$

where D is the receiver aperture diameter and $x = \rho \big/ D$ with ρ being the separation distance between two points.

Geometric Loss. It is a fixed loss for a given FSO link caused by the spreading of the laser beam when propagating in free space. This inherent beam divergence increases with link distance and is independent of weather conditions. Assuming the optical transmitter has an ideal Gaussian beam profile and is well aligned with the receiver, the geometric loss for a fixed point-to-point link can be approximated as [8]

$$h_g = \left[\mathrm{erf}\left(\frac{\sqrt{\pi}a}{\sqrt{2}w_L}\right)\right]^2; \tag{20}$$

where $w_L \approx \phi \times L$ is the beam width at a link distance L, ϕ is the beam divergence angle, and $a = D \big/ 2$.

3 Performance Analysis

Considering OOK modulation for the system under study, the BER can be expressed as [6, 18]

$$P_e = P_X(0)P_X(e|0) + P_X(1)P_X(e|1); \tag{21}$$

where $P_X(0)$ and $P_X(1)$ resemble the probabilities of transmitting "0" and "1" bits, respectively, and $P_X(e|0)$ and $P_X(e|1)$ are the corresponding conditional probabilities for bit "0" and "1". The bit error probabilities conditioned to the channel state h are given by

$$P_X(e|0,h) = P_X(e|1,h) = Q\left(\sqrt{\Gamma}\right); \tag{22}$$

where $Q(\cdot)$ is the Gaussian-Q function defined by

$$Q(y) = \frac{1}{\sqrt{2\pi}}\int_y^\infty \exp\left(\frac{-t^2}{2}\right)\mathrm{d}t. \tag{23}$$

Assuming symmetry with $P_X(0) = P_X(1) = 0.5$ and $P_X(e|0) = P_X(e|1)$, the average BER can be determined from the following relation:

$$P_e = \int_0^\infty f_h(h)\, Q\left(\sqrt{\Gamma}\right) \mathrm{d}h. \tag{24}$$

4 Numerical Results and Discussion

In Fig. 3, we examine the average BER P_e as a function of the transmit optical power P_{FSO} for the conventional SISO single-hop FSO system (i.e., Relay (0)) and the relay-assisted multi-hop FSO link configurations (i.e., Relay (N)), where $N = \{1, 2, 3\}$ denotes the number of relay nodes. Different weather conditions including the clear, haze, and light fog are considered, for a link distance $L = 12$ km and receiver aperture diameter $D = 40$ mm. The system parameters and weather-related settings are summarized in Table 1. A maximum BER threshold of 10^{-9} (i.e., only one erroneous bit out of 10^9 received bits is tolerated) is required for establishing seamless wireless communication and hence is chosen as our reference BER. For telecommunications applications, the specified maximum BER ranges from 10^{-9} to 10^{-12}.

Under the clear weather scenario with a visibility $V = 10.27$ km and turbulence strength value $C_n^2 = 5 \times 10^{-14}$ m$^{-2/3}$ (in Fig. 3), the conventional SISO FSO system can achieve a desirable error performance of $P_e < 10^{-9}$ at $P_{\mathrm{FSO}} =$

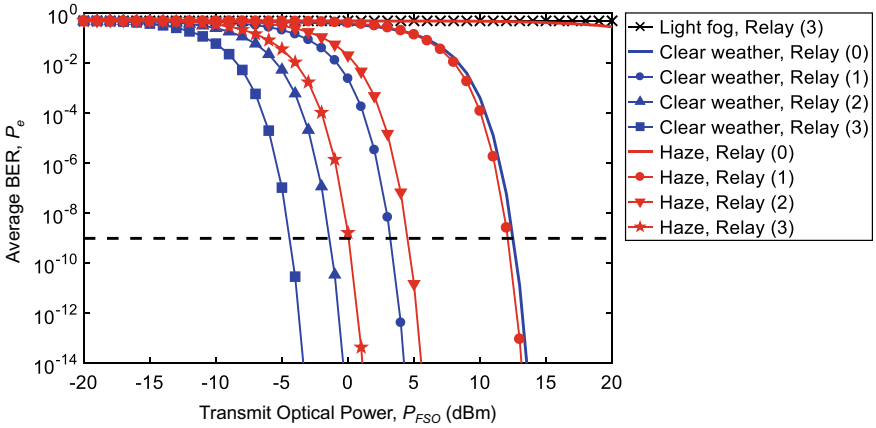

Fig. 3 Error performance comparison between the conventional SISO FSO system (Relay (0)) and the relay-assisted multi-hop FSO link configurations (Relay (N), where $N = \{1, 2, 3\}$), for $L = 12$ km and $D = 40$ mm, under the clear weather, haze, and light fog conditions

Table 1 FSO system parameters and simulation settings

System parameters		
Description	**Symbol**	**Value**
Laser wavelength	λ	1550 nm
Photodetector responsivity	γ	0.5 A/W
Noise variance	σ_0^2	10^{-14} A^2
Beam radius at 1 km	w_L	$\cong$ 2.5 m
Link distance	L	{3.0, 8.0, 12.0} km
Receiver aperture diameter	D	{20, 40, 80 150} mm
Separation distance between two points	ρ	5 mm
Weather-dependent parameters		
Weather condition	$\boldsymbol{V}$**(km)**	$\boldsymbol{C_n^2}$**(m$^{-2/3}$)**
Clear air	10.27	5.0×10^{-14}
Haze	3.50	1.7×10^{-14}
Light fog	0.77	3.0×10^{-15}
Moderate rain (12.5 mm/h)	2.80	5.0×10^{-15}
Heavy rain (25 mm/h)	1.90	4.0×10^{-15}

15 dBm. On the other hand, the single-hop FSO link undergoes complete system outage under the haze and light fog conditions with relatively lower link visibilities of 3.50 km and 0.77 km, respectively, as evident from the poor error performance with P_e approaching 1. This is mainly contributed by the atmospheric loss due to the presence of numerous gaseous molecules within the earth's atmosphere, which severely attenuates the optical intensity of the propagating laser beam.

For the relay-assisted FSO link configuration (see Fig. 3), it is observed that a significant reduction in P_{FSO} requirement in excess of 9 dB can be achieved by a dual-hop system (Relay (1)) while maintaining the average BER at 10^{-9}, under the clear weather condition. The P_{FSO} requirement can be improved by up to 16.5 dB for a quadruple-hop FSO system (Relay (3)), as compared to the conventional single-hop system. In addition, the average BER can be significantly improved using a dual-hop system under the haze condition, whereby $P_e < 10^{-9}$ can be achieved at $P_{\text{FSO}} =$ 12 dBm, as compared to the conventional SISO FSO system with $P_e \sim 1$. A further reduction in P_{FSO} requirement of 12 dB can be made possible using a quadruple-hop FSO system albeit the presence of haze. However, the multi-hop FSO configuration is unable to mitigate the system outage under the visibility-limiting light fog condition, particularly for long-distance FSO transmission with $L > 5$ km.

Next, Fig. 4. presents the error performance of the conventional SISO FSO system and the relay-assisted multi-hop FSO link configurations, under the moderate and heavy rain conditions, with $L = 12$ km and $D = 40$ mm. It is evident that the

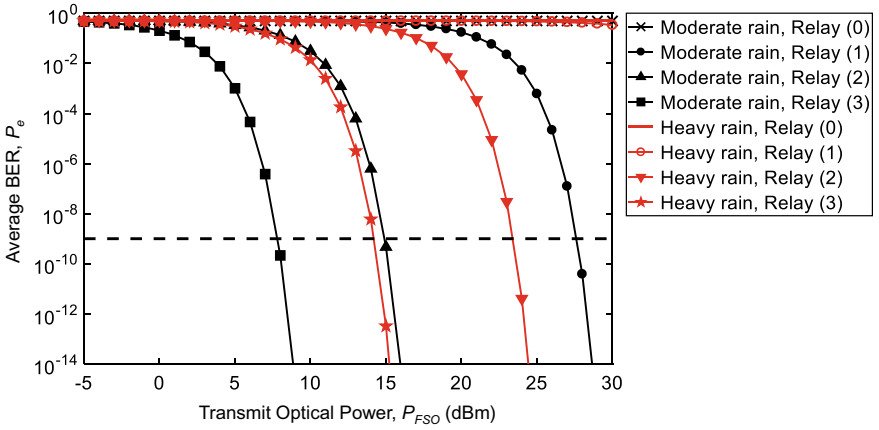

Fig. 4 Error performance comparison between the conventional SISO FSO system (Relay (0)) and the relay-assisted multi-hop FSO link configurations (Relay (N), where $N = \{1, 2, 3\}$), for $L =$ 12 km and $D = 40$ mm, under the moderate and heavy rain conditions

conventional SISO FSO link undergoes complete system outage in the presence of moderate and heavy rain, which can be effectively mitigated with the multi-hop FSO implementation. By adopting a triple-hop FSO system through the placement of two relay nodes between the optical transmitter (source) and receiver (destination), a desirable error performance of $P_e < 10^{-9}$ can be achieved at $P_{\text{FSO}} = 25$ dBm during heavy rain, which is also attainable with a much lower P_{FSO} of 15 dBm under the moderate rain scenario. For a quadruple-hop FSO system, the P_{FSO} requirement can be further minimized by more than 7 dB while maintaining $P_e = 10^{-9}$, under both the moderate and heavy rain conditions.

Figure 5 illustrates the changes in the BER performance, P_e with respect to the transmit optical power, P_{FSO} for the conventional SISO FSO system and relay-assisted triple-hop FSO system, during clear weather at $L = 8$ km. In particular, we examine the aperture-averaging effects with increasing receiver aperture diameter settings of $D = \{20, 40, 80, 150\}$ mm, which potentially mitigates the undesirable turbulence-induced signal fading. With the adoption of receiver apertures with larger values of D, the error performance of the FSO link is significantly improved, in which a P_{FSO} reduction of more than 25 dB is observed at $P_e = 10^{-9}$ by using $D =$ 150 mm, in comparison with $D = 20$ mm, for the conventional SISO FSO system. It is observed that the P_{FSO} requirement can be further reduced by 10 dB while maintaining $P_e = 10^{-9}$, for a triple-hop FSO system with $D = 150$ mm, thus resulting in an astounding overall P_{FSO} improvement of ~ 38 dB.

Figure 6 depicts the BER characteristics as a function of the transmit optical power requirements due to the changing aperture-averaging effects with $D = \{20, 40, 80,$ $150\}$ mm. Both cases of the conventional SISO FSO system and relay-assisted dual-hop FSO system are studied for the low-visibility light fog scenario at $L = 3$ km. Our results show that the conventional single-hop FSO link is highly susceptible to

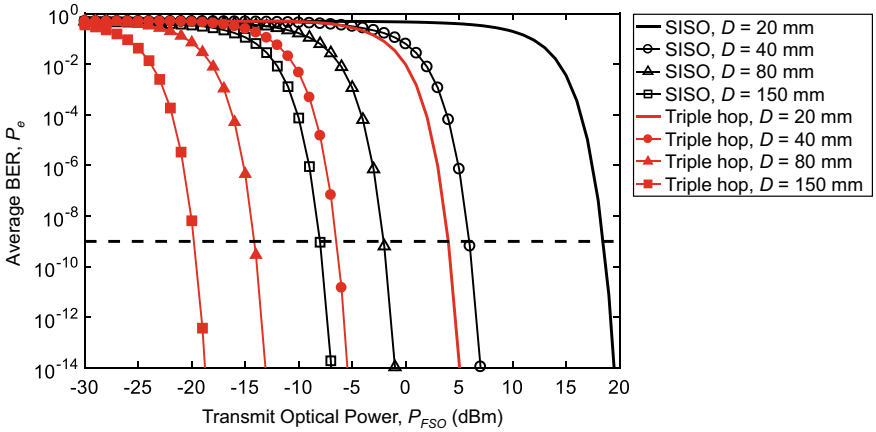

Fig. 5 Average BER versus the transmit optical power for the conventional SISO FSO system and relay-assisted triple-hop FSO system, under the aperture-averaging effect with $D = \{20, 40, 80, 150\}$ mm. The clear weather scenario at $L = 8$ km is considered

system outage, particularly for smaller aperture dimensions $D = \{20, 40\}$ mm. While larger receiver apertures $D = \{80, 150\}$ mm can establish wireless communication with $P_e < 10^{-9}$, the P_{FSO} requirements are impractically high (i.e., > 28 dBm). With the placement of a single relay node for enabling a dual-hop FSO link, the P_{FSO} requirement can be greatly reduced, especially when combined with larger receiver apertures. Comparing the single-hop and dual-hop FSO systems with $D = 150$ mm, it is evident that the latter is capable of establishing better performance of $P_e < 10^{-9}$ with a significantly lower P_{FSO} requirement of < 0 dBm. Therefore, we conclude that the relay-assisted multi-hop FSO system with aperture averaging is a feasible approach toward reducing the error performance with minimum power requirement.

5 Conclusions

In summary, we have proposed a multi-hop FSO system based on optical relaying as a feasible alternative for effectively mitigating the undesirable effects of atmospheric attenuation and turbulence-induced scintillation. Along with relays, aperture-averaging effects are also observed, which in some cases evince better output. SNR, BER, link distance, and optical power were considered under different weather conditions and turbulence effects. According to result analysis, consumed optical power can be reduced by adding multi-hopped relays under clear weather haze, moderate rain, and heavy rain at 12 km link distance with an achievable bit error rate of 10^{-9} or lower than that except light fog condition. Furthermore, it is clear that introducing an aperture-averaging effect with different receiver diameters in clear weather at

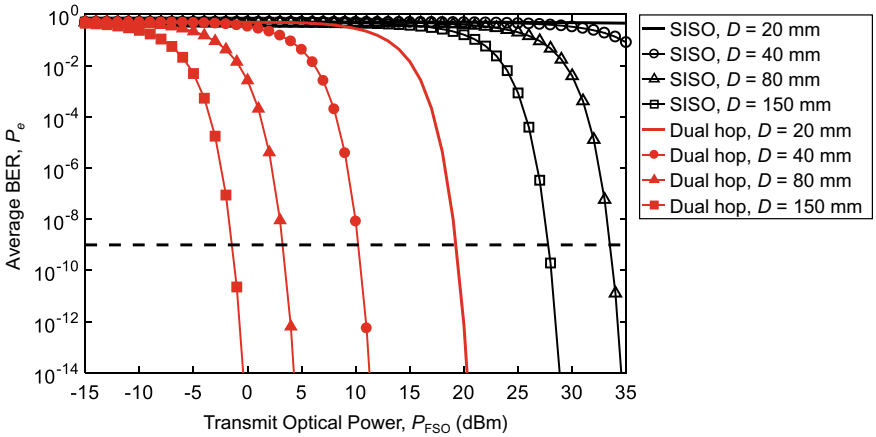

Fig. 6 Average BER versus the transmit optical power for the conventional SISO FSO system and relay-assisted dual-hop FSO system, under the aperture-averaging effect with $D = \{20, 40, 80, 150\}$ mm. The low-visibility light fog scenario at $L = 3$ km is considered

8 km and light fog at 3 km significantly improves the performance of the relay-based multi-hopped channel over SISO FSO system. Observation for light fog at $L > 5$ km applied with a multi-hopped relayed FSO system was unable to get an acceptable system outage, which can leave future work in order for the betterment of long-distance turbulence in a cost-effective way.

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A Study of the Potential of Online Learning of Kasetsart University Faculty Members

Boonrat Plangsorn and Sutithep Siripipattanakul

Abstract The purpose of this study was to study the potential of online learning of Kasetsart University faculty members. This study was qualitative research, and eight key informants were selected by maximum variation sampling. The data were collected by using online interviews. The qualitative data were analyzed employing content analysis and analytic induction performed by using MAXQDA. The result was found that Kasetsart University faculty members had four dimensions of potential for online learning, which are (1) online learning knowledge consists of content expertise, technology, learning management, and online learning management; (2) online learning skills consisting of adaptive technology skills, integrating technology into learning skills, learning technology skills, and technology skills; (3) ability to manage online learning consists of the ability self-learning and ability to update technology skills; and (4) attitude toward online learning consists of technology acceptance and attitude toward online teaching. For the factors conditioning the potential of faculty members for online teaching, there are six factors at Kasetsart University: (1) faculty members' experience in using technology, (2) investment in resources to support online learning, (3) utilization of a consistent application system throughout the university, (4) development of technology competence for faculty members, (5) support staff, and (6) supporting online learning materials for students.

Keywords Online learning · Lecturer potential · Online learning potential

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1 Introduction

Globally, the trend of online teaching at universities is increasing. In 2015–2020 Canada saw a 10% increase in online enrollment. Many universities are developing new online learning models [1]. For example, universities in California's Online Community Colleges allow enrollment and study online at other network universities. For Thailand, online teaching is an alternative way to increase university professors' teaching efficiency. The government has announced the 12th National Economic and Social Development Plan, which is consistent with the concept of online teaching. Emphasis is placed on encouraging learners of all groups to access knowledge conveniently and thoroughly, without time and place restrictions. There is adequate network system support for all universities. Thailand is shifting from traditional teaching methods to embracing digital media for learning purposes.

Kasetsart University has continuously encouraged faculty to improve teaching and learning using digital media and online learning. The university provides various online teaching tools and systems, such as EduFarm, Google Classroom, and Microsoft Team. In the epidemic of coronavirus disease 2019 (COVID-19), the university has announced guidelines for teaching and learning. For the academic year 2020, the focus will be on providing both online learnings and blended learning to maintain physical distancing following the prevention and control measures of the Ministry of Health.

Quality online learning requires step-by-step planning and preparation. Online Instructional Designers not only know about digital technology, teaching design, and teaching materials but also know the learner's information to design an environment to suit the characteristics and behaviors of the learners. Well-designed online instruction will enable students to learn according to their potential. Learners can repeat the lesson if they do not understand and learn from a place convenient for them [2] without traveling to the university. However, online learning is limited: learners need computer and internet skills and are responsible and disciplined to attend online classes regularly.

2 Research Objectives

The purpose of this study was to study the potential of online learning of Kasetsart University faculty members.

3 Research Methods

This study employed qualitative research to understand the potential of online learning of Kasetsart University faculty members.

3.1 Sampling Methods

A total of eight faculty members were identified as potential participants—all participants must have online teaching experiences during the pandemic. The number of participants—8 in total—is consistent with the sample size recommendation [3]. A maximum variation sampling strategy [3] was employed to ensure that the qualitative study results reflect the diversity of experiences of faculty members at the teaching level—undergraduate level and graduate level. There were four faculty members from the undergraduate level and four from the graduate level.

3.2 Data Collection

This study was approved by the Kasetsart University Institutional Review Board (IRB) before data collection. The participants were contacted by phone in order to explain the purpose of the study, ask for permission to conduct semi-structural interviews, and explain the details until those participants were well understood. The researcher made an appointment for the date and time that were most convenient for both the interviewer and interviewees. All interviews were conducted by using online interviews via Zoom. The duration of each interview lasted approximately 40 min. Due to confidentiality concerns, all these recordings were removed after the transcripts were completed. Also, the transcripts of these semi-structural interviews were destroyed after the study was finished.

3.3 Data Analysis

All transcripts from the individual interviews were loaded into MAXQDA 2022, a software for supporting qualitative data analysis. An inductive coding procedure was implemented as an analytical method in order to understand the potential of online learning of Kasetsart University faculty members.

4 Research Results

The result was found that Kasetsart University faculty members had four dimensions of potential for online learning, which are (1) online learning knowledge, (2) online learning skills, (3) ability to manage online learning, and (4) attitude toward online learning. The details of each dimension are as follows:

4.1 Online Learning Knowledge

The potential concerns of online learning knowledge were divided into four sub-dimensions: content expertise, technology, learning management, and online learning management.

Content expertise

Content expertise is recognition, understanding, and specializing in their own content and professions.

"…specializing in their own sciences."
The first male lecturer from graduate school.

Technology

Know the basic techniques and technology.

"...should have a certain level of tech knowledge."
The fourth female lecturer from graduate school.

Learning management

Learning management entails creating a better learning environment that fosters a positive experience for the learners. The aim is to ensure that learners feel comfortable, engaged, and motivated throughout their educational journey. This involves implementing effective instructional strategies, designing engaging learning activities, and fostering a supportive learning environment. By doing so, the learners' satisfaction and overall learning outcomes can be enhanced.

"...create a better learning environment, make the learner feel good."
The seventh female lecturer from undergraduate school.

Online learning management

Online learning is different from onsite learning. There is no need for learners to turn on the camera every time. Instructors should plan, prepare, and be able to study anytime, anywhere. Moreover, they should use uncomplicated technology.

"…From making my own online courses, I understand that learners will focus no more than 7 min. The right time is 5 min."
The eighth female lecturer from graduate school.

4.2 Online Learning Skills

Online learning skills encompass four sub-dimensions: adaptive technology skills, integrating technology into learning skills, learning technology skills, and technology skills as follows:

Adaptive technology skills

Skills to adapt to technology changing.

"...When technology changes, we should be able to adapt to a new one."
The first male lecturer from graduate school.

Integrating technology into learning skills

Skills of integrating technology with teaching and learning make use of technology to help to teach and learn, such as video capture and live events through the application.

"…Learners cannot practice in the classroom. Compose the melody. in a computer program as an audio file instead of".
The second male lecturer from graduate school.

Learning technology skills

Skills of fast learning new functions or technology.

"...have the skills to learn technology quickly"
The first male lecturer from graduate school.

Technology skills

Skilled and proficient in technology for teaching and learning.

"…When it comes to teaching, especially online teaching, teachers have to have the ability to use technology."
The first male lecturer from graduate school.

4.3 Ability to manage online learning

The ability to manage online learning involves two sub-dimensions: self-learning and ability to update technology skills. It encompasses being proactive in seeking knowledge from online sources, continuously adapting to evolving technologies, and staying updated with the latest advancements. By effectively managing online learning, individuals can enhance their educational experience, stay relevant in the digital age, and optimize their learning outcomes.

Ability self-learning

Ability to find out more from the Internet on your own.

"...rely on learning based on YouTube and online education."
The eighth female lecturer from undergraduate school.

Ability to update technology skills

Technology updates are keeping track of modern technologies.

"...technology keeps changing, but we have to track of it."
The fourth female lecturer from graduate school.

4.4 Attitude toward online learning

Attitude toward online learning refers to an individual's disposition and perspective when engaging in online educational activities. It encompasses two sub-dimensions: technology acceptance and attitude toward online teaching as follows:

Technology acceptance

An open mind to accept technology.

"…have to be an open-minded person."
The fourth female lecturer from graduate school.
"…IT exposure."
The third male lecturer from undergraduate school.

Attitude toward online teaching

A positive attitude toward online teaching that all sciences can study online.

"...have an attitude that every science can be feasible to study online."
The fourth female lecturer from graduate school.

Conditions of the potential of online teaching

There are six factors of Kasetsart University, namely (1) faculty members' experience in using technology, (2) investment in resources to support online learning, (3) utilization of a consistent application system throughout the university, (4) development of technology competence for faculty members, (5) Support staff, and (6) Supporting online learning materials for students., as follows:

Faculty members' experience in using technology

In the beginning, Faculty members may not be fluent in technology. If they have more technical experience, they will be able to practice using it until they are proficient.

"…Using technology is like a skill that requires constant practice. when we keep using it, we'll know it's not good; we're going to change.
I think experience is one of the important things."
The first male lecturer from graduate school.

"…Teacher has to sit and teach himself that you have to post this, press like this, edit like this, add something like this, and now, Let's do it. Let's start having fun."
The sixth female lecturer from undergraduate school.

Investment in resources to support online learning

Investment in resources includes providing facilities and supplies to support online learning.

"I personally feel that universities shouldn't be building anything of their own.
If we don't really have the people and the potential,
we should either buy it or hire a company."
The seventh female lecturer from undergraduate school.

Utilization of a consistent application system throughout the university

Using the right application encourages the use of the same system throughout the university, so learners and instructors will not have to worry about using it.

"…too many platforms are being used. This is also feedback from students that teachers use a variety of platforms. It made him focus on platforms a lot."

The seventh female lecturer from undergraduate school.

Development of technology competence for faculty members

Choosing training methods for developing personnel competencies.

"…The faculty members didn't understand, they went to train every week, and finally, he didn't have to train anymore. It's all used up by everyone."

The fourth female lecturer from graduate school.

"...So let the team arrange a course for the professors here"

The eighth female lecturer from undergraduate school.

Support Staff

Providing support staff to assist online learning will help ease the burden of online teaching.

"...We have an educational technology unit to record, and then we post a link to it in the online group, and the learner can view it all the time."

The seventh female lecturer from undergraduate school.

Supporting online learning materials for students

Among students, there is still a disparity in online school supplies. The University should encourage students to borrow equipment for online learning.

"…There's a disparity in equipment."

The eighth female lecturer from undergraduate school.

"...Important devices, tablets, and notebooks should be available for lending."

The first male lecturer from graduate school.

5 Discussion

Instructors must possess a solid foundation of knowledge and proficiency in the subject matter taught by Martin [4]. Skills and abilities are essential because instructors have technology deployment skills, technology integration skills with teaching, technology learning skills, and technology skills, combined with the ability to learn in person and the ability to update technology, which will enable them to manage online lessons. Interact with learners and choose the right technology to provide online instruction, in line with Martin [4], which discusses the online environment. This is consistent with Martin [4], which discusses the online environment. Instructors have the technological skills and knowledge to implement a learning management system (LMS) and understand communication technologies that can facilitate online interaction, and instructors need to have the technical ability to guide learners through technology and make learners feel relaxed in online learning.

This is in line with the findings of Bhuvijit [5], which concluded that instructors through online learning should have the skills to use technology for educational and creative purposes, as instructors must be able to use technology as a medium or as the main channel for knowledge transfer and thought processes, instead of transferring and listening to information face-to-face. Regarding attitudes, when instructors are receptive to embracing modern technologies and adapt to online teaching and learning, they are able to design engaging online lessons that harness the full potential of these technologies.

This is in line with Thapanee's findings [6] which concluded that approaches to teacher development at the individual level should motivate instructors. The teachers are aware of the needs and need for online teaching and learning, and the conditional factors include: (1) the experience of using the technology of teachers, (2) investing in resources to support online teaching and learning, (3) using the same system application throughout the university, (4) developing technological competencies for faculty, (5) providing support personnel to support online teaching and learning, and (6) supporting online learning equipment for students. In order to support the growth of teachers' capabilities and enable them to provide effective online instruction, it is crucial to implement strategies and resources that foster their professional development. This includes offering training programs, providing access to technological resources, promoting continuous learning opportunities, and establishing a supportive environment that encourages experimentation and innovation in online teaching practices. By investing in teacher development, educational institutions can empower instructors to deliver high-quality online education and meet the evolving needs of learners in the digital era.

Thapanee [6] emphasizes the importance of institutional support for teacher development, highlighting the need for dedicated budgets and clear guidelines and enhanced awareness among faculty and administrators. This multifaceted approach ensures effective assistance for teachers while also promoting broader recognition of the significance of open online instruction and its benefits for a wider audience.

6 Conclusion

Kasetsart University faculty members have the potential for online learning. However, Kasetsart University faculty members have the determinants of online learning such as faculty members' experience of using technology, the investment in resources to support online learning, using the same application system throughout the university, the development of technology competence for faculty members, provision of support personnel to support the management of online teaching, and supporting online learning materials for students.

Acknowledgements This research is part of the "A study of the potential of online learning of Kasetsart University faculty members" project. Special thanks to Kasetsart University for the financial support.

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Rehabilitation of the Lower Limb Motor Skills for Patients Using Cable-Driven Robot

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Abstract As the technological advancements in felid such as electronic, robotics, and artificial intelligence continue to grow and flourish, the more the traditional methods of doing things starts to get absolute. This phenomenon cannot be more clearly observed in like medicine, technological advancements changed the ways things are done from the way that the doctors preform their surgical operations to the way they prescribe pills and after surgery treatments. The purpose of this work is to develop a low-cost cable-driven manipulator robot to be used in the rehabilitation of human lower limb problems caused by stroke, accidents, and cerebral palsy. The robot offers a lot of advantages, but some of which is that is the robot is easily deployable anywhere where a power source is present and that the therapist does not to be present with the patient in the same room to monitor the sessions. The robot consists of a stationary frame and an end-effector (splint) connected to four and up to eight wires and can conduct individual hip/knee motions. The paper starts with a look at rehabilitation of the lower limb, then moving on to the kinematics, workspace, and hardware structure.

Keywords Robotics · Medical robots · Rehabilitation · Cable-driven parallel robots

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1 Introduction

Ever since the exponential advancement in the field of robotics, many are using robots to infiltrate the field of medicine by using the advantages it could provide the field. In this paper, we will focus on the advantages that the cable robot could provide to the field of neural rehabilitation .

The paper is going to investigate the rehabilitation of the motor skills for post-stroke patients using the cable robots. The focus on post-stroke patients stems from the number of people affected by it and the aftereffect. To begin with, stroke is the leading cause of paralysis, and about 33.7% of paralysis are caused because of a stroke [1].

Globally one in four adults that live over the age of 25 will have a stroke in their lifetime according to the "World Stroke Organization" [2]. Regionally, the number of new strokes in Egypt per year may be around 150,000–210,000 if we generalize the local reports [3]. Cable robots are finding appeal in the fields of rehabilitation and haptic training. Fundamentally, this is due to their lightweight and large workspace as rigid links are replaced by lightweight cables. This allows them to aid therapists during training sessions by having the ability to perform intensive, different kinds of motion strategies like passive, active an aid-assisted which can effectively improve the outcome of the therapy [4].

Rehabilitation of the patient and recovery of the motor functions all depends on the brain's ability to reconfigure itself after injury and how early the treatment was started in relation to the time of the damage Stroke rehabilitation take different forms such as range of motion therapy, mobility training, constraint-induced movement therapy, electrical stimulation and robotic therapy. The success and effectiveness of the treatment depend on the severity of the damage in the brain and the timing of the rehabilitation. However, the success of the rehabilitation in most of the types of therapy depends on the activity of the supraspinal neural plasticity. The supraspinal neural plasticity activates only if a neuronal signal that matches the proper afferents. To conclude, for an efficient rehabilitation the patient must intend and want to move to activate the cerebral cortex at the same time the muscle movement occurs [5]. The designed robot traits the patient by the method called assisted motion, taking into consideration that assisting the motion of the patient and not creating the motion for the patient [6].

Early exoskeletons such as Lokomat allow the movement of patients' limbs such as the knees and hips through the use actuators. Many of these exoskeletons use a myriad of sensors to be able to monitor controlling and adjusting the movement of the device and the patient. An example of this is some use force sensor to allow the patient to have more freedom and control the start and end of their limb movement [7, 8].

Another example of the sensor is using cameras as visual feedback to visually process factors that include but are not limited to the location of the end-effector and patient limb behavior [9]. Newer versions of the exoskeletons like LOPES and ALEX attempt to induce the feeling of neutral limb movement by using elastic actuators [10, 11]. Another type of devices took advantages of that the cables robots provide over

Table 1 Different types of parallel robots used in rehabilitation

Prototype	Researcher, affiliation, country	Application	Classification
MariBot	Rosati/Rossi, University of Padova, Italy	Rehabilitation	Redundantly constrained
MACARM	Mayhew et al., IAI and RIC, USA	Upper limb neurorehabilitation	Redundantly constrained
Marionet-Rehab	Merlet, INRIA, France	Rehabilitation tasks and other industrial applications	Completely constrained
NeReBot	Rosati/Rossi, University of Padova, Italy	Neural rehabilitation	Fully constrained

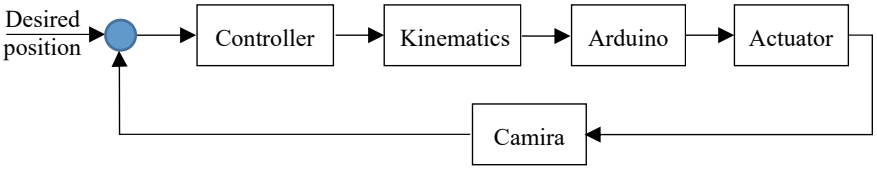

Fig. 1 Major components of our project

the use of exoskeletons, devices like Hepatic Walker, G-EO and lastly Gait Trainer I [12] including all its other variants that are used like the MoreGait both made under Stefan Hesse. All these devices stimulate the limb by moving the end-effector attached to it in a walking like movement (Table 1).

This paper will go through the movement of the proposed robot and the improvement it offers over traditional forms of therapy and even other robots. The hardware and the kinematics will be thoroughly discussed. From the kinematics, the neural network will be discussed, and the therapeutic motion will be achieved (Fig. 1).

2 Motion and Hardware

2.1 Motion Characteristics

First the approach that the robot is taking in the motion is on of assessed motion. This means that the robot needs to learn the movements to assist the patient's movement. Since the initial focus is on the patient's lower body (hips and knees), the motion done by the robot needs to be custom made to the patient's body proportions and specific treatment routine [13]. This is done by using various number of sensors like motor digital encoders that track the speed and positions of each motor as the therapist adjusts the motion pattern to fit the patient's treatment routine. Also, to allow accurate actuators rotation facilitating fluid end-effector movement, load cells

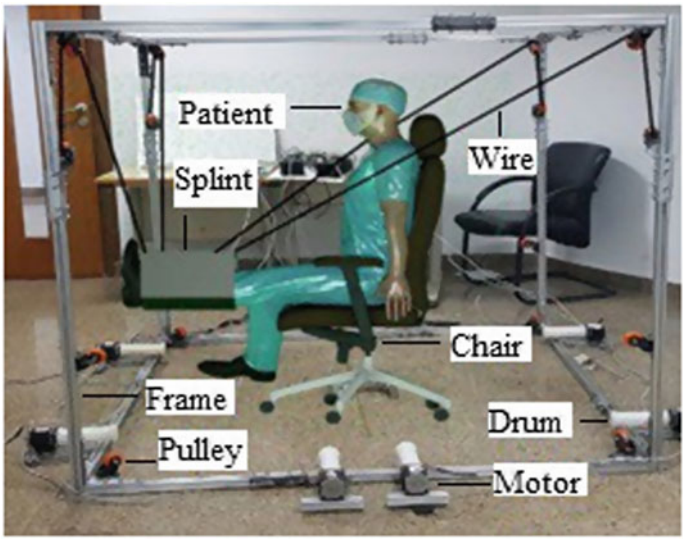

Fig. 2 Simulation indicating the target movement

are attached to the cables, its output signal is used as a control variable, and based on it, a PWM is sent to the actuator [14]. As this iteration of the robot focuses on just the knees, the control just focuses on learning the pattern given by the therapist, maintaining the tension in the cables during all operations and flexion and extension on the knee. Figure 2 shows a simulation of the target movement.

2.2 Hardware

The work process contains several stages, with multiple layers per stage. We are starting with a survey that will help us to narrow down the design specification and allow us to have a clear image of the existing advancements already present in the field. The second stage is the design of both the mechanical and electrical workings on parallel. After designing the model of the mobile platform and machine frame using SOLIDWORKS as shown in Fig. 3, we have calculated the kinematics and workspace calculations using MATLAB.

The. device introduced in this paper has these characteristics: the physiotherapist will be able to control the speed of the motion and the repetitions number, the movement must be fully performed by the device, the mechanism is relatively inexpensive and comfortable to attach to the patient, and it will allow the physiotherapist to record data to follow up and provide reviews and feedback to the patient.

The proposed device consists of four cables and could be up to eight cables arranged in a fixed frame and having a moving platform (splint) [15], and Fig. 4

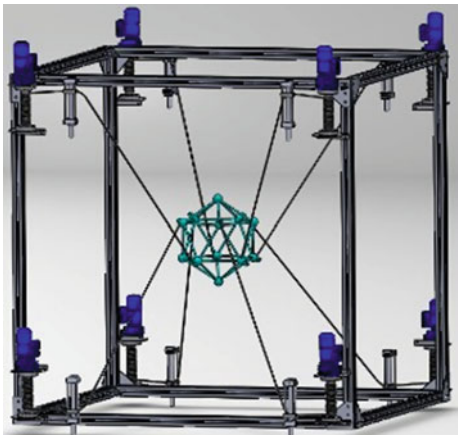

Fig. 3 SOLIDWORKS model

shows a prototype built at the Laboratory of Robotics at Nile University. Figure 5 shows a volunteer setting in the device to test it.

Table 2 shows the elements of the cable-driven parallel manipulator, consisting of: Nema 23 stepper motor with a drum connected to each motor's shaft, encoder with 500 pulses per revolution, Arduino, Kinect camera, driver for each motor, and two guidance pulleys for each cable.

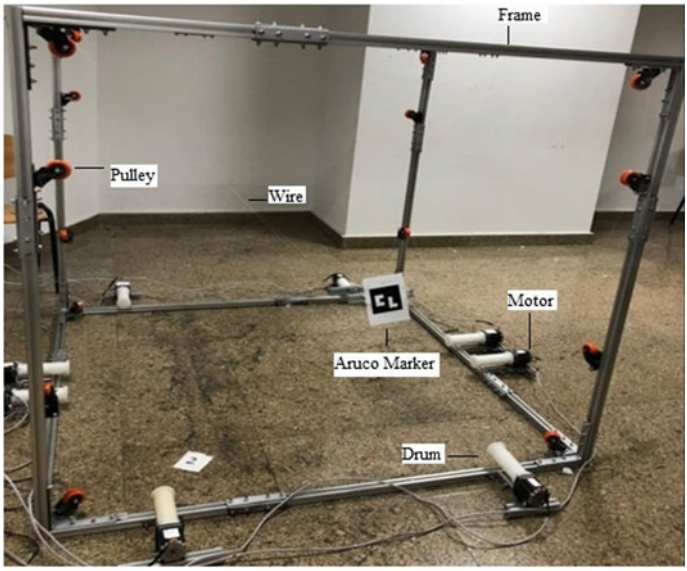

Fig. 4 Robot moving to a target location (test without the patient)

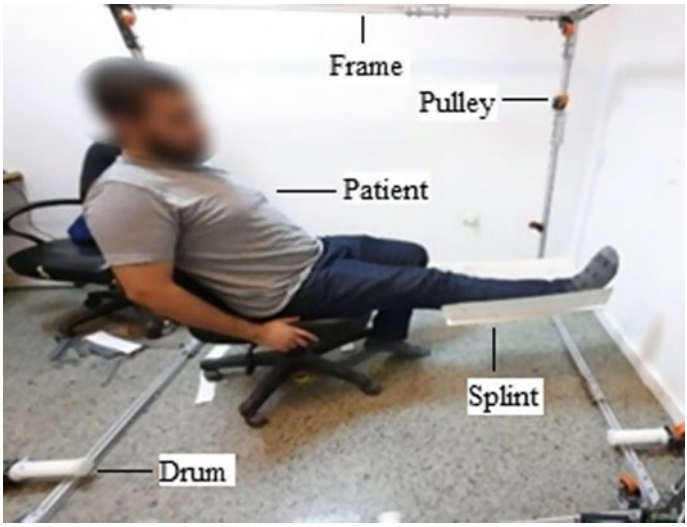

Fig. 5 Robot lifting the limb of the volunteer

Table 2 Device parameters

Parameter	Value/component	Units
Number of cables	From 4 to 8	
Size of robot frame	1.5 × 1.5 × 1.5	m
Rated cable force	2–80	N
Actuator	Nema 23 stepper motor	–
Driver	HY-DIV268N-5A	–
Drum diameter	0.04	m
Cable material	Nylon	
Cable diameter	0.004	m
Cable strength	20	kg
Controller	Arduino Mega and Raspberry Pi 4B	–

The acceleration and velocities are limited based on keeping the cables from reaching elastic properties and on keeping up with the limitations of the tracking system, and this will be based on the frame rate of the tracking camera.

One of the most important hardware components is the drum length and diameter as it plays a role in the length of cables released per pulse. Also, the diameter and material of the cables and diameter of the pully affect the workspace and the end position of the end-effector. Below on the drum, cables and pully are shown in Fig. 6.

Drum dimensions are: Cable diameter is 0.40 mm, Unmachined Artelon Rod Diameter is 4 cm, and maximum cable length to be released by the Drum is 2.7 m.

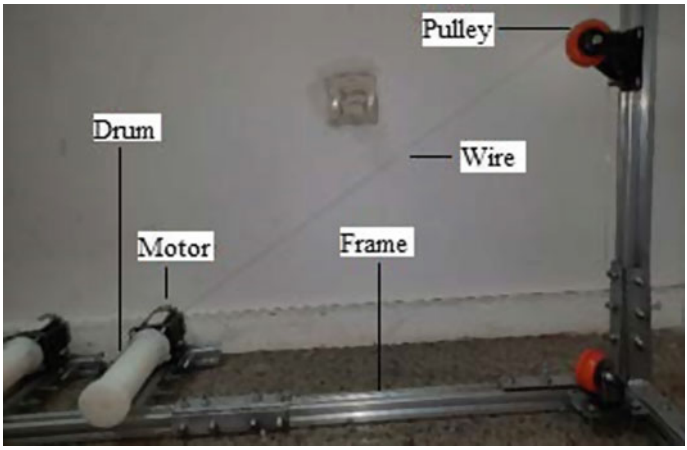

Fig. 6 Cables being reeled in by the motors from the guide pully, around the drum

The drum we used are machined and its dimensions are calculated based on the size of the cables and size of the drum. All motors are connected to individual drivers, each driver is connected to the Arduino and the power supply. Each driver takes the pulse it needs to move to release or reel in the cable that is attached to it. The motor takes the pulses from the low-level control handled by the Arduino, and the hardware setup for this is shown in Fig. 7.

All the motors are connected to individual drivers, and each driver is connected to the Arduino and the power supply. Each driver takes the pulse it needs to move to release or reel in the cable that is attached to it. The motor takes the pulses from the

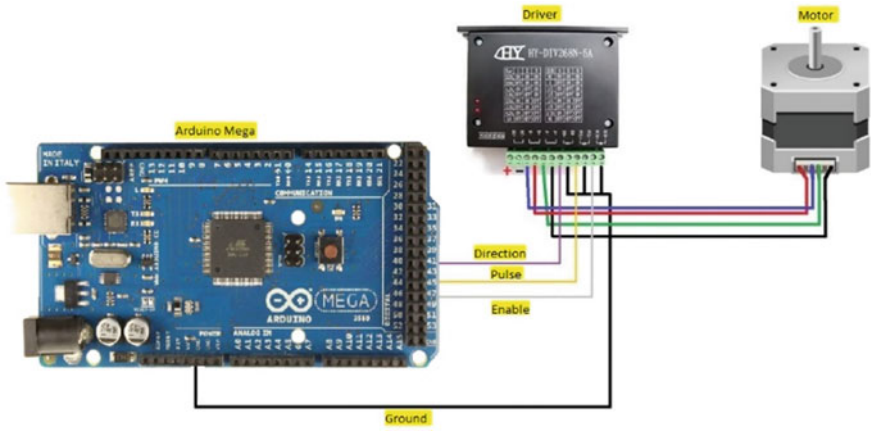

Fig. 7 Driver, electric wiring, and the motor wiring schematic

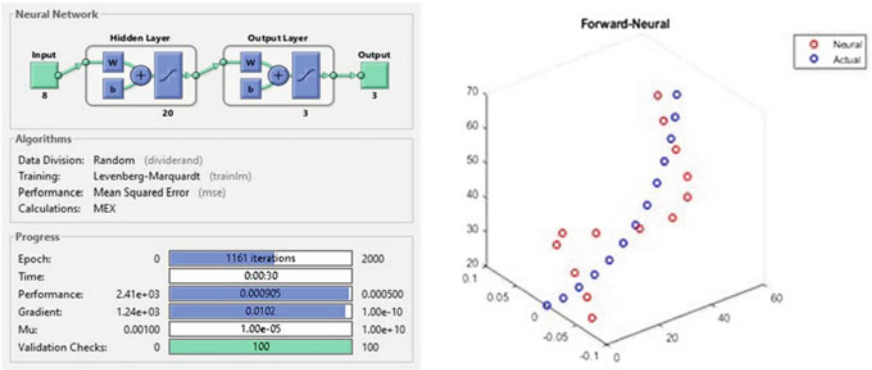

Fig. 8 Performance of neural network after training on dataset and comparison between the desired motion and the actual system output based on the neural network

low-level control handled by the Arduino, and the hardware setup for this is shown in Figs. 6 and 7.

The Kinect I of the Xbox 360 was used as to measure the pose of the end-effector, the translation, and the orientation. The camera detects physical marker called fiducial markers.

Fiducial markers are mainly used in pose estimation which could be used in robot navigation, augmented reality, and multiple other applications. It works by establishing connection between points in the real physical environment and their 2D image projection, and fiducials come in different types, shapes, and sizes, as seen in Fig. 8. These different markers have different libraries and use many ways of detection and pose estimation. However, this paper is going to focus on "Arco Markers". Before the marker is detected a calibration to the used camera need to be made, the calibration is done by using a chess whiteboard with the length and width of the chess boxes known. This helps us to extract the distortion and calibration matrix. Those two matrices help us to accurately detect the distance and pose of the Aruco Marker: kinematics and workspace simulation.

When tackling the kinematics of the cable-driven robot, the difference between the standard model and the actual physical cable robot raises from the assumptions made for the standard model. These factors not taken into consideration vastly affect the physical model behavior, and these assumptions were put in place for the sake of simplification. The camera detects physical marker called fiducial marker.

3 Kinematics and Workspace Simulation

When tackling the kinematics of the cable-driven robot, we have to note the differences between the standard model and the actual physical cable robot. The difference raises from the assumptions made for the standard model, these factors not taken into

consideration vastly affect the physical model behavior, and these assumptions were put in place for the sake of simplification.

The kinematic model of cable-driven parallel robots is obtained similarly to the model obtained from traditional parallel structures. The standard model is designed to know the general relation between the forces in different parts of the robot and how the motion of these parts is linked together. The standard model treats the cables as linear distance between to coordinates in space and both ends of the cables, the anchor point on the fixed frame "A_i" and the distal anchor point on the mobile platform "B_i", are modeled as spherical joints. In addition, the following two vectors are assumed to be not dependent on the pose of the end-effector. The vector "a_i" represents the distance from the world origin frame "F_O" to the anchor point on the fixed frame "A_i", and the vector "b_i" represents the distance from the origin frame of the end-effector "F_E" to the distal anchor point on the mobile platform "B_i".

In this section, we will used the standard model characteristics assumptions to drive the Chain closer equations of the robot. The equation is derived in relation to the world origin frame "F_O"; thus, it is written as:

$$l_i = a_i^O - \left(r + R * b_i^E\right) \tag{1}$$

The equation is finding the length of the cable "l_i" in which "$i = 1, 2, \ldots, m$, where "i" is the number of cables and the transformation between frames "F_O" and "F_E" is in terms of prose (r, R), where "r" is the Cartesian position of the end-effector (mobile platform) and "R" is the orientation of the end-effector.

The length of the cable "l_i" can be written as a unit vector "u_i", where "u_i" represents a vector pointing from the end-effector's distal anchor point "B_i" to the base "A_i". The direction is made so as the positive force on the cable is assumed to be the pulling forces. The normalized vector of the cable length "u_i" can be written as follows:

$$u_i = \frac{l_i}{\|l_i\|_2} \tag{2}$$

4 Result

In this section, we show the results of the neural network and compare between the theoretical and actual path of the rehabilitative motion.

As shown in Fig. 8, the theoretical path that we want is labeled "Actual" which is the path we wish the motion of the end-effector to follow and the "Neural" path which is the actual path based is the output we will get based on the dataset we collected. The performance of training the dataset based on the mean-square error is 0.000905 which is acceptable in our case since this error translates to 1 mm difference which is actually very good relative to our application. This is achieved after 1161 epochs

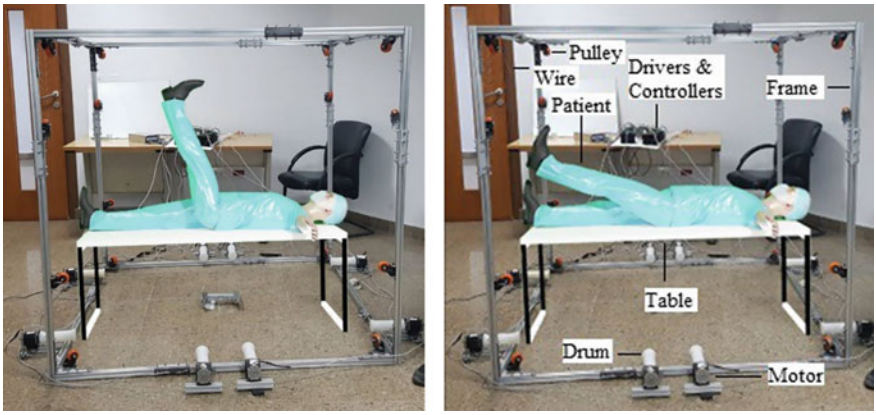

Fig. 9 Initial targeted position of the patient's limb

and 30 s. However, since this is an offline calculation, the time is not taken into consideration and so in our case accuracy is the more important factor.

5 Future Work and Conclusion

5.1 Future Work

We are working on adding the ability for our robot to provide an accurate way to treat the hips of the patients, this will be done by designing around the setup shown in Fig. 9, we are also going to improve the feedback that the doctor gets from the patients using the robot to accurately reflect the stage of rehabilitation the patient is in, and this is not only concerning the feedback analytics that the doctor gets but also with the user interface software specially designed for our robot.

5.2 Conclusion

To conclude, in this paper, we presented an 8-cable parallel robot that is used in the rehabilitation of the lower limbs. A neural network was used in place of the forward kinematics that we used then to validate between the actual and theoretical motions needed for rehabilitation. Along with this, the device is receiving visual, active feedback of its live pose and position to ensure that the correct rehabilitation movement is being performed by the patient. This allows the doctor to monitor the rehabilitation process and update the treatment according to the patent progress regardless of being present in every present in every rehabilitation session. This can

be especially helpful if the doctor cannot be present in the patient in the same room such the case quarantine for COVID-19 or simply for the inconvenience of many patients being treated.

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Assessing Synthetic Voices for Mental Health Chatbots

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Abstract Considering the possibility to exploit information and communication technologies (ICT) and specifically speaking chatbots, in the mental health domain, a study is proposed aimed at testing the perceptual features of different synthetic voices considering some fundamental aspects of human–computer interaction, namely users' acceptance and expectations. More specifically, the effect of synthetic voices' gender and quality on user's preferences were investigated. The study involved 40 participants, recruited in Northern Ireland, split into two groups: mental health experts and participants living with depression and/or anxiety. Six synthetic voices, three females and three males, characterized by different quality levels were developed for the experiment, exploiting free online synthesizers. The Virtual Agent Voice Acceptance Questionnaire (VAVAQ) was used to collect data regarding preferences toward the different synthetic voices. Results showed that participants' preferences seem to be affected by both the gender and the quality of a synthetic voice. In particular, participants preferred female voices and high-quality voices. Results also seem to suggest that the quality of a synthetic voice could have a stronger impact on users' evaluations compared to voice's gender.

Keywords ICT and mental health · Chatbots · Synthetic voices · User Acceptance (UA) · Depression · Anxiety

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1 Introduction

World Health Organization [1] estimated that the percentage of global population living with anxiety and depression in 2015 was 3.6% and 4.4%, respectively; moreover, the COVID-19 pandemic led to a significant increase of adults which experienced mental illness [2]. Despite these data highlights the need to effectively address mental health issues, having access to mental health services is often hampered by factors such as social stigmas [3], the shortage of mental health specialists (i.e. psychiatrists, therapists, and counsellors) and the financial cost of undergoing a psychological treatment [4]. Information and communication technologies (ICT) could represent a modality to improve the exploitation of mental healthcare services. For instance, conversational technologies as chatbots could represent an approach to overcome these barriers and meet needs of people living with mental ill as depression and anxiety. A chatbot is a specific typology of interactive interface which consist in a computer software/programme able to simulate human conversation through natural language, [5] and it is also defined as a "disembodied conversational agent (DCA)" [6].

Chatbots represent a promising way to support psychological well-being [7, 8]. In fact, technology can support mental health from different points of view; it can be used as a diagnostic tool for monitoring and treating symptoms and it is helpful in decreasing clinicians' workload [9]. There are a large number of benefits and possible applications of these conversational technologies within the psychological field. For example, it emerged that conversation with a chatbot that uses Structured Association Technique (SAT) as a counselling method, based on identify unrecognized feelings and desires, increases self-esteem and reduces stress [10]. Conversational technologies can also be exploited to assess users' tendency to be implicated in risky behaviours such as excessive alcohol consumption [11], to encourage users adopting behaviours able to reduce stress [12], to monitor the conversation with the user and detect the presence of depressive symptoms [13]. Further examples of conversational technologies, and more specifically chatbots, employed to promote psychological well-being are "SleepBot" designed to promote good sleep habits [14], "TeenChat" developed with the aim of helping teenagers coping with stress [9], "MYLO" inspired by the principles of perceptual control theory (PCT) and developed with aim of supporting users' problem solving processes [15] and "Owlie", a chatbot which operates on the Messenger application, able to empathically listen to the user, providing therapeutic exercises and helping managing emotional crises [16]. A further example is "Wysa", a free mobile application designed by Touchkin eServices company to support mental health; the chatbot asks questions to the user, provide multiple response options, and suggests exercises and strategies in order to help the user in managing stress, depression, and anxiety and its frequent use seems to improve the user's mood [17]. "Woebot" is a Facebook Messenger chatbot that, using Cognitive Behavioural Therapy (CBT), helps users with everyday symptoms of depression and anxiety providing technique, exercises, and self-help principles, in an effective and engaging way [18]. "Tess" chatbot has proved to be helpful in

reducing anxiety and depression symptoms [19] through interventions also inspired by CBT.

In order to meet users' expectation and needs, chatbots should incorporate key features, i.e. easiness in starting the interaction, accurately understand user's words [20], be credible and provide correct and relevant answers [21] and also own the ability of expressing emotions [22] which could increase users' acceptance. An additional strategy to improve user-chatbot interaction would be to provide the chatbot with a synthetic voice. Examples of speech-based technologies equipped with voice are smart speakers such as Alexa and Google assistant. In 2016 [23] was proposed an "Educational Chatbot" developed for visually impaired people, able to provide the user with information from the Wikipedia engine using the user's voice as input and producing a speech output. Another voice equipped chatbot is Taidhgin [24] that was developed to teach the Irish language (Gaeilge), which receives as input the text typed by the user and produces a vocal output. Further guidelines concerning the features that a synthetic voice should possess in order to meet user's need and expectations come from studies which investigated the role that the voice plays in the acceptance of virtual agents, these works showed that older people prefer to interact with female speaking virtual agents [25] and with synthetic voices, even if not equipped with a visual interface or virtual avatar [26], rather than with mute agents.

Despite the considerable number of studies investigating users' acceptance of synthetic voices in several areas, the mental health domain has been somewhat neglected, and this leads to the impossibility to transfer these results to users living with mental health issues. Considering that, we propose a study aimed at shedding light on this topic. The investigation was carried out in order to test perceptual features of synthetic voices in terms of users' acceptance, requirements, and expectations for mental health chatbots. The proposed study is positioned inside the Horizon 2020 project MENHIR (Mental health monitoring through interactive conversations, https://menhir-project.eu/) which aimed to develop conversational technologies, more specifically a speaking chatbot, in order to encourage mental health, supporting people living with mental illness, in particular mild depression and anxiety, to help self-managing their symptoms. The main aim of the study consists in providing guidelines for the implementation of a talking chatbot, investigating the following issues:

- The effect of synthetic voices' gender on users' evaluation.
- The effect of synthetic voices' quality on users' assessment.
- Test if there are differences between mental health experts and people living with anxiety and/or depression in the evaluation of the proposed synthetic voices.

2 Materials and Methods

2.1 Stimuli

Six synthetic voices were developed for the experiment, three female voices (named Alice, Bridget, Grace) and three male voices (named Daniel, Gabriel, George). Three free online synthesizers have been used in order to develop the voices: Text to speech (https://www.fromtexttospeech.com) used to develop George and Alice voices; Natural Reader (https://www.naturalreaders.com/online) used to develop Grace and Gabriel voices; Odd cast (http://ttsdemo.com) used to develop Bridget and Daniel voices. Each voice produced the English sentence: "Hi, I am sure today will be a nice day, no matter if it is raining or sunshine". In our opinion this sentence was sufficient to assess the quality of the voices, since it was chosen on the basis of its phonemic variety, moreover the sentence was selected as the English version of an Italian sentence that would have been administered to an Italian population of participants. After voices' development, experts in the field of synthetic voices and human–machine interactional exchanges qualitatively examined the voices, discussing about voices' naturalness, clearness, and expressiveness, and made the distinction between low, medium, and high-quality voices; raters always agreed on stimuli's quality, highlighting an inter-rater confidence rate of 100%. More specifically, George and Alice were identified as the low-quality voices, Grace, and Gabriel as the medium-quality voices, while Bridget and Daniel were identified as the high-quality voices.

2.2 Tools

Subjects' acceptance of the proposed synthetic voices was investigated exploiting the digitalized and the paper version of the Virtual Agent Voice Acceptance Questionnaire (VAVAQ). For details about questionnaire's developing and usage, please consult [27]. The questionnaire consisted of a first part made up by six items allowing to collect socio-demographic information and by 9 sections:

- Section 1 (with seven items) concerned participants' degree of experience with technological devices such as smartphones, tablets, and laptops, and the degree of difficulty while using them.
- Section 2 (one item) concerned participants' willingness to interact with the proposed voices.
- Section 3, 4, 5, 6, and 7 (6 items) assessed:
  (1) Pragmatic Qualities (PQ), voices' usability and practicality.
  (2) Hedonic Qualities-Identity (HQI), voices' pleasantness.
  (3) Hedonic Qualities-Feeling (HQF), voices' ability to arouse positive and negative emotions.
  (4) Attractiveness (ATT).

(5) VOICE, voices' intelligibility, expressiveness, and naturalness.

- Section 8 (three items), assessed voices perceived and preferred age
- Section 9 (composed by four items) evaluated which occupations participants would entrust to the proposed voices among: Healthcare, Housework, Protection and security occupations, and Front office occupations.

Questionnaire's items from sections 2 to 7 needed a response based on a five-point Likert scale from 1 = strongly agree to 5 = strongly disagree. Some questionnaire's sections (3, 4, 5, 6, and 7) were composed by both positive and negative items, scores from negative items were corrected in a reverse way, indeed low scores reflect voices' positive evaluations, whereas high scores negative ones.

2.3 Participants

The research involved 40 participants, aged between 21 and 61 years, split into two groups. Group 1: a group of mental health experts (professionals in the field of mental health, as counsellors and psychiatrists) made by 19 participants (10 females and 9 males, mean age = 44.89; SD = ± 11.8). Group 2: 21 participants living with depression and/or anxiety (10 females and 11 males, mean age = 45.54; SD = ± 11.8) recruited among Action Mental Health clients. Action Mental Health (AMH) is a Northern Irish (UK) non-profit organization which operates to improve the well-being of people with mental health needs and assisting them in their professional integration. Participants belonging to this group were previously diagnosed with depression and anxiety, then those who were eligible for the study were directly indicated to the researchers by the organization and, in order to protect their privacy, the data relating to the diagnoses cannot be shared.

Participants belonging to the group of experts were selected among Action Mental Health staff members, New Life Counselling (member of the Action Mental Health Group) staff members and members of the Royal College of Psychiatrists. Participants' recruitment took place in Belfast (Northern Ireland). Participants voluntarily participated to the study after having signed an informed consent. The study was authorized by the ethical committee of the Ulster University. Figures 1 and 2 are graphically showed information regarding participants' degree of experience and difficulty of using technological devices.

Participants' relationship with technology is relevant since the study is aimed at investigating users' preferences towards technological systems as synthetic voices, as a consequence knowing participants starting level of experience with the technology could represent a useful information.

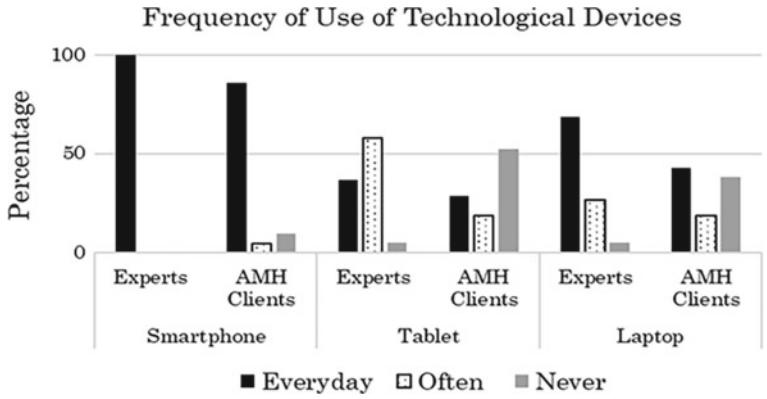

Fig. 1 Participants' frequency of use (in percentage) of smartphone, tablet, and laptop

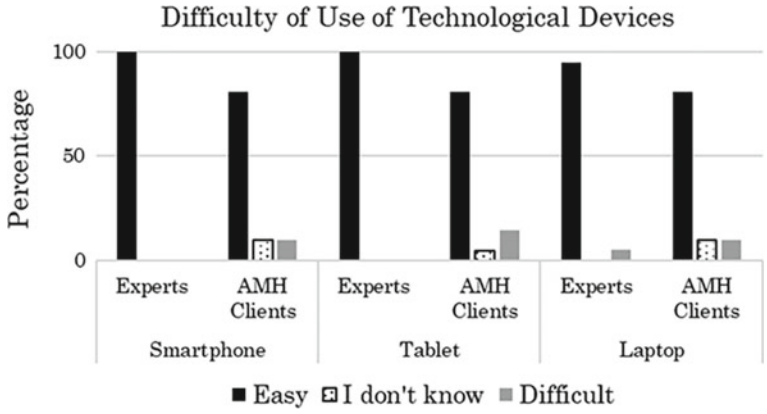

Fig. 2 Participants' difficult of use (in percentage) of smartphone, tablet, and laptop

2.4 Procedures

First, subjects were informed about the aims of the MENHIR project and of the experiment, then signed the informed consent and told how to proceed. They firstly provided socio-demographic information and answered to the items of the section 1. Then, after listening to each voice they were required to complete the remaining sections of the VAVAQ questionnaire. Participants belonging to the group of experts randomly listened to all the voices and were individually administered the digitalized version of the questionnaire, while the group of AMH clients were administered the paper version of the questionnaire since data were collected in the context of group workshops organized within AMH facilities; in this case voices were administered randomly within each small group who joined the workshops.

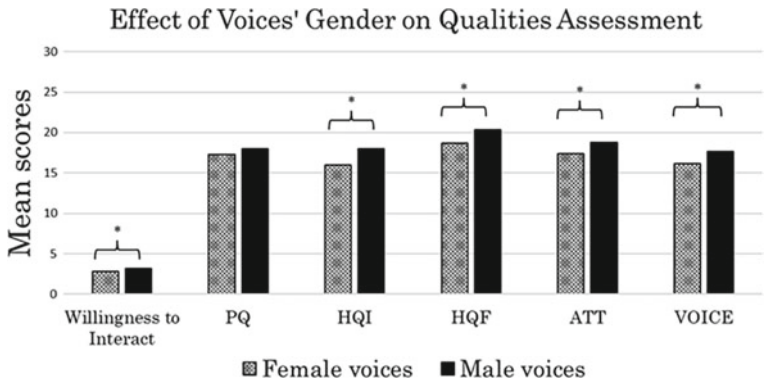

Fig. 3 Mean scores concerning subjects' willingness to interact and for each investigated quality obtained by female and male voices. The ordinate axis represents means which can vary between 0 and 30 (low scores = better voices evaluation; high scores = worse evaluation of the voices, (*) indicates which means are statistically different from the others

3 Results

Repeated measures Analysis of Variance (ANOVA) were carried out on the total scores obtained by the voices at each VAVAQ section (willingness to interact, pragmatic qualities, hedonic qualities—identity and feeling—attractiveness and voice). Participants' gender and group (Group 1: experts, Group 2: AMH clients) were considered as between factor variables, while voices' gender and quality (low, medium, high) were considered as within factors variables. The significance was set at $\alpha < 0.05$ and differences among means were assessed through Bonferroni's post hoc tests. Due to the reverse correction of negative items, low scores summon to positive voices' assessments whereas high scores to negative ones. ANOVA repeated measures analyses were also carried out on scores obtained by each voice for their entrusted occupations—among healthcare, housework, protection/security, and front office jobs. Once again, participants' gender and group were considered as between factors and voices' gender and quality were considered as within factors variables. The significance was set at $\alpha < 0.05$ and differences among means were assessed through Bonferroni's post hoc tests. Below, results will be graphically depicted, while the complete version of the paper with results of the statistical analysis can be found at: http://becogsys.ddns.net:9080/papers/ICICT23.pdf (Figs. 3, 4, 5, 6, 7 and 8).

4 Discussion and Conclusions

A study was proposed introducing an experiment aimed at exploring features of synthetic voices which could affect the way people interact with them. Whether and how users' perception and preferences are shaped by synthetic voices' gender and

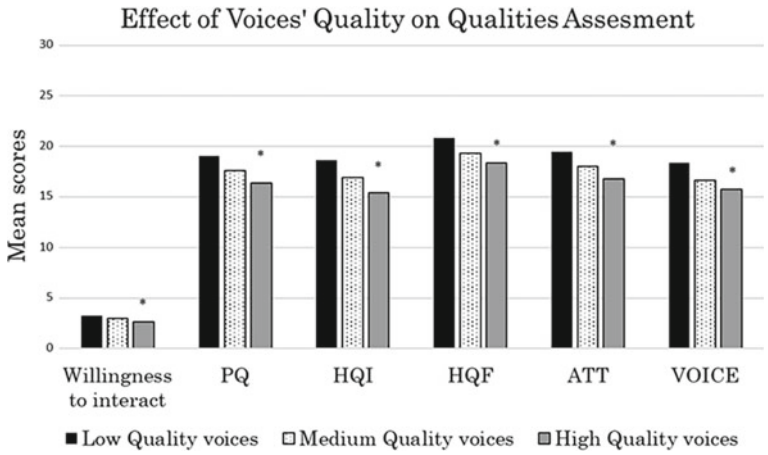

Fig. 4 Mean scores concerning subjects' willingness to interact and for each investigated quality obtained by low, medium, and high-quality voices. The ordinate axis represents means which can vary between 0 and 30 (low scores = better voices evaluation; high scores = worse evaluation of the voices, (*) indicates which means are statistically different from the others

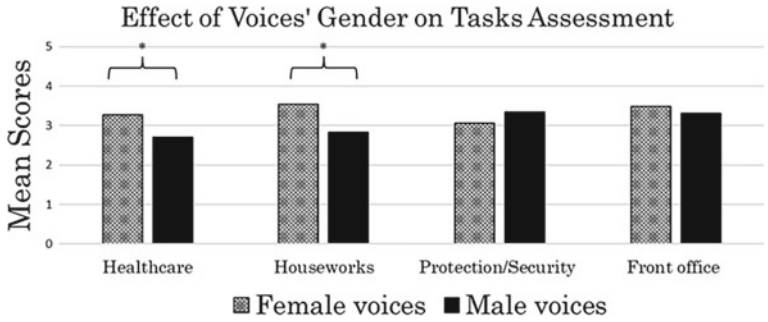

Fig. 5 Participants' evaluation of voices' suitableness at accomplishes tasks obtained by female and male voices. The ordinate axis represents mean scores which can vary between 0 and 5, (*) indicates which means are statistically different from the others

quality has been investigated and more specifically how these variables influence participants' willingness to interact with the proposed voices, the assessment of voices' pragmatic (PQ), hedonic (HQI and HQF) and attractive (ATT) qualities, voices' intelligibility (VOICE) and voices' appropriateness at accomplishing several tasks (healthcare, housework, protection/security, and front office). The study also investigated potential differences between mental health experts and people living with anxiety and/or depressions in the evaluation of the proposed synthetic voices. To this end female and male voices with different quality levels were administered: George and Alice (low-quality voices), Grace and Gabriel (medium-quality voices), Bridget and Daniel (high-quality voices).

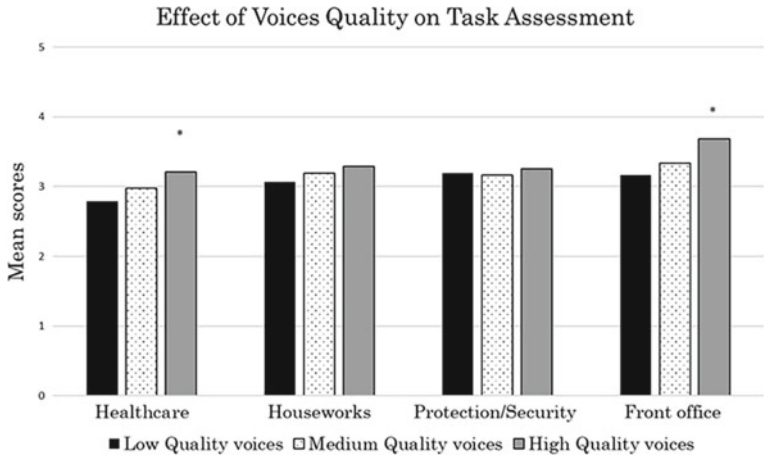

Fig. 6 Participants' evaluation of voices' suitableness at accomplishes tasks obtained by low, medium, and high-quality voices. The ordinate axis represents mean scores which can vary between 0 and 5, (*) indicates which means are statistically different from the others

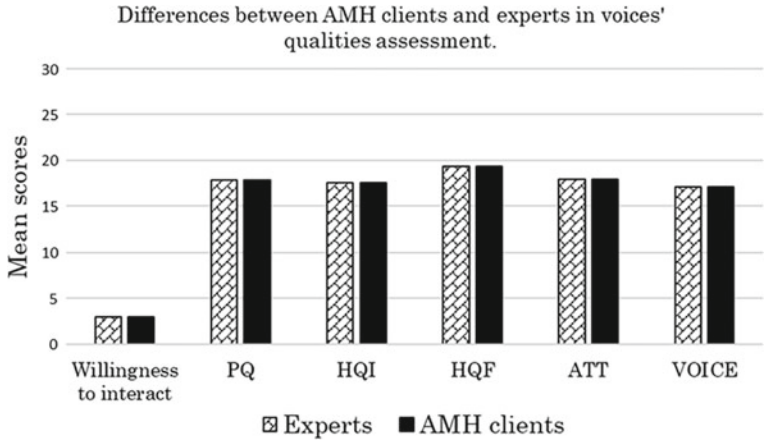

Fig. 7 Experts' and AMH clients' assessment of voices' qualities. The ordinate axis represents mean scores which can vary between 0 and 30 (low scores = better voices evaluation; high scores = worse evaluation of the voices, (*) indicates which means are statistically different from the others

Participants expressed greater willingness to interact with female voices (Alice, Grace, and Bridget) compared to male ones (George, Gabriel, and Daniel) and with high-quality voices (Bridget and Daniel) rather than low-quality voices (George and Alice), however when assessing low-quality voices participants reported more openness in starting an interaction with the male voice (George) rather than the female one (Alice). When assessing voices' pragmatic qualities (PQ) participants did

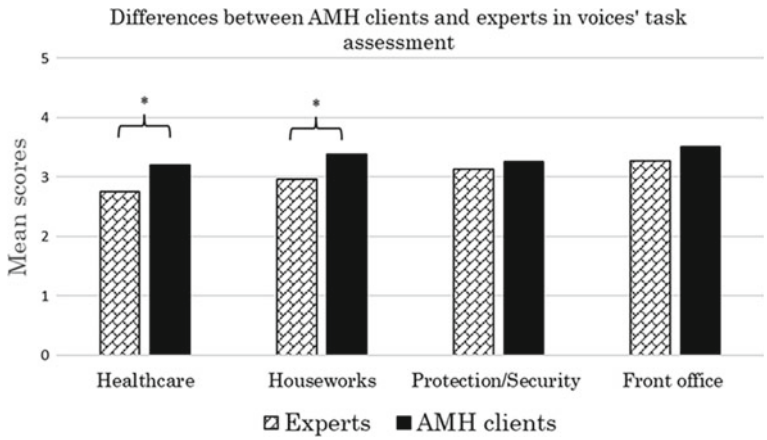

Fig. 8 Experts' and AMH clients' assessment of voices' tasks. The ordinate axis represents mean scores which can vary between 0 and 5, (*) indicates which means are statistically different from the others

not express a preference neither for female nor male synthetic voices; participants evaluated low-quality voices as less usable and effective compared to medium-quality voices (Grace and Gabriel) and high-quality voices. Even in this case when assessing low-quality voices participants rated the male voice as more pragmatic compared to the female one. Concerning the assessment of voices originality and pleasantness (HQI) female voices were recognized as more endowed of these features than male voices, while low-quality voices were assessed as less appealing compared to high-quality voices; once again when comparing the two low-quality voices, participants rated the male voice as more pleasant than the female voice. Participants also rated female voices as more likely to arouse positive emotions (HQF) than male voices, and the same happened for high-quality voices when compared to low-quality voices, even though when referring to low-quality voices participants rated the male voice greater when compared to the female one. Female and high-quality voices were also considered as more attractive (ATT) when compared to male and low-quality voices, respectively. When assessing voices' intelligibility, expressiveness, and naturalness (VOICE) once again the participants rated female voices greater when compared to male ones; they also expressed worse evaluation of low-quality voices compared to medium and high-quality voices. When comparing the two low-quality voices, the male voice was rated as more expressive and natural compared to the female one. Data showed that when participants were asked to assess voices' suitability to healthcare occupations, mental health experts rated the voices as less capable of performing care functions to assist children, elders, and disabled people compared to the group of AMH clients living with depression and/or anxiety. Female voices and high-quality voices have been assessed as more adapt at performing healthcare tasks when compared to male and low-quality voices. The two groups of participants showed different points of view even when assessing voices' suitability to housework

tasks, with the group of mental health experts, in particular male experts, showing less confidence in voices' ability to accomplish domestic duties compared to AMH clients; once again female voices were considered more competent in conducting housework jobs compared to male voices. Concerning protection and security tasks, female participants were more prone to entrust this function to the proposed voices when compared to male participants, no differences were found between female and male voices and among voices with different quality levels. Finally, participants evaluated high-quality voices' as more capable to fulfil front office receptions when compared to low-quality voices, while, when comparing the voices belonging to the low-quality category, they showed a preference for the female voice rather than the male one.

Participants expressed a positive attitude toward female voices showing that they would prefer to interact with them rather than with male voices. Female voices were also rated as more pleasant, original, creative, attractive, and capable of arousing positive emotions. Compared to male voices, female ones were also rated as more natural, expressive, and intelligible and more suitable at accomplishing healthcare and housework tasks; this could be linked to a gender stereotype, which may lead people to consider females more suited for caring and welfare occupations and male more adapt to accomplish defensive tasks. These results are consistent with those achieved by other studies investigating users' preferences toward assistive social robots [28] and assistive virtual agents [3]. In contrast, [29], in a study testing female and male gendered human and synthetic voices' ability to persuade the listener; the authors observed higher acceptance toward female human voice compared to female synthetic voice, and a preference toward male voice, when comparing females and male's synthetic speech.

Voices' quality affected participants' evaluations as well; they expressed greater willingness to interact with high-quality voices, considering them as more pleasant, creative, positive, and attractive than those of inferior quality. High-quality voices were also considered as more intelligible, useful, effective, and controllable than the medium and low-quality voices, as showed by previous studies [30]. Low-quality voices were assessed less natural and expressive compared to medium and high-quality voices. Unfortunately, in our knowledge, the comparison between high- and low-quality synthetic voices is a fairly neglected topic, consequently there are not enough studies to which compare our results, most likely because there is the tendency to assume that users should prefer high-quality voices. When required to assess voices' suitability to distinct types of tasks, participants assessed high-quality voices more adapt in performing healthcare and front office jobs compared to low-quality voices. Although it clearly appears the impact of synthetic voices' gender and quality on potential users' preferences, another interesting effect emerged. Even though participants generally preferred female voices over male ones, when comparing low-quality voices (Alice and George) it turned out that the participants preferred the male voice George, showing greater willingness to interact with him, evaluating George as more useful, pleasant, understandable, and more suitable for front office tasks than the female voice Alice. This could lead to the assumption that when the quality of a synthetic voice is actually low, the power of the gender effect decreases; it's likely

that between the two low-quality voices the male one is qualitatively better than the female voice leading participants, when required to express their preferences, to no longer consider the gender of the voice as a key variable, suggesting that the quality of a synthetic voice has a stronger impact on users' evaluations when compared to the voice's gender. Differences between the two groups of participants, emerged just as regards the assessment of voices' suitability in performing different tasks, revealing that the group of mental health experts tended to evaluate the voices more negatively compared to AMH clients living with depression and/or anxiety, in particular concerning healthcare and housework tasks. It is conceivable that AMH clients in quality of potential users, showed a more cheerful outlook toward the voices, especially if considered as assistant in performing welfare tasks and housework. The presented research is positioned inside a European Project called "MENHIR" (https://menhir-project.eu/), the acronym stands for "Mental health monitoring through interactive conversations", and the aim of the project consist into developing a conversational system able to facilitate the life of people living with mental ill (depression and anxiety) helping in the process of symptom monitoring and managing of their conditions. A way to make the conversation easier and more natural, consist into endowing the system with a voice, for this reason were assessed several synthetic voices. As already stated, the presented research born from the need to specifically investigate users' acceptance of synthetic voices within the mental health domain, a topic that has been unfortunately neglected, leading to the impossibility to transfer these results to users living with mental health issues. This is because the results of research conducted in other contexts could, but not necessarily, be generalized to this type of population, since it owns specific characteristics and needs. Overall, we observed a general positive attitude of potential users toward synthetic voices, in compliance with other studies highlighting that the use these technologies within the field of mental health is related to a wide variety of advantages, for instance [31] highlighted that people using Internet-based self-help psychological treatments for depression show reduced risk symptom deterioration compared to controls; another advantage is related to the evidence that people are more prone to disclose themselves, to reveal more information, to express their emotions more intensely and be more available to discuss their mental health symptoms when interacting with a computer rather than with a human being [32]. Users' positive attitude towards conversational technologies was also highlighted in a study [33] in which was assessed the perception of a conversational agent from hospitalized patients' living with depression, the agent was developed to provide patients with information about their discharge plan; it emerged that patients evaluated agent's performance as satisfactory and also claimed to have established a good level of therapeutic alliance with him.

To conclude, results presented within this study could be useful especially as regards as mental health chatbots and the design of virtual therapy environments, providing guidelines to AI designer which should be considered while developing this typology of assistive technologies. Future studies could overcome limits of the proposed research involving wider samples of participants, from different countries and cultures and belonging to differently aged groups. Moreover, synthetic voices developed to conduct the present research were implemented exploiting free online

synthesizers, in a future study may be useful to employ more professional tools and also try to develop genderless synthetic voices, since a trend toward the choice of this kind of voices is getting stronger [34, 35]. Further investigations are needed in order to deeply explore which features of a synthetic voice have a stronger impact on users' preferences, these last are crucial aspects which should not be underestimated. User's perspective, expectations and needs are essential whenever the aim consists in improving human–computer interaction and the implementation and development of assistive technologies.

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Anomalous-Aggressive Event Detection Techniques

Manar M. F. Donia, Aliaa A. A. Youssif, and Wessam M. H. El-Behaidy

Abstract Human behavior refers to the way humans interact with their surroundings. It can be classified as either being normal or anomalous behavior. Anomalous events are behaviors that are deviant against all societal norms. One event makes another event happen, where the cause-effect relationship in behavior is the law of science. Automatically detecting anomalous events has become an important research area. It plays a significant role in video surveillance security, especially in public places also human–computer interaction. Recently, researchers have oscillated between traditional learning, deep learning, and hybrid-based models. The traditional learning-based model depends on extracting the best features to contribute to the result. The deep learning-based model deals directly with data and skips the manual step of feature extraction, offering an end-to-end problem solution. The hybrid-based model combines the benefits of both models to improve the detection result. This paper presents an inclusive review of traditional learning, deep learning, and hybrid-based models for anomalous event detection. It also hands out discussions on state-of-the-art approaches used.

Keywords Computer vision · Artificial intelligence · Video understanding · Multimedia · Traditional learning · Deep learning

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1 Introduction

Humans are the elements that continuously engage within complex and ever-changing surroundings while interacting with the environment. The behavior of humans refers to the way they interact with their surroundings. Human behaviors study aims to develop a deeper perception of how humans are affected by environmental conditions and make decisions. Gottlieb [1], sees that genetic and environmental factors contribute to human behaviors. Skinner [2], provides that the causes of behavior are the external conditions of which behavior is a function. One event makes other events happen, which is the cause-effect relationship in behavior is the law of science. Human behavior can be classified as either being normal or abnormal behavior. When we look at different cultures, we can see that the sorts of things that are considered normal are often similar. So normal behavior is culturally shaped. Anomalous behavior is the human attitude that drifts from anticipated, common, or natural action. It could be the behaviors that deviate from the group behavior, such as walking in the opposite direction or violence outbreak in riots among the masses. There's no exact definition of anomalous behaviors. But what is common among these behaviors is it causes harmful accidents.

In [3], 79 people died, and more than 500 were injured after a violent outbreak among spectators at Port Said Stadium in Port Said, Egypt. In [4], a crush and stampede accident happened, causing the death of at least 700 pilgrims in Mina, Saudi Arabia. In [5], a tragic fight between soccer fans before the game began caused the death of four people and injured many more at the National Stadium in Tegucigalpa, Honduras.

To spot anomalous behaviors, one needs to understand human behaviors, [6] traced the role of emotional contagion theory and the process of hysterical contagion. They conclude that emotional contagion is the triggering of behaviors between others. Negative emotions have quicker and stronger emotional effects than positive ones. Anomalous behavior is any unusual activity, but aggressive or violent ones are the most harmful between them. We focus on the present trend of detecting aggressive events in this research. Slutkin [7], clarifies that violence is a contagious disease. Contagion of violence is like infectious diseases in different aspects, including spreading. Violence eruption can be in numerous situations, including protests, demonstrations, or even soccer riots. Once it is detected, we might prevent their chain reaction. Detection of such behaviors at the initial spark is critical for guiding public safety decisions and a key to its security. Most of the work done in violence detection is two paths: local violence detection or global violence detection. Datta et al. [8], detect local violence, which is the behavior of one individual as one individual threatening other with a weapon. Spaaij [9], detects global anomalous, which refers to the behavior of more than one individual as soccer riots.

Different approaches detect aggressive human behavior in a scene, as shown in Fig. 1. Those approaches are categorized into, the traditional learning-based model, deep learning-based model, and hybrid model. Datta et al. which can detect normal

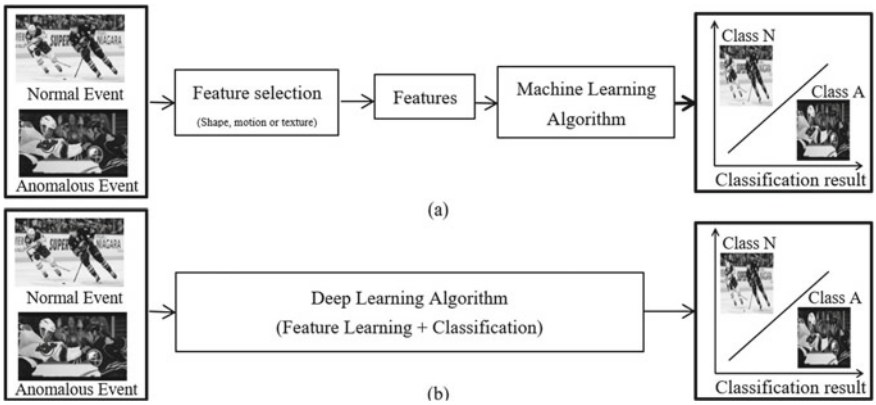

Fig. 1 **a** Traditional learning-based model, **b** Deep learning-based model

and anomalous events in crowded or uncrowded scenes. The traditional learning-based model depends essentially on two steps: feature representation and feature analysis. Feature representation is handcrafted features through choosing and extracting a set of features like motion or texture. Feature analysis is through employing a machine learning classifier. Its main obstacle is the wide-ranging features of actions in traditional models. The deep learning-based model performs automatic feature extraction without human intervention. It performs automatic feature extraction without human intervention. Also, provide an end-to-end problem solution by combining the two steps of the traditional learning-based model. But it requires a large amount of training data. Table 1 gives the factors that differentiate traditional learning from deep learning. Some researchers combine the benefits of a traditional learning-based model and a deep learning-based model in a hybrid model. Features representation in this model is a handcrafted feature or deep feature learning. Feature analysis is through a machine learning classifier or more sophisticated convolution neural networks.

The remainder of this paper is as follows. The well-known dataset is in Sect. 2. Demonstrations of the current methodologies used for detecting the aggressive events are in Sect. 3. Finally, Sect. 4 is a conclusion.

2 Datasets

In this section, frequently public datasets used for violence detection are discussed. The primary input to the system is video which includes violent and nonviolent behaviors to detect either local or global violence. Local violence detection, uses the movie fights (MVF) dataset [10], it includes close-ups of a person-on-person fight from 200 video clips obtained from action movies. While the global violence detection, uses the violent flows (VF) dataset [11], it comprises violent outbreak

Table 1 Traditional learning versus deep learning

Factors	Traditional learning	Deep learning
Data requirement	Requires less amount of data for training	Big data, requires a large amount of data
Feature engineering	Choosing and extracting a set of features are done by expert	Automatic without human intervention
Hardware dependency	Can be trained on CPU	Requires high-performance GPU
Interpretability	Some algorithms are easy to explain their behaviors while others are hard	Hard to explain its behavior
Preprocessing	For better result preprocessing step is needed	Doesn't need preprocessing
Training time	Requires less training time	Requires long training time

scenes from 246 videos downloaded from YouTube. The dataset is divided into training and testing, as shown in Fig. 2 to evaluate system prediction. The training data is to train the algorithm to predict the outcome while test data is to measure its performance.

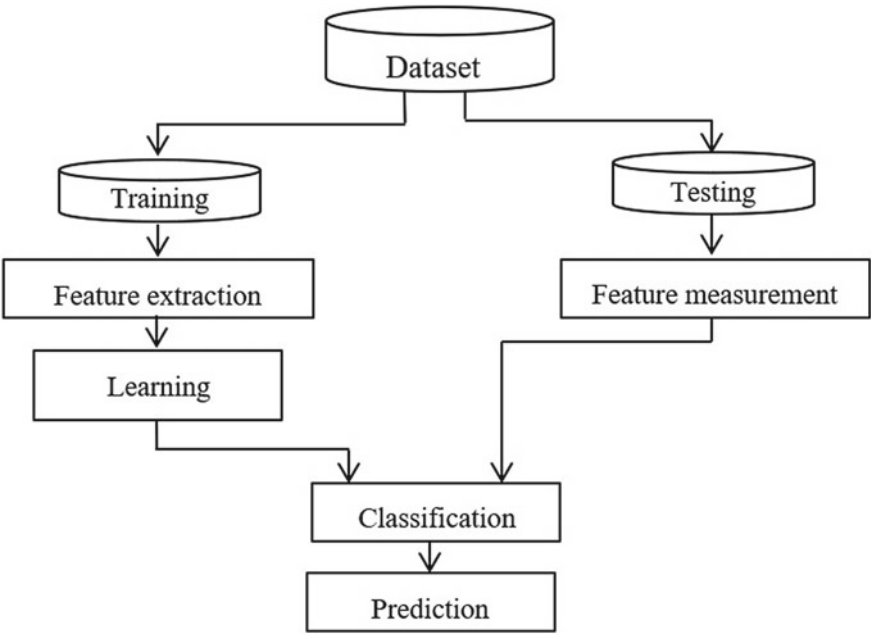

Fig. 2 Basic violence detection system model

Those datasets are categorized into (I) single scene datasets composed of videos performed by actors or extracted from movies. VSD dataset [12], consists of scenes from 18 movies of violent and nonviolent content. There are 1317 clips collected from these movies, with the start frame indicating the beginning of the action and the end frame showing the finish of the action. SBU Kinect dataset [13] contains 300 interactions of eight categories of violent and nonviolent actions performed by seven participants. Shaking hands, approaching, departing, exchanging objects, and hugging are all examples of nonviolent action. Pushing, kicking, and punching are violent actions. The hockey fight (HF) dataset [10] includes 1,000 clips from National Hockey League games. Each clip consists of 50 frames labeled as fight or non-fight. (II) Real events are recorded by surveillance cameras. UCF-Crime dataset [14] includes violent and nonviolent actions. It consists of 1900 long real-world surveillance videos of 13 violent acts, such as robbery, fighting, shoplifting, and shooting. CCTV-Fights [15], is a collection of 1000 videos of real fights labeled with their exact start and endpoints. Recording fights were for an average of 2 min with CCTVs or mobile cameras with an average length of 2 min.

3 Methodologies

Currently, there are various researches interested in anomalous aggressive event detection. Detection of violent events in crowded and uncrowded scenes has a critical role in public safety and security. Detecting such behaviors depends on feature learning, which is a part of our day-to-day life. Feature learning techniques are used every day, from teaching a child to recognize different objects to detecting deceiving persons from their facial expressions [16]. Feature learning is done in two stages: feature representation and feature analysis. Recent studies are categorized into three models: traditional learning-based model, deep learning-based model, and hybrid model. Where traditional learning-based model strength depends on engineering features that give the best features largely contribute to the results. The deep learning-based model offers end-to-end problem solutions by manipulating raw data to extract information to detect violent actions. Then researchers examine the benefits of combining deep learning with a traditional learning-based model in a hybrid model.

3.1 Feature Representation

The violent actions are mainly related to body movement, represented by a large amount of raw data. Feature representation reduces the raw data into more doable sets for processing. It depends on extracting a set of features in the spatiotemporal domain combined and used for violence detection. Many techniques based on traditional features, deep features, and hybrid models have emerged.

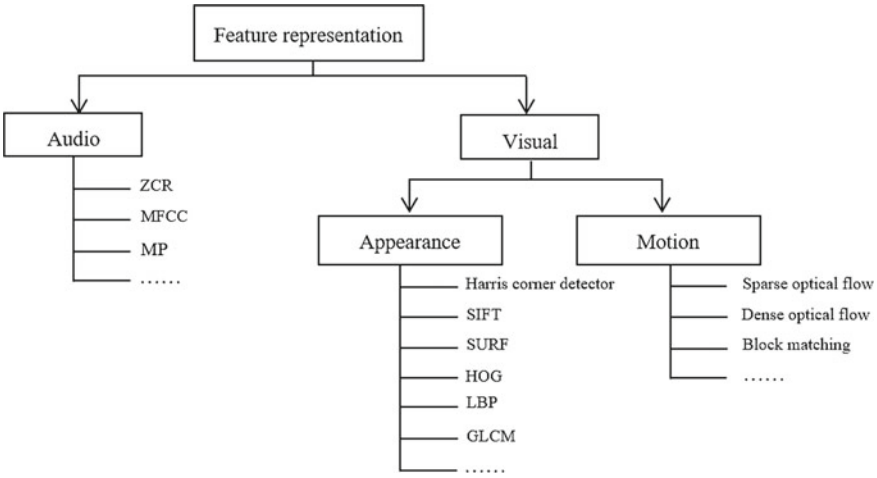

Fig. 3 Traditional model feature representation

Traditional Learning-Based Model: Instead of using raw data, which causes the curse of dimensionality, researchers work on feature engineering. That reduces raw data into a set of features without sacrificing critical information to decrease computational complexity. The extracted features are varied between audio and visual clues, as shown in Fig. 3. A different set of features such as zero-crossing rate (ZCR), mel-frequency cepstral coefficients (MFCC), spectral centroid (SC), energy entropy (EE), matching pursuit (MP) algorithm, are employed to detect violent audio signals. In [17] and [18], ZCR and other features are extracted from the audio signals and used for violence detection. Appearance and motion features reflect the visual clues. Appearance-based features focus on the shape of human bodies during actions, while motion-based features focus on the direction of the moving body parts.

The appearance-based features deal directly with the pixel intensity where color, texture, and shape are used for classification Most of the work based on appearance features either use spatio-temporal interest points (STIPs), local appearance, or global appearance-based approaches to analyze appearance attributes. STIPs approaches are used to identify and extract features localized on a collection of interest points, such as contours, edges, or corners. Local features operate on image patches, while global describe the entire image. Both contain discriminating information robust to scaling, rotation, and translations. Harris corner detector has been employed in [19], to detect corners and edges of the shape, location, and direction features. In [20], scale-invariant feature transform method (SIFT) was utilized to detect interest points and extract SIFT descriptors, allowing invariants of scale and rotation. Speeded-up robust features (SURF) is a speeded-up form of SIFT that is used in [21], for computational efficiency. Das et al. [22], employed histogram of oriented gradient (HOG) to extract features by counting occurrences of edge intensity orientation in localized portions. In [23], a texture features fusion descriptor was extracted using a

local binary pattern (LBP) and a gray level co-occurrence matrix (GLCM). In [24], oriented fast and rotated BRIEF (ORB) and HOG, as well as SIFT and SURF, are employed to extract feature descriptors for violent event identification. The motion-based features employ motion direction and magnitude as the set of features for detection. Different algorithms are applied to capture motion features, where the motion vector is extracted either per block of pixels or around a sample of points to estimate motion or even for each pixel in the video frame. The block matching algorithm is used in [25], to extract one motion vector per block of pixels to estimate direction and magnitude values. Sparse optical flow algorithms, such as the Lucas–Kanade method or the Horn-Schunck method are used to detect any rapid change of a set of points at the pixel level through estimating optical flow magnitude and orientation, as in [26], and [27]. The dense optical flow algorithm estimates motion magnitude and orientation per pixel for the entire frame, as in [28], [29], and [30]. Fusion strategies are then adopted to develop more discriminative features. Some researchers adopt fusion strategies to obtain the benefits of both appearance and motion features by combining both in one descriptive vector. Shi-Tomasi corner detector combined with the sparse optical flow of Lucas–Kanade method, in [31], to define parameters of moving objects. A motion magnitude image based on the modified sparse optical flow of Lucas–Kanade method in [32], is used to extract local HOG in addition to a local histogram of optical flow (LHoF) in [33]. The extracted features are then passed to the Bag of Words (BOW) model to express the diversity of violence. In [34], a movement filtering algorithm (MF) is used to exclude nonviolent actions from feature extraction, and then a SIFT descriptor, HoF, and motion boundary histogram (MBH) feature are combined to produce a discriminative descriptor of appearance and motion features called MoBSIFT. Others, as [35], [36], and [37], fused audio along with visual clues in one feature vector to produce discriminative features. Table 2 gives a collection of studies that use such models. The traditional learning-based model provides a way to visualize and analyze features, to choose the best features that contribute significantly to the results. But still, the feature representation has wide-ranging features which don't contribute enough to decreasing computational complexity. As a result, researchers attempt to investigate alternative models to get better detection with less complexity.

Deep Learning-Based Model: Deep learning is built on artificial neural networks to replicate the human brain. It skips the manual feature extraction step and deals directly with raw data, with traditional feature extraction algorithms are replaced by a deep learning scheme. Deep learning algorithms manipulate raw data to extract information to create knowledge. Knowledge provides an understanding that leads to wisdom [38]. After the success of deep learning schemes in image classification [39], researchers have examined its ability for anomalous detection. The extracted features varied between audio and visual clues in a multimodal fashion [40], and [41]. Several types of neural networks are employed to capture deep features, but the commonly used is feed-forward neural networks. The feed-forward neural allows information to flow in one direction from input to output. Convolutional neural network (CNN) is the commonly used feed-forward neural network for feature representation. It consists of

Table 2 Summary of research work using the traditional learning model for violence detection accuracy

Author	Feature representation	Feature analysis	Accuracy and dataset			
			HF (%)	VF (%)	MVF (%)	Others (%)
[17]	ZCR + MFCC along with others	SVM	–	–	–	78
[19]	Harris corner detector	KNN-entropy	–	95	–	–
[21]	SURF	SVM	–	–	–	87
[22]	HOG	RF	86	–	–	–
[23]	LBP + GLCM	SVM	91	89	–	–
[29]	Optical flow	SVM	92			94
[33]	LHOG + LHoF + BOW	SVM	95	94	–	–
[34]	MoBSIFT + MF	RF	96	–	98	–
[35]	Optical flow + HOG + MP	SVM/RF	–	–	–	88.7
[81]	HoF + statistical features	SVM	91	84	–	–
[85]	STIP + HOG	Max-entropy	–	–	–	91
[86]	ECG signals	KNN	–	–	–	88
[88]	STIPs + Sparse optical flow	DT-SVM	–	–	–	97

three main types of neural layers. First, the convolutional layers that generate feature maps. Second, the pooling layers are employed to reduce the dimension of the feature map, resulting in reduced computational overhead. At last, the fully connected layers map the extracted features into the final output. Many researches based on deep CNN architectures have been proposed for violence features representation, such as ResNet architecture [42] and [43], GoogleNet [44] and [45], VGGNet [46] and [47], and C3D [48] and [49]. Other feed-forward neural networks, such as auto-encoders and deep belief networks (DBN) are also employed for anomaly feature representation. An auto-encoder is a form of the artificial neural network consisting of an encoder that converts input into code and a decoder to reconstruct inputs again from this code. It was employed in [50] and [51], for anomaly event detection through learning normality to detect the anomaly. The DBN is a fast deep learning scheme that works well with the problem of becoming stuck in local minima. It is composed of multiple layers trained in a greedy manner. DBN is used in [52], to extract features from labeled videos to detect suspicious behavior, also used in [53] and [54], to detect hate speech from text to avoid arousing violent attitudes. To obtain more discriminative features, some researchers adopt a fusion strategy. The extracted features from the feed-forward neural network are fed into a recurrent neural network (RNN) where the classifier layer of CNN is removed, and the output of the fully connected layer is given as input to the recurrent neural network. The robustness of the extracted features

is that they represent long-short term temporal information and spatial information. Adding the CNN layer in front of the RNN layer improves accuracy. The most used RNNs are long-short term memory (LSTM), bi-directional LSTM (BiLSTM), and gated recurring units (GRUs). The LSTM network handles long-term dependency by storing information in its memory, not just for short periods but also for a longer duration. It uses a gating mechanism consisting of; forget, input, and output gates, to regulate information that controls the memorizing process. The forget gate decides which information to store and which to throw. The input gate updates the new cell state. The output gate updates the next hidden state. ResNet features combined with LSTM in [55], for features representation, while VGGNet combined with LSTM in [56]. In [57], MobileNet CNN was employed for spatial features extraction, followed by LSTM to extract spatio-temporal features. The BiLSTMs RNN is an expansion to the LSTM network where it consists of two LSTM, not just one which enhanced its performance. The first LSTM learns the original input data provided, while the second model learns its reverse sequence. In [58], VGGNet features combined with BiLSTM for feature representation. GRUs network contains two gates: update gate and reset gate. The update gate decides which data to store and which to throw. The reset gate determines the amount of data to forget. In [59], MobileNet is combined with the GRU network to model the long-term dynamics. MobileNet combined with LSTM in [60], in which MobileNet V2 is for spatial features extraction followed by LSTM for temporal feature extraction. Srivastava et al. [61] proposed a hybrid-deep network model incorporating transfer learning for violence detection in addition to individual detection by face recognition. The spatial features were retrieved using (InceptionV3 + ResNet101V2) followed by LSTM for the temporal feature. Recently, vision transformer (ViT) has piqued researcher's attention in violence detection. Transformer model is primarily employed in advanced natural language processing and, more recently, image recognition and classification in [62]. The transformer model architecture consists of multiple self-attention layers that capture long-term dependencies between sequences of image patches. It learns by measuring the relationship between input image patches. In [63], spatial features are extracted using ViT model for fight detection. In [64], ViT model in conjunction with 2d-CNN is used for spatio-temporal learning. In [65], measures the efficiency of a ViT model in conjunction with different CNN such as I3D and C3D for feature learning and analysis. Table 3 gives a collection of studies that use such models. The deep learning-based model offers end-to-end problem solutions. However, due to its multilayer structure, it is not easy to be traced. It will be challenging to solve any problems that arise.

Hybrid Model: As wide-ranging features of traditional learning increase the computational complexity and the deep learning traceability problem, some researchers investigate the advantages of integrating both models to overcome their obstacles. Table 4 gives a collection of studies that use such models. In such a model, feature representation produces discriminative features obtained from both models. In [66], audio and deep-visual features using MFCC and 3D CNN are extracted for campus violence representation. Some studies combine standard appearance with deep-visual features. In [67], feature representation employed the discrete wavelet

Table 3 Summary of research work using the deep learning model for violence detection accuracy

Author	Feature representation	Feature analysis	Accuracy and dataset			
			HF (%)	VF (%)	MVF (%)	Others (%)
[42]	3D ResNet	2 FC layers + sigmoid layer	–	–	–	76 AUC
[44]	GoogleNet	3 FC layers	99	–	99	–
[49]	3D CNN	3 FC layers + softmax layer	99	98	–	–
[50]	Residual auto-encoder	reconstruction error	–	–	–	94
[55]	ResNet + LSTM	Sigmoid classifier	–	–	–	97
[56]	VGGNet + LSTM	2 FC layers + softmax layer	91	–	–	–
[57]	MobileNet + LSTM	2 FC layers + sigmoid layer	99	–	100	89
[58]	VGGNet + BiLSTM	3 FC layers + sigmoid layer	96	92	100	–
[60]	MobileNet v2 + LSTM	2 dense layers + binary cross entropy	96	–	99	82
[61]	InceptionV3 + ResNet101V2 + LSTM	Softmax classifier	97	–	–	–
[82]	C3D	3 FC layers + binary cross entropy	–	–	–	91
[83]	DAGMM auto-encoder	Reconstruction error	–	–	–	72.9
[89]	VGGNet + LSTM	Softmax classifier	–	–	–	90
[90]	MobileNet + LSTM	Softmax classifier	–	–	–	87
[91]	ResNet + LSTM	3 FC layers + sigmoid layer	86	91	100	–
[93]	VGGNet + WDRB + LSTM	Softmax classifier	98	97	99	95
[94]	C3D	1 FC layers + softmax layer	–	–	–	96

transform (DWT), CNN, and BiLSTM. A one-level DWT extracts the diagonal spatial features. It passed to CNNs for distinctive spatial features, which fed into BiLSTM for discriminative spatio-temporal features extraction. In [68], HOG features are fed into BiLSTM for extracting discriminative appearance features. A novel GLCM is integrated with CNN for feature representation and analysis in [69]. Some studies combine motion features along with deep-visual features. In [70], a sparse optical flow algorithm was employed to estimate optical flow magnitude and orientation, then fed into AlexNet CNN to reduce dimensionality and extract high-level features. In [71], long-term temporal information is extracted through a deep convolutional neural network, consisting of three individual components; spatial using 2DCNN,

acceleration using optical flow, and temporal using CNN. Each of them goes through an LSTM network to acquire long-term temporal information. Dense optical flow features are fed into bidirectional ConvLSTM to extract discriminative spatial and temporal features in [72]. In [73], high distinctive information is extracted. VGGNet extracts spatial features from RGB frames and temporal features from dense optical flow. The fisher vector is employed to encode final features. Others combine both appearance and motion features along with deep-visual features. Others combine both appearance and motion features along with deep-visual features. Others combine both appearance and motion features along with deep-visual features. In [74], movements in the scenes are represented by combining both RNN and CNN to extract deep features with the help of optical flow. CNN network with three streams; appearance, speed of movement, and spatio-temporal are employed to learn and identify violent action in [75]. The first stream represents appearance features where frames are processed directly in the CNN network. The optical flow obtains pixel velocity to represent temporal features. Spatio-temporal stream is derived from motion energy images (MEI). Li [76] proposes hybrid traditional features, in which spatio-temporal characteristics are input into 2DCNN, resulting in high accuracy. In [77], motion features using optical flow around STIP points are input to the ResNet network to extract deep features. Combining both deep learning-based models with traditional learning-based models produces discriminative features, as in [78], [79], and [80]. Those features provide a strong baseline by gaining the benefits of both models, which help improve the results.

3.2 Feature Analysis

Different machine learning (ML) algorithms have been used for feature analysis to take an intelligent decision for distinguishing violent from nonviolent scenes. Traditional ML techniques or deep learning algorithms are employed for feature analysis. Deep learning is a subset of ML, where analyzing and learning the high-level features are incrementally through its hidden layers. The decisions depend on the learning style of the ML algorithms, which can either be a supervised or unsupervised learning model. The supervised and semi-supervised models depend on labeled training sets to teach models to produce the required output based on example input–output pairs. This training set includes inputs that have been labeled (violence–nonviolence) for a particular result, which allows the model to learn over time and adjust its precision. The unsupervised models don't need human intervention. Since the definition of violence is highly subjective, some researchers use such a model as it learns from raw data without any corresponding output to discover hidden patterns and information. Traditional learning and deep learning approaches have been applied in both supervised as in [27], [81], and [82], and unsupervised as in [19], [83], and [84], learning styles.

Table 4 Summary of research work using the hybrid-learning model for violence detection accuracy

Author	Feature representation	Feature analysis	Accuracy and dataset			
			HF (%)	VF (%)	MVF (%)	Others
[27]	Yolo-V3 + Sparse optical flow	RF	–	–	–	97
[66]	MFCC + 3D CNN	3 FC layers + softmax layer	–	–	–	97
[67]	DWT + CNN + BiLSTM	3 FC layers + sigmoid layer	94	–	–	–
[68]	HOG + BiLSTM	Softmax layer	–	–	–	94
[70]	Sparse optical flow + AlexNet	SVM	94	80	96	–
[71]	Optical flow + VGGNet + LSTM	Softmax classifier	93	–	–	–
[72]	Dense optical flow + DenseNet + BiLSTM	3 FC layers + sigmoid layer	99	96	100	95
[73]	Dense optical flow + VGGNet	SVM	98	92	–	–
[75]	Optical flow + MEI + CNN	2 FC layers + softmax layer	100	99	100	
[78]	C3D	SVM	98	99	–	–
[79]	Dense optical flow + GoogleNet	Binary classifier	–	–	–	78
[95]	VGGNet	SVM	95	93	–	–

Traditional Learning-Based Model: In traditional learning-based models, classical ML algorithms such as entropy classifier, K nearest neighbors (KNN), random forest (RF), decision tree (DT), and support vector machine (SVM), are employed for feature analysis. A set of researches adopt such a model given in Table 2. The entropy classifier is a probabilistic classifier based on the probability distribution to determine the different interaction classes. In [85], spatio-temporal features are fed into a maximum entropy-based classifier achieving an accuracy rate of 91.25% with the SBU dataset. The KNN classifier determines the interaction classes based on feature similarity, which measures how similar or related two items are using distance measures. In [25], motion features are extracted and fed to a KNN classifier for violence detection, which discriminates fight scenes with significantly high accuracy. In [86], electrocardiogram (ECG) signals are extracted and fed to a KNN classifier for violence detection, achieving 87% of fifthth-grade pupils' data. A combination of the KNN concept and entropy has been used in [19], to detect anomalous behavior, where extracted appearance features are fed into the KNN-entropy classifier to detect anomalous crowd behavior with an accuracy of 95% in the VF dataset. The DT is easy to understand as it visualizes the decision-making. It consists of three types of nodes (root, internal, and leaf), with branches that connect nodes and represent a decision rule. The root node is the topmost node, internal nodes represent a feature,

and leaf nodes represent a decision. The RF classifier robustness is due to the number of DT participating in the detection process. In [23], the extracted features are input into different classifiers for features analysis, where they achieved the highest accuracy rate of 86% with the RF classifier in the HF dataset. In [34], appearance and motion features are extracted and fed into the RF classifier achieving an accuracy of 96.5% and 98.8% in HF and MVF datasets, respectively. SVM classifier applied for violence detection by finding the hyperplane helps classify the data points well. In [87], motion features are extracted and fed into the SVM classifier achieving an accuracy of 89.3%. In [81], a statistical feature descriptor based on motion is input into the SVM classifier for feature analysis achieving an accuracy of 91.50% and 84% in HF and VF datasets, respectively. The SVM, KNN, and others have applied for features analysis in [24]; the accuracy of SVM outperformed KNN achieving 91.5% versus 87.5% and 89% versus 83.1% in HF and VF datasets, respectively.

Deep Learning-Based Model: To predict the output of deep learning models, the researchers either use the activation function of the output layer or apply fully connected (FC) layers which in combination act as a classifier. A set of researches adopt such a model given in Table 3. The activation function defines the output of its node. The choice of activation function in the output layer will specify the type of predictions the model can sustain. There are different activation functions, such as the ReLU, sigmoid, tanH, and softmax. The most commonly used in violence and nonviolence classification are sigmoid and softmax functions. In [55], spatio-temporal features extracted by ResNet50 in combination with LSTM are fed into the sigmoid classifier layer achieving an accuracy of 97.06%. In [89], a fused spatial and temporal feature extracted by VGGNet in combination with LSTM was utilized to detect crime scenes through the softmax classifier layer achieving 90% accuracy. In [90], deep features are extracted by MobileNet in combination with LSTM and fed into the softmax classifier layer achieving a precision of 87% for anomalous detection in UCF-crime datasets. In [57], the extracted features of CNN and LSTM are passed into the classification layer that consists of two fully connected layers followed by the sigmoid layer. Accuracy of 99.50% 100% has been achieved for violence detection in HF and MVF datasets, respectively. To classify video frames into violence and nonviolence in [91], spatio-temporal features are passed through a chain of fully connected dense layers consisting of three layers followed by a sigmoid layer. Accuracy of 92.3% was achieved for violence detection in the HF dataset. In [49], improved spatio-temporal features using 3D CNN are input into three fully connected layers, followed by the softmax layer achieving an accuracy of 99.0% and 98.08% in the HF and VF datasets. Following the ViT model's success in image classification, researchers compared its prediction results to those of other deep learning models. In [63], 16×16large ViT results compared to ResNet50 for frame-based fight detection on both HF and MVF datasets showed that the prediction accuracy was 98%, 99% on HF, and 100%, 99% on MVF, respectively. In [92], ViT results compared with ConvLSTM and VGG16 with LSTM for violence detection on the HF dataset show that the ViT-based model prediction accuracy is better than the investigated models with an accuracy rate of 97%.

Hybrid Model: Feature analysis in such a model employed with a classical machine learning classifier and deep feature extraction or more sophisticated convolution neural networks with traditional feature extraction. A set of researches adopt such a model as given in Table 4.

4 Conclusion

Detecting aggressive events in video surveillance faces a series of challenges. Ambiguity; acts that are considered violent in one situation are bad jokes between friends in other. It requires facial expressions, vocal cues, beside body pose analysis to get reliable results. Also, video clips collect in challenging environments because most real-world data is from outdoor cameras with low resolution and different illumination that contains a lot of noise. It requires a comprehensive preprocessing step to optimize data before extracting features. The lack of positive samples compared with negative in the datasets, makes training models difficult. It requires developing datasets with sufficient reliable data for positive and negative samples. We provide a survey of state-of-the-art aggressive behaviors detection approaches, including traditional learning, deep learning, and hybrid-based models. A violence detection model consists of many steps; preprocessing, feature representation, feature analysis, and decision-making. Each step is in charge of a specific action, responsible for the whole system's results. The traditional learning-based models deliver the opportunity to visualize and analyze features. Its strength lies in engineering features that give the best features that largely contribute to the results, but its wide-ranging features increase computational complexity. The deep learning-based models manipulate raw data to extract information to create knowledge. It is suitable for real-time violence detection as it performs automatic feature extraction without human obtrusion. However, the amount of learning depends on the quality and quantity of the data, which affects the result. Also, it's not easily traceable by humans due to its multilayer structure. If it contradicts, an issue will be tough to fix. Some researchers investigate the advantages of integrating both models to overcome obstacles and obtain their benefits. Feature representation extracts discriminative features, by combining both engineered and deep features. Feature analysis is employed using a machine learning classifier or more sophisticated convolution neural networks. Therefore, the combination of both models gives a strong baseline by extracting more discriminative features. Currently, the researchers are attempting to raise the rate of violence detection by making various alterations in each of the examined models to achieve the best possible outcome.

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EMG Controlled Modular Prosthetic Hand–Design and Prototyping

Alexander Suddaby and Jamshed Iqbal

Abstract Prosthetic hands can be essential for those without a biological hand(s) to accomplish everyday tasks but the cost, of up to tens of thousands, keeps them out of reach for many people. This paper reports on the development of a low-cost affordable and adaptable 3D printed modular prosthetic hand. The prosthetic is also able to adapt to many different users through the use of electromyographic sensors; a neural network and a genetic algorithm built into the software. In addition, if the user gains muscular definition in their forearm, the system can be retrained to adapt. The final product is a 3D printed, motorized, prosthetic hand, with interchangeable motors and fingers costing less than £400 to produce. Preliminary experiments with the developed prototype indicate that the presented hand has a great potential in prostheses.

Keywords Robotics · Prostheses · Electromyography · Artificial intelligence

1 Introduction

People who are born without their hands, or who undergo amputation, often turn to prostheses to help them with everyday activities [1]. In the United States alone there are an estimated 1.7 million people living with the loss of a limb [2]. For those missing their hand(s), a prosthetic can also play a significant role for their mental health [3]. One of the biggest issues with prostheses is accessibility. Many of the available prosthetic solutions cost multiple tens of thousands of pounds so while dynamic prostheses are available, they are often too expensive to be accessible to many people.

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Table 1 Specifications of some existing prosthetic hands

Hand name	No. of joints	Degrees of freedom	No. of actuators	Weight (g)
iLimb Pulse	11	6	5	460–465
Bebionic v2	11	6	5	495–539
Michelangelo	6	2	2	420
Rehand	11	1	1	467
F3Hand	13	6	5	255
SSSA-MyHand	10	6	3	478

Scientific literature reports several robotic hands specifically developed for prosthetics, rehabilitation or motion assistance. These include but not limited to; Rehand, BeBionic, Hy5 MyHand, iLimb (and its variants), F3Hand, the Vincent, iLimb, iLimb Pulse, Bebionic, Bebionic v2, and Michelangelo hands. Mode of actuation for these devices range from standard electronic actuators to pneumatics and artificial muscles. Some of these methods are still experimental, however, as actuated prosthetic hands are a relatively recent innovation.

Table 1 shows the specifications of existing prosthetic hands and shows that it is not common to have a fully actuated mechanism for prosthetic devices.

This research focuses on the design and development of an affordable, adaptable, modular, and human-mimicking prosthetic hand that can be controlled using Electromyography (EMG) readings acquired from the user's forearm. Increase accessibility of such devices, to a much broader demographic, is another potential benefit. Also, the system can adapt to work for various users.

2 Requirements and System Design

The requirements are related to hardware functional requirements, device physical specifications, nature of interface, functional capabilities, safety, and other financial constraints. Most of the available prosthetic devices are out of the range of common people owing to their extremely high cost. Given this, one of the key aims of the present research is to propose a low-cost device targeting £500 cost. Also, there is a loose size constraint for the prosthetic, aiming for closely mimicking a human hand. Figure 1 presents an overview of the system. Multiple components need to work together. This includes the communication between different devices such as the Myo to the PC software, the software to the Arduino and the Arduino to the motor via Pulse Width Modulation (PWM). The PC is capable of running Fusion 360 for the design of parts.

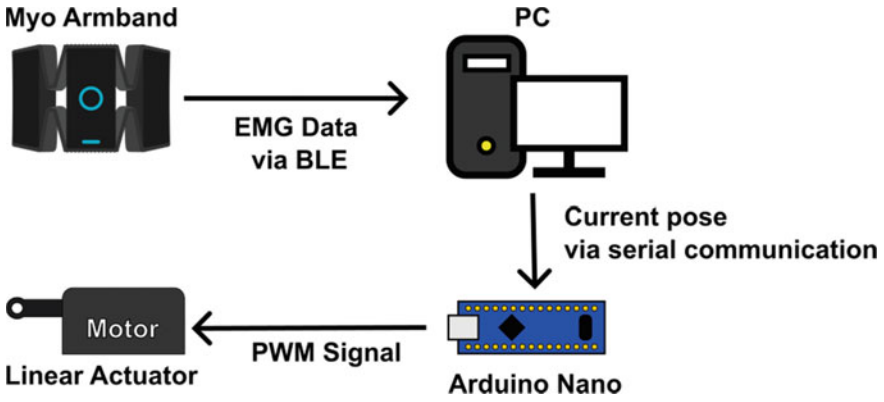

Fig. 1 System block diagram

2.1 Hardware Design

Important parameters to be considered for design of the prosthetic hand include; size, actuator's type, additional components. Initially, the standard DC motors were considered to be used in the proposed device. However, the problem with the standard DC motors were the requirements of additional components including but not limited to potentiometers or encoders, which would have been increased the complexity. Given the requirement of the device to be modular, servo motors were selected for their ability to move to a given position and relatively high torque and speed.

The first part of the report to be designed was the finger mechanism. Research reported in [4] shows that there are several trade-offs of each design. Ultimately, the choice of mechanism came down to the type of motor to use, i.e., PQ12-R (100:1 gear ratio). Using linear servos for the actuation of the fingers dictated the working of the finger mechanism. As a result, a levered mechanism consisting of four main parts was selected. The thumb was designed to use the same mechanism as the fingers. However, the thumb as the added complexity of needing to be able to rotate too. This allows for more grip options and greater flexibility. Many existing prosthetic hands use detent mechanisms as part of the thumb (including the Bebionic hand and Open Bionics Hero Arm). The issue with this approach is that part of the current hand position must be set manually by the user. To circumvent this, an SG90 servo motor would be used to rotate the thumb. As this motor is unlikely to encounter much resistance, the main concern was price and size. While larger than the PQ12-R, the SG90 is still compact and is very low cost. By using this approach, user does not have to adjust the position of the thumb by force. Figure 2 shows the designed finger mechanism.

To improve the gripping capabilities of the hand, the thumb was also widened. This gives the fingers more area to push objects against when gripping them and should make the hand more reliable as a result.

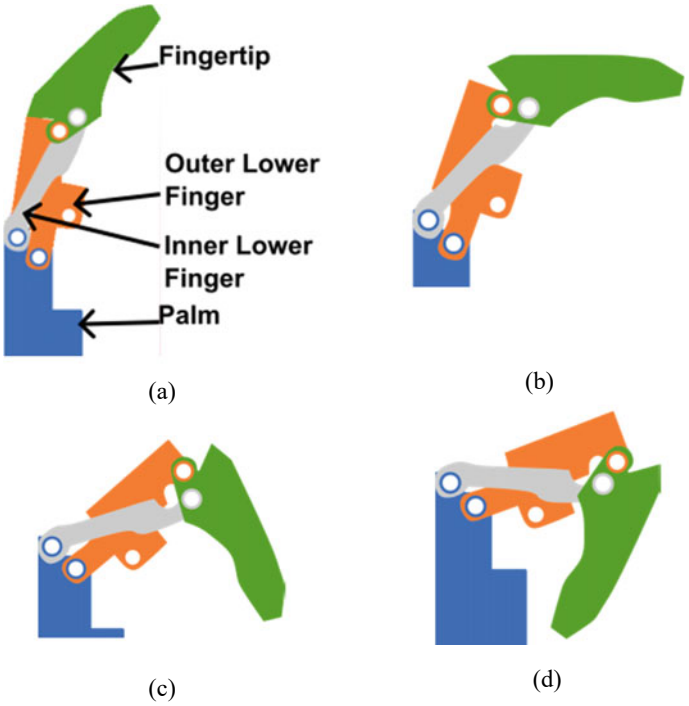

Fig. 2 Diagram of finger mechanism from extension to flexion: **a** extension, **b** partial extension, **c** partial flexion, **d** flexion

2.2 Electronics Design

The electronic design of the prosthetic was heavily influenced by the motors selected. Since all motors selected for the prosthetic were servo motors, it meant that the design of the electronics was straightforward. Each servo motor has three wires: power, ground, and signal. This meant that the microcontroller did not need to have many pins to control H-Bridges and read potentiometers. As a result, the decision to use an Arduino Nano was a straightforward one due to the low cost of Arduino Nano clones and their power efficiency (consuming 19 mA per hour as opposed to around 73.19 mA per hour for an Arduino Mega 2560). The Arduino Nano also has twenty-two digital pins, six of which have PWM output which is perfect for the control of six servo motors.

2.3 Software Design

A Myo armband provided by 3D Web Technologies Ltd. uses the Myo Bluetooth Protocol. For the sake of simplicity, it was decided that any AI should not only be trainable on the PC but also run on it. The Arduino would have to be plugged into the PC anyway to communicate with the Myo and it meant that no Arduino resources would be used for signal interpretation.

3 Implementation, Testing and Evaluation

3.1 Implementation

Hardware. All parts of the hand, besides the fasteners and rubber strips, were 3D printed using Polylactic Acid (PLA) and Thermoplastic Polyurethane (TPU). The final fabricated versions of the index finger, thumb, and the full hand can be seen in Fig. 3.

Using two types of filament allowed different components to make use of different properties. PLA's rigidity was utilized for the structural elements of the hand (printed in black). Alternatively, the TPU (printed in white) was used for the fingertips and palm to aid grip through deformation. It also meant that the motors would be held in place more securely in the palm. This is due to the motor slots bolting into the main frame meaning, the tighter it is attached, the more secure the motors.

For rotation of the thumb, to prevent the hand from becoming too long, the motor was offset and uses a pulley system. The motor uses nylon cord to pull the thumb into position. As a result, the thumb had to become more integrated into the frame of

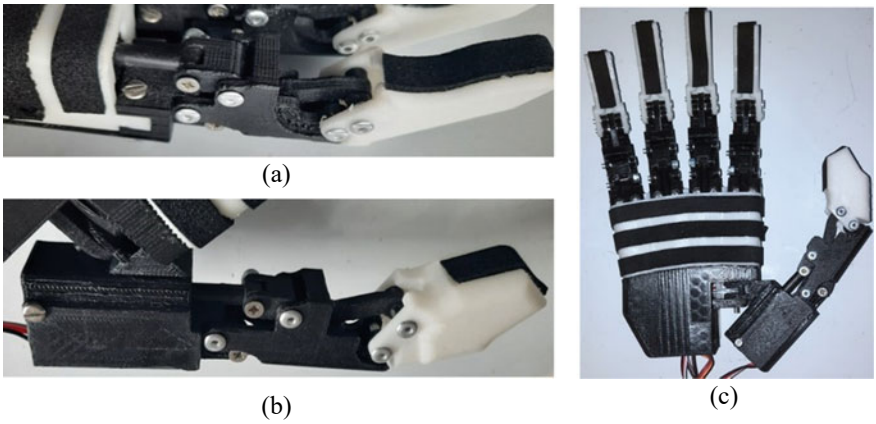

Fig. 3 **a** Index finger, **b** thumb, **c** finished hand

the hand. This removed the opportunity for the thumb to be a modular component of the device as it became a part of the core assembly. It was a trade-off that ultimately had to be made to make the hand a reasonable size and still low cost.

Software. To access the EMG sensors, a connection to the Myo armband was required. A new, C#, windows forms project was set up using Visual Studio 2019 and the ".NET" framework. Using the released Myo Bluetooth Protocol it was possible to retrieve the required data. The Myo acts as a server and uses BLE to communicate with other devices. Using the released protocol, and the BLE libraries available in .NET, connecting to the Myo was relatively straight forward. A successful connection is shown by the blue LED turning on near the bottom of the armband.

The next challenge was to determine which muscles were being flexed by the wearer. While the Myo has a built-in system for this, a custom system was created because the built-in method is fixed and cannot be altered and adapter to different users. To make the data more reliable, an Root Mean Square (RMS) operation is carried out on the data received to reduce the noise in the data as well as any unexpected peaks. The last fifty readings from each EMG sensor are used in the RMS operation to keep the input data smooth but still responsive. Following this, once every 10 times a reading is received, the data is drawn to a graph in the UI.

A neural network was designed to interpret this data. Due to being unable to gather data from potential users because of the pandemic, training data for the neural network was generated. This was estimated by looking at the data being received from the Myo with the wearer's hand in certain variable poses. From here, bounds for the values of each pose were estimated and one-thousand value sets per pose were generated. The selected poses were: resting; wrist flexion; wrist extension and a fist. Using these poses proved reliable due to each pose utilizing a different combination of the two muscles used in the forearm.

The network went through many architectures and each network was tested against the same generated data. Though the architecture of the hidden layers changed, the input and output were consistent throughout. Two input nodes for the normalized readings of the EMG sensors and four output nodes, one for each pose. An architecture of 2–6–6–4 was used ultimately as the score proved to be the best of those trialed (95.8% on generated data). However, this may not be optimal as the design of this neural network was largely a process of trial and error. The final architecture can be seen in Fig. 4.

Each version of the network was trained using a genetic algorithm and scored against the generated data. Each neural network went through one-thousand generations with a population of one hundred. In-between each generation, tournament selection and mutation took place with a mutation rate of 0.05 and a crossover rate of 0.5 with 25 networks selected for each tournament.

To allow for interpreting the data, and enabling the software to adapt to different users, the neural network was integrated into the PC software. In the software, the training system takes a user through the aforementioned poses. It records data from the EMG sensors of the user in these positions and uses it to retrain the network. The training windows in the software can be seen in Fig. 5.

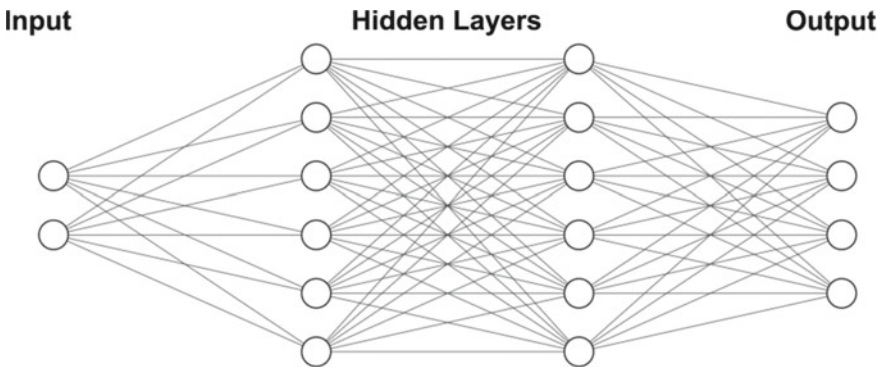

Fig. 4 Final neural network architecture

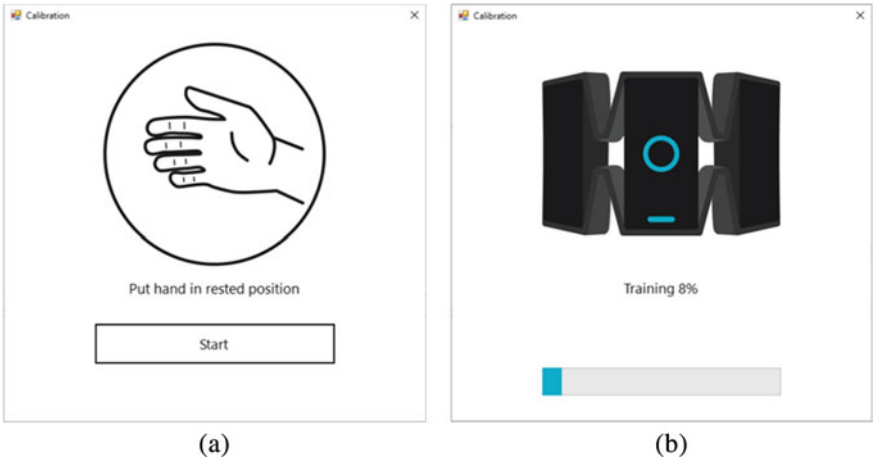

Fig. 5 Neural network training windows: **a** current pose prompt, **b** training window

The network made from generated data is used as a starting point for retraining the network to help increase accuracy and goes through the same training process as before. However, the software uses the recorded data from the individual and only goes through 250 generations. It was reduced to 250 generations to reduce the time. Although the network improves with more generations, it seemed that after 250 generations these improvements tend to be minimal. Various scores through the generations for the training of the final network against the generated data can be seen in Fig. 6.

The final part of the PC software is used for serial communication with the Arduino. Communication with the PC is setup and the pins connected to the motors are set to output. Then, each time the Arduino updates, there is a check to see if any

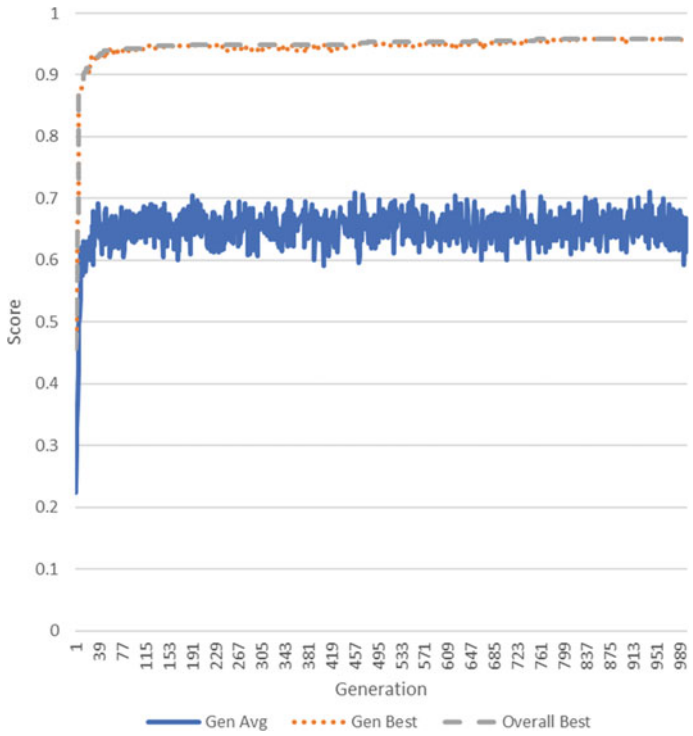

Fig. 6 2–6–6–4 network training scores per generation

new data has been received. If it has, the variable storing the current user input is updated.

Using the received serial communications, the software on the Arduino adjusts the position of the motors. This is done by interpolating between predefined values allowing for different grip patterns.

3.2 Testing

The software and hardware were tested manually. As a lot of the software functionality is automated, it was decided that testing the software manually would be more efficient. This is because a lot of the functionality of the software is behind the scenes. It also meant that, if any bugs were found, they could be solved quickly. Testing the system with everything connected and set up worked as expected. The outcome of this can be seen in Fig. 7 (motor for the little finger was not connected).

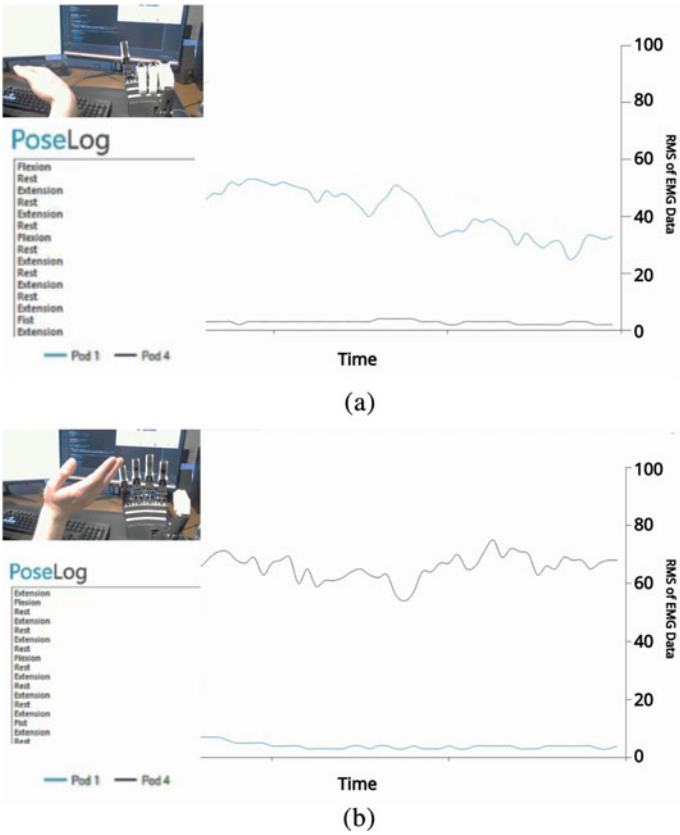

Fig. 7 System testing: **a** closing the hand, **b** opening the hand

The hardware was also tested to ensure that it could grip the objects outlined in the aims and objectives. This included a bottle, USB stick and a card. Results from these tests can be seen in Fig. 8.

3.3 Evaluation

The final device has a weight of 420 g which meets the target of being below 500 g. It also makes it much lighter than some of the previously discussed devices (Table 1). Furthermore, the device met its cost objective (£500) costing a total of £345.04 (not including EMG sensors). A cost breakdown can be seen in Table 2.

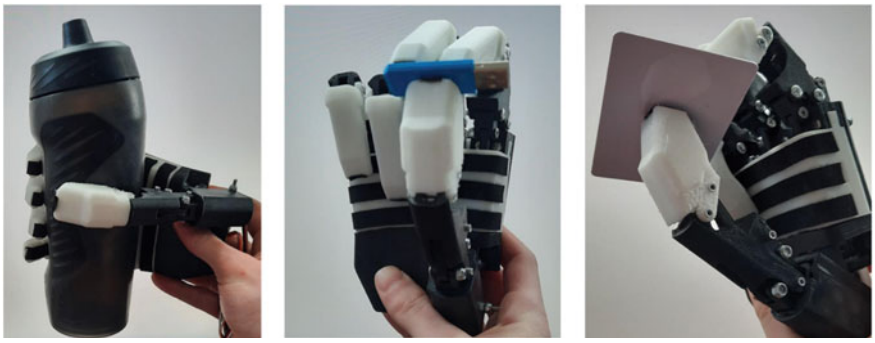

Fig. 8 Hand demonstration: **a** power grip, **b** pincer grip on USB, **c** pincer grip on card

Table 2 Cost breakdown

Component	Quantity	Price (£)
PQ12-R linear servo	5	323.10
Arduino Nano	1	4.00
M3 locking nuts	21	2.88
16 mm M3 bolts	10	2.75
20 mm M3.2 rivets	20	2.75
PLA filament	128 g	2.72
30 mm M3 bolts	8	2.20
SG90 servo	1	1.80
TPU filament	37 g	1.25
Magnets	6	0.74
40 mm M3 bolts	2	0.55
Adhesive rubber	59 cm	0.32
Total		345.04

4 Conclusion

Overall, this research provides some exciting potential development in the domain of upper limb prostheses. The concept has proven to be sound, achievable, budget-friendly, and replicable. After further in-depth testing and trials, the proposed device is expected to have a great potential in prostheses.

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"Social Media Police" and "Wonder Girl": Phenomenological Accounts of Content Moderators' Experiences in the United States and India

Marlyn Thomas Savio, Timir Bharucha, Miriah Steiger, and Xieyining Huang

Abstract Content moderation is a relatively new occupation wherein reviewers peruse content produced by users of digital platforms to maintain its safety and decorum. Besides news reports, sparse empirical literature exists detailing the nuances of content moderators' work life. This paper captures the subjective voices of content moderators in the United States ($n = 16$) and India ($n = 16$) using phenomenological interviews to unravel their experiences and work identity. Four theme clusters emerged through interpretative phenomenological analysis–Content (Variations in acclimatization; Mixed outcomes of content exposure), Individual and Home (Coming of age; Family vs. content), Team (Symbiotic relationship across team hierarchy; Team culture), and Client and Employer (Work targets and guideline inconsistencies; Culture of care). The themes revealed several similarities in both regional cohorts such as positive perceptions of the occupation, transformative self-growth, and centrality of team relations. Adjustment to content on the job, and effects of the timing of the study and place of work were two areas of differences between American and Indian moderators. The study evinces the scope and importance of the content moderation profession for individuals' and society's well-being, as well as makes recommendations for work policy and research.

Keywords Business process outsourcing · Content moderation · Digital safety · Interpretative phenomenological analysis · Social media

1 Introduction

With social media platforms burgeoning since the last two decades, user generated (UGC) has been abundant. This has, in turn, instituted the content moderation profession to regulate content at scale. A typical day at work for a content moderator

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involves continual review of content generated on the platform in multiple formats, and flagging/removal of material that violates its guidelines [21]. This effortful endeavor upholds the safety and interests of the users and the Internet at large.

Cramped workspaces, unregulated hours, and psychological hazards characterize the mainstream portrayal of content moderators' work environment [5, 18]. Even though content moderators' work may be more organized and protected by labor regulations, UGC is still unfiltered, and repeated exposure to certain types of content may be potentially disturbing. Yet, considering the indispensability of the job and the reliance of artificial intelligence systems on human decision, people-driven content moderation is unlikely to completely disappear. The business process outsourcing (BPO) industry has thus been urged to implement psychological wellness interventions for frontline workers [22].

According to Transparency Market Research [25], the Asia-Pacific geography possesses a commanding market share for global content moderation followed by the United States (US). India is a key Asian hub for outsourced content moderation, employing several thousands of employees [4]. A qualitative study [1] interestingly noted that Indian moderators regarded their job as exciting and growth-oriented. They reportedly took pleasure in performing their work and demonstrated utmost adherence to job guidelines.

On the other end, the US is home to some of the largest social networking/media giants. However, not much has been systematically documented about the US workforce in content moderation, and hardly any evidence exists on comparisons with their Indian counterparts. The two countries are known to have varying socioeconomic, cultural, and organizational values and processes [20]. It therefore is worth exploring how content moderators' experiences in the US and India match and/or differ.

This study endeavors to gather the much-needed first-person and culturally-nuanced perspective of content moderators in the US (outside of media reports) and India. Exploring individuals' lived experience of doing the job and of "becoming" a content moderator will make known the psychological issues of identity and well-being across the two regions. Secondly, the comparative qualitative approach is aimed at adding individuality and diversity to the minimal empirical literature available on content moderation. Cross-cultural insights will help tailor resources in the trust & safety industry to align with work-related perceptions and adjustment.

2 Methods

2.1 Design

A semi-structured interview approach, based on interpretative phenomenological analysis (IPA), was chosen to explore the individual experiences of content moderators. IPA emphasizes that subjective knowledge/perception is a window to the individual's reality and psyche. When IPA is applied in research, the investigator equally contributes by interpreting the experience alongside the participant [9]. This study fills a gap where very little is known about content moderators' daily encounters on the job. IPA thus offered the potential to rely on individual stories to construct and comprehend their experience [15].

2.2 Participants

The purposive sample altogether comprised 32 content moderators from TaskUs LLC (16 from the US and India each) who had volunteered and given informed consent. The US sub-sample had a mean age of 28.31 years (SD = 8.50) with six male and 10 female participants. Within the Indian sub-sample, there were eight male and female participants each with a mean age of 24.19 years (SD = 2.23). Consistent with content moderator demographics, the sample was overall young with a roughly equal proportion of male and female interviewees.

2.3 Materials

Due to interruptions caused by COVID-19, the study was conducted at two different time-points (US cohort in 2020, Indian cohort in 2021) using separate interview schedules that reflected the corresponding sociocultural and pandemic circumstances. For participants from the US, the interview consisted of 21 questions that focused on general experiences, reactions to content material, worldview, and stress management. For the Indian sub-sample, seven questions were used pertaining to the participant's motivation for joining content moderation, day-to-day reality of the job, exposure to content, training, dealing with client requirements, and impact on life.

2.4 Procedure

The study adhered to the code of conduct, legal regulations, and ethical guidelines stipulated by TaskUs LLC. The research team was an independent unit having no direct relationship with or oversight of content moderation teams or projects at the company. These efforts helped ensure minimal conflict of interest. Furthermore, an ethics review of the study was conducted by an external mental health researcher belonging to a Carnegie R1 institution. There was no report of adverse outcomes during the course of the study.

As part of the participant recruitment efforts, content moderators were contacted via email. A plain language statement was shared, and those who voluntarily expressed interest were requested to sign the informed consent form, and an interview was scheduled. Participants were not offered any monetary compensation.

All participants were individually interviewed on tape for 40–60 min. They were encouraged to share their experiences with as much detail as possible. Participants were also given the opportunity to pause during interviews or entirely terminate their participation without having to provide reason. The interview recordings were stored securely in an encrypted drive accessible only to the core research team.

3 Results and Discussion

The data obtained through interviews were transcribed verbatim. The steps outlined for IPA by Alase [2] were applied in analyzing the data. Each transcript was read repeatedly to identify key experience points, tagged as codes. Further reading helped collate codes across transcripts into themes.

A total of eight themes, grouped under four clusters, were identified (Table 1). The emphasis of the analysis is on participants' perception and meaning-making in their becoming and being content moderators. The researchers' interpretation situates the findings within psychological theories and research literature.

3.1 Theme Cluster I: Content

The participants' content moderation tasks included scrutiny of UGC to identify non-compliant or suspicious activity and to execute relevant actions. In the words of a US participant, they were the "social media police." Given the predominance of content in this job, participants recounted different adjustment trajectories and diverse consequences of being exposed to content.

Variations in Acclimatization. The US moderators largely reported feeling unnerved when reviewing disturbing content. They nonetheless discussed the ability to skip jobs or not needing to perform a full review as a way of dealing with

Table 1 Themes based on interview excerpts depicting content moderators' experiences

Cluster	Theme	Excerpt
Content	Variations in acclimatization	*"Complete your queues, complete your target, and then just switch it off."*
	Mixed outcomes of content exposure	*"(I'm) more knowledgeable now as opposed to just the personal knowledge that I had or what I thought was correct."*
Individual and home	Coming of age	*"I had to learn and adjust myself to be open minded, because even though I see something and I think it's wrong, I'm, I'm looking at it the wrong way."*
	Family versus content	*"When I used to work, I was like, 'No, mom, don't come to me, please knock before coming…'"*
Team	Symbiotic relationship across team hierarchy	*"Just there's a lot of teamwork, a lot of people just reaching out and connecting with each other*
	Team culture	*"We might be virtually connected, we are still more connected than the people working on the floors."*
Client and Employer	Work targets and guideline inconsistencies	*"I guess you have to be the right kind of person to be working like having this job because some people can get overwhelmed and just be like, oh, no, I can't do this and too much many changes."*
	Culture of care	*"Just because of all the support which I have gained from the organization, I'm today a team leader."*

content. The peek-and-avert approach helped them strategically complete their jobs without getting attached to the content. Hofmann and Hay [12] argued that avoidance/disengagement coping when used firsthand to distance oneself from the stimulus can be effective to minimize the significance of such stimulus.

> There might be like some screen caps of what's happening in the video and I could kind of see from the screen caps like what's going on. And it might be graphic. However, I'm labeling the comment to where I don't have to review that content, so I'm actually able to avoid it. (US participant)

Indian participants, on the other hand, adopted two perceptual strategies to normalize the content they were witnessing. First, they did not consider explicit or graphic material as entirely unusual and viewed it as something humans can be involved in. This empathetic outlook helped them achieve what medical practitioners are also recommended to develop in the face of vicariously traumatic experiences: meaningful habituation rather than blunted desensitization [27].

> It's a part of life, and it's normal. (India participant)

Second, participants resisted getting deeply attached to the content by not overthinking it beyond the action report, thereby reducing their emotional engagement with the material.

> Complete your queues, complete your target, and then just switch it off. (India participant)

The ability to draw boundaries, emotionally and physically, reinstates control over one's well-being [13], and that was evident in these participants' approach of separating themselves from the egregious material at work.

Mixed Outcomes of Content Exposure. Participants from India considered their job as a window to the world, helping broaden their cross-cultural knowledge as they reviewed global profiles. US interviewees, too, reported an increased awareness of the happenings around.

> Now I know more about, you know, ideologies and what it actually means as it relates to politics in a way that people view politics. So, yeah, it has changed so, so more knowledgeable now as opposed to just the personal knowledge that I had or what I thought was correct. (US participant)

The expansion in worldview has been argued to even transform the self-view [8]. The interviewees mentally evolved to appreciate the diversity of lifestyles and practices world over, and their being was becoming more intercultural.

> There are benefits, absolutely… In today's life, we really don't have enough time to search and learn about outside cultures. On one hand, I'm doing my job and on the other, I'm gaining knowledge. (India participant)

A couple of participants, however, seemed to fall prey to overgeneralizations about certain countries whose content they were constantly encountering. Still others were beginning to feel cynical about social media platforms.

> It's a constant battle because sometimes you do perceive things, you're like, oh, wow, I didn't know these people were like that, but then like in the back of my head, I know it's wrong and it's just seeing the same type of content over and over and over again. You start believing it. (US participant)

Previous studies have highlighted inherent implicit biases in the content moderation space [10, 19, 24]. As a US interviewee further explained, owing to biases "you're not going to be able to do your job correctly because you're thinking of it (content) in your own way." Psychoeducation becomes critical to help content moderators recognize the impact of beliefs as well as the influential power of virtual content.

3.2 Theme Cluster II: Individual and Home

Participants conveyed that their job was impactful beyond occupational aspects. For one, it was a catalyst of change at the individual level. However, the content involved in the job was a point of contention in the home and family space.

Coming of Age. This job was the first for many interviewees, and thus marked their transition into adulthood starting with an evolution in mindset that not only facilitated the moderation work but also demonstrated psychological maturity.

> I had to learn and adjust myself to be open minded, because even though I see something and I think it's wrong, I'm, I'm looking at it the wrong way. And it's, it's definitely like something that everybody should be, you know, looking at it as to where it's open minded. (US participant)

Financial independence was another major milestone. And the satisfaction of contributing to the digital trust & safety industry was a game changer for them.

> I've worked in my own family business… I have my own business of sweets… and then I also joined my uncle's business, in medical shop. Apart from that I was thinking something for my own personal growth. And I was thinking like, I need my own money. Because asking for money in family business is like getting pocket money. (India participant)

> This job is very significant because in a way it is for people's safety. And safety matters a lot… I feel like a Wonder Girl. (India participant)

This theme highlights the contribution of the profession to the larger lifesphere, such as the shaping or refining of individual identity and worldview. One's occupation has been argued to not just shape the individual into a person but a "particular" person [7]. The nature of their job bestowed a strong sense of purpose and contribution for the greater good.

Family versus Content. The Indian sub-sample was entirely working from home at the time of this study owing to the pandemic. Although they had individually become habituated to the content and workflow, they were apprehensive about working with content in the midst of their family, most of whom were unaware of the nature of these participants' jobs. The interviewees were extra cautious to ensure confidentiality such as through switching explicit queues with their teammates or even requesting their family to allow them privacy while working in the intergenerational home.

> When I used to work, I was like, 'No, mom, don't come to me, please knock before coming…' (India participant)

In addition, managing domestic and professional obligations during the pandemic was a balancing act.

> For work from home (WFH), there are domestic duties at times, even small works. But in office, one is mentally free as one has to only do office work. (India participant)

Literature on pandemic-related work-from-home scenarios underlines that "segmentors" (those who prefer distinctly separating work from home) tend to have more negative experiences in remote work circumstances [26]. Considering the confidentiality and non-disclosure necessary in the content moderation job, provisions (e.g., privacy screens) to reduce inhibitions and allowing flexible breaks to work efficiently in one's home settings are essential.

3.3 Theme Cluster III: Team

The team at work represents a critical support network for content moderators. Participants conceptualized their team not merely as a forum for friendly banter to get through the work shift but as an imperative to enable each other's growth.

Symbiotic Relationship across Team Hierarchy. All interviewees, without exception, vouched for the assistance sought and provided in teams. Interestingly, support moves in both top-down and bottom-up paths. Team leaders, too, relied on their reportees to achieve goals and wade through crises.

> I have such a good team now. Even if I have the slightest tension, they're like, 'Ma'am, what happened?' and then they crack several jokes and get me to laugh that I forget all of my tension. And they're aware that I get stressed if their performance is even slightly affected, so from the starting of the week, they work hard and perform well... They also remind me, 'Ma'am, it's time to drink water.' (India participant)

> Just there's a lot of teamwork, a lot of people just reaching out and connecting with each other. (US participant)

Critical team behavioral processes—coordination, cooperation, and communication [14]—thus come into play in content moderation teams, making them highly cohesive and committed units.

Team Culture. Beyond the call of duty, team members in both regions backed each other up even in times of personal difficulties by extending advice and instrumental support. At work, they reviewed each other's performance in order to prevent corrections from external sources. The pride felt for one's team indicated a seamless blending of individual and team identities.

> If I took some wrong action, if my teammate found this thing that I took some wrong action, so he immediately sends this to me rather than taking a second action on it… So that's how they support us. And if somehow I am facing a power cut, I'm not able to take my meeting, I took an off day... So they let me know, 'These changes were made and we guys had a meeting and all.' We might be virtually connected, we are still more connected than the people working on the floors. (India participant)

> What helps me get through those tough days is definitely my coworkers and my team. The campaign that I'm on, they are very, very... like… tight group. And we're. We like to hang out outside of work. So usually we like to communicate outside of work and we have this group chat. Usually when one of us is going through something, even if it's outside of like the campaign, we like to tell each other how we feel. (US participant)

The team furnished a frame of collective reference for content moderators undertaking unconventional and time-sensitive work. Some members of the Indian subsample even reported dissatisfaction on moving into another team. Inter-team movements are not only known to create uncertainty for the transiting individual but also engender a temporary flux in coordination and lower productivity/output for the team [6, 23]. Minimizing constant transfers or facilitating smoother, supported transitions (when unavoidable) can ease the disruption.

3.4 Theme Cluster IV: Client and Employer

Key stakeholders in outsourced content moderation are the client and the employer. Participants had high regard for their client and were ecstatic for being able to protect and promote the client's business. However, client regulations on metrics and changes were identified as being challenging. Yet, the employer's culture and provisions helped balance the effort participants were putting into their work.

Work Targets and Guideline Inconsistencies. Most teammates articulated the pressure felt in achieving targets set by clients, and adapting to changes in job guidelines. Interestingly, most participants sustainably achieved these targets with guidance from their team and leaders.

> Everybody is supporting. So the team leader keeps on coming in and telling us the change in guidelines. And we have some quality analysts (QAs) as well; they keep on sending us mails, tip of the day, and you know team leader comes daily in the pre-shift meeting and then he tells everything that's happening. So I'm able to catch up. (India participant)

The interviewees revealed, however, that just as they had memorized one set of guidelines, a new update was already en route for immediate implementation.

> I guess you have to be the right kind of person to be working like having this job because some people can get overwhelmed and just be like, oh, no, I can't do this and too much many changes. (US participant)

Participants preferred a system of communication/updates that was predictable and gave them some sense of control. Variability in the workflow process was found to lead to higher completion duration, more delays, and increased number of unfinished jobs [3]. Streamlining the workflow with a clear-cut schedule for policy updates can instill preparedness for change and facilitate work life satisfaction.

Culture of Care. Having a supportive workplace in terms of one's team and the organizational culture was regarded as being important to thrive in the content moderation profession. The interviewees appreciated wellness initiatives namely one-on-one counseling sessions, break rooms, and gym as these gave an impetus to do more than just work.

> We're able to have one-on-one and just vent if we need to better our life or if it's about work. I personally have used a one-on-one to really open up about my own life. (US participant)
>
> In my life, the one that has nurtured me is this company because I was so hopeless, I was so useless when I joined. I was not getting a job anywhere. Even in this company, I was selected after three attempts. Even after that, there were so many challenges in life. Just because of all the support which I have gained from the organization, I'm today a team leader. (India participant)

Liljeholm and Bejerhom [16] argued that work identity can be rehabilitative. For certain participants (such as above) who were earlier dejected due to life circumstances, the job and organizational culture held a therapeutic value in helping them thrive professionally and personally.

4 General Discussion

Gini [11] asserted that we cannot make sense of a person unless we examine their work and how they handle it. This phenomenological study has thrown light on the daily lives and experiences of frontline content moderators in the US and India. The retelling of their stories through this research work helped unravel the evolution in content moderators' identity and life-world parallel to their professional development.

Interestingly, both the US and Indian interviewees revealed greater similarities than differences. Across the two groups, the job was described as an avenue facilitating societal safety, team collaboration, career growth, and individual metamorphosis. Another commonality in the two regions related to the considerable influence that the work culture and interpersonal relationships exerted on their adjustment. Reliance on the team, sense of purpose, considerations for open-mindedness were evident in both cohorts. These findings reiterate the contribution and significance of the content moderation profession at the individual, organizational, and societal levels. Opportunities for workflow improvement (e.g., policy change management and communication) were also unanimously articulated by the two sub-samples.

A few variations were nonetheless seen for the two cohorts. Adapting to the job, for instance, was quicker and more normalized among Indian participants. Contrastingly, US interviewees were more likely to avoid exposure to reduce the content impact. In line with another known qualitative study on content moderators (i.e., [1], the finding echoes the analytical approach that Indian moderators practice to be successful on the job. A second aspect of group peculiarity pertained to the setting, timing, and interpersonal contexts of work. Since the Indian sub-sample was interviewed amidst the pandemic work-from-home circumstances, they experienced discomfort in moderating content in the family setting. The US sub-sample, being an early-pandemic cohort, perceived family and home only as a social support resource outside of work. How one interprets and adjusts to the job can thus be influenced by the space and time in which one conducts work. Furthermore, moving teams within the company was cited by the Indian participants to be a difficult experience. Businesses must be cognizant of these interpersonal and contextual factors that facilitate or impinge on employees' experiences and satisfaction, depending on culture and geography. Being sensitive in these respects and offering support/resources can ease spatial, temporal, and social transitions for content moderators.

Several practical implications emerge from the current study. Psychoeducation that inculcates adaptive habituation to content, mental hygiene techniques, and sociocultural awareness must be integral to training and onboarding content moderators. Prioritizing an organizational climate that allows for flexible work breaks, scheduled work process changes and minimal team transfers can increase adaptation and satisfaction with the content moderation job. While participants themselves expressed pride for their profession, the business in parallel must bolster their sentiments through periodic appreciations, advocacy for their rights and benefits, and implementing measures for their well-being and professional development.

The results altogether help expand the limited literature on content moderators. Pertinently, the current study validates the need for such systematic and scientific examination of certain sensationalized media reports. Secondly, the cross-cultural design was apt to represent a diverse professional group that is steadily gaining a global footprint. Finally, through capturing the first-person life-world, the IPA-based study helped voice what participants themselves thought, felt, and experienced.

Like most research pursuits, this study is not comprehensive in itself. For example, an exploratory qualitative approach was adopted here given the scant literature on this topic. Future studies may undertake mixed or quantitative methods to investigate the role of intervening psychosocial variables in the adjustment and performance of content moderators. The potential presence of self-report bias cannot be completely excluded despite extensive measures taken (described under procedure) to mitigate such bias [17]. Though collaborating with an external research team or with a university may arguably further reduce self-report bias, this is unlikely to completely solve the problem because a collaborative relationship still exists between the company and the external team. Nonetheless, there is reason to believe that the present findings are not severely impacted by the potential bias as participants spoke freely of both the positive and negative sides of their experience. Lastly, including employees from different companies may be an important next step to reveal the effects of organizational culture and provisions. These efforts, however, are traditionally thwarted by barriers such as non-disclosure and proprietary business information. The meager content moderation literature and the minimal studies involving cross-collaborations reflect this challenge. Within the constraints faced by the entire industry, this study provides critical and essential information on content moderators' experience to-date.

In conclusion, this interpretative phenomenological study puts forward meaningful experiential perspectives of content moderators. Besides being a social need, the occupation was also inferred by the participants to be a necessary challenge leading to their personal maturity. Their sense of safety relied on the close-knit team and the organization's people-centric culture although improvements in workflow were also called out. This study serves as one of the crucial first steps to better understand content moderators' experience. Future studies are encouraged to build upon the current work to further shed light in this area.

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Robot-Based Auto-labeling System for 6D Pose Estimation

Hsien-I. Lin and Jun-Shiang Chang

Abstract 6D object pose estimation is an ongoing research area in the field of computer vision. Many existing methods rely on supervised deep learning models which require multiple accurate 6D pose annotations to predict object poses. However, labeling the 6D pose is complex and time-consuming in traditional methods. In this study, we propose a robotic-arm-based 6D object pose auto-labeling approach which has limited human interaction involved. Translations and rotations of the object in the camera coordinate system can be calculated using a sequence of known robot poses and the transformation between the camera and the robot. We also implemented our custom dataset generated by the auto-labeling system in the existing 6D object pose estimation approach. Evaluation results show that the model can recognize our own test dataset and attempted 90% accuracy using ADD metric with 0.05 threshold.

Keywords 6D object pose estimation · Pose annotation · Robotic-arm-based · Annotations · Auto-labeling

1 Introduction

Estimating object pose is an important technique that provides 3D information for the system to make further decisions. It can be implemented in various applications in industries such as robot manipulation tasks, autonomous driving, and augmented reality. In recent years, many deep learning approaches have provided end-to-end object pose estimation solutions that can handle objects with less texture, symmetric,

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and irregular shapes. Many researchers established various 6D object pose training datasets such as Linemod, T-less, and YCB-V [1], which were all collected in the Bop challenge benchmark [2]. These datasets allow users to evaluate their pose estimation model and compare it with others methods with the same standard.

Despite having those open source datasets, users in industries need to create their custom datasets to implement object pose estimation models on the new object. However, in traditional methods [3, 4], complex mechanism designs and additional markers are required to generate different camera viewpoints and mark the object's pose in camera frames. To address these problems, [5, 6] proposed simulation methods to create a synthetic dataset for training. In spite of the help of 3D simulators, high-quality mesh models are demanded to create realistic simulation photos. Moreover, the colors of the object and shadows would differ from the actual scenes captured using the camera due to the different light positions.

To generate object pose annotations more conveniently, in a relevant study that a depth camera was mounted on an industrial robot end-effector to autonomously capture RGB-D images from numerous perspectives. The robot was operated to push objects in the real world to change the object's orientation and collect training data continuously. While in this method, the pre-trained model was demanded to detect the object in the beginning. In recent, self-supervised 6D pose estimation methods [7, 8] were proposed to overcome the difficulty of acquiring real pose annotations. With the collections of object 6D pose datasets, several object pose estimations can be implemented. In [9, 10], the estimation is done only from a single RGB image. 6D pose problems can be addressed by adding depth information in the source, as presented in [11], which may increase the computation cost and equipment level.

The objective of this research is to develop a novel robot-arm-based 6D object pose auto-labeling approach. The system has limited human interaction involved and can be easily operated by users without prior knowledge. Object poses in the camera coordinate system are automatically calculated according to a sequence of known robot poses and the predefined transformation from the camera to the robot. In addition, the system imports object CAD models to create segmentation masks simultaneously. We also implemented the dataset generated by the auto-labeling system in the existing 6D object pose estimation deep learning model. The proposed system can be applied in factories equipped with robotic arms. Automatically collecting training data for AI models drastically reduces the data labeling time which was conducted by human in tradition.

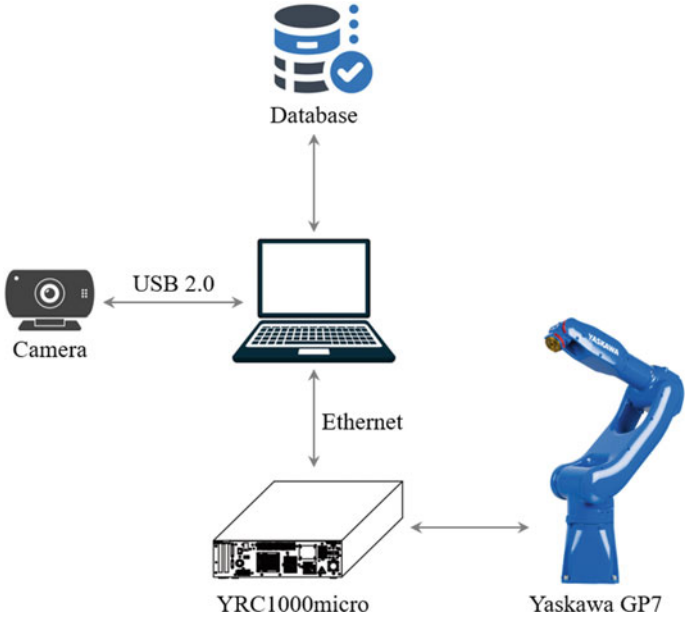

Fig. 1 System architecture

2 Methodology

2.1 System Overview

The proposed auto-labeling system employs a 6-DoF industrial robotic arm and a camera in this study. The robotic arm was required to move the object mounting on the end-effector, while the camera helped to collect the image of the object. Figure 1 shows the architecture of the auto-labeling system. The robot of the auto-labeling system is assisted by the Yaskawa GP7, which is used to rotate the object and provide known robot poses for inferring ground truth object poses. We used a laptop to communicate with the camera and control the robot through Ethernet. The database saved all the training images and corresponding annotations.

2.2 Hand-Eye Calibration

We conducted the eye-to-hand calibration to know the transformation from the robot to the camera. We prepared the checkerboard and attached it to the robot end-effector. We collected calibration data by moving the robot in several different poses and

recorded images with corresponding robot coordinates at the same time. The calibration process comprises the computation of extrinsic and intrinsic parameters. The extrinsic parameters represent a transformation from the checkerboard to the camera. The intrinsic parameters represent a projective transformation from the 3D camera coordinate into the 2D image coordinates.

It is explained that the transformation matrix from camera to robot base (${}^{\mathrm{B}}_{\mathrm{C}}T$) can be solved through the mathematical function, as in Eqs. (1) and (2). The calibration toolbox loads images and extracts grid corners of each image, and the transformation from the checkerboard to the camera (${}^{\mathrm{C}}_{\mathrm{Cb}}T$) is calculated with the known grid size. We can acquire the robot end-effector pose relative to the robot base from the controller and convert it to the transformation matrix $\left({}^{\mathrm{E}}_{\mathrm{B}}T\right)$ by following z–y–x Euler angle rotation. The calibration procedure is repeated until the minimum error value is obtained.

$$ {}^{\mathrm{E}}_{\mathrm{B}_1}T\,{}^{\mathrm{B}_1}_{\mathrm{C}_1}T\,{}^{\mathrm{C}_1}_{\mathrm{Cb}}T = {}^{\mathrm{E}}_{\mathrm{B}_2}T\,{}^{\mathrm{B}_2}_{\mathrm{C}_2}T\,{}^{\mathrm{C}_2}_{\mathrm{Cb}}T \tag{1} $$

$$ {}^{\mathrm{E}}_{\mathrm{B}_2}T^{-1}\,{}^{\mathrm{E}}_{\mathrm{B}_1}T\,{}^{\mathrm{B}_1}_{\mathrm{C}_1}T = {}^{\mathrm{B}_2}_{\mathrm{C}_2}T\,{}^{\mathrm{C}_2}_{\mathrm{Cb}}T\,{}^{\mathrm{C}_1}_{\mathrm{Cb}}T^{-1} \tag{2} $$

2.3 Object 6D Pose Computation

We annotate the object pose in the first image with the 6D object pose annotation toolbox, which is an online open source [12]. In this step, we manually align the 3D mesh model to the object in the 2D picture by rotating and moving the object mesh model along the x–y–z-axis. The object 3D mesh model is projected onto the image with intrinsic parameters to visualize the alignment result, as shown in Fig. 2. After the annotation process, the transformation matrix from the object to the camera (${}^{\mathrm{C}}_{\mathrm{O}}T$) will be recorded, including the translation and the rotation part.

With the hand-eye transformation matrix computed in the preparation step and the transformation matrix from object to camera frame in the first image annotated using the toolbox, the transformation from object to robot end-effector can be computed using Eq. (3) and used to calculate object poses. The object is fixed on the robot end-effector, which will not be moved during the data collection. The transformation between the object and end-effector, denoted as ${}^{\mathrm{E}}_{\mathrm{O}}T$, remains the same and only needs to be calculated once. With the known camera-robot transformation, combined with a sequence of recorded robot poses, the object 6D pose in each image can be solved by following Eq. (4). One concern is that the accuracy of the annotations relies on the quality of the first manual annotation to some degree.

$$ {}^{\mathrm{E}}_{\mathrm{O}}T = \left({}^{\mathrm{C}}_{\mathrm{B}}T\,{}^{\mathrm{B}}_{\mathrm{E}}T\right)^{-1}\,{}^{\mathrm{C}}_{\mathrm{O}}T \tag{3} $$

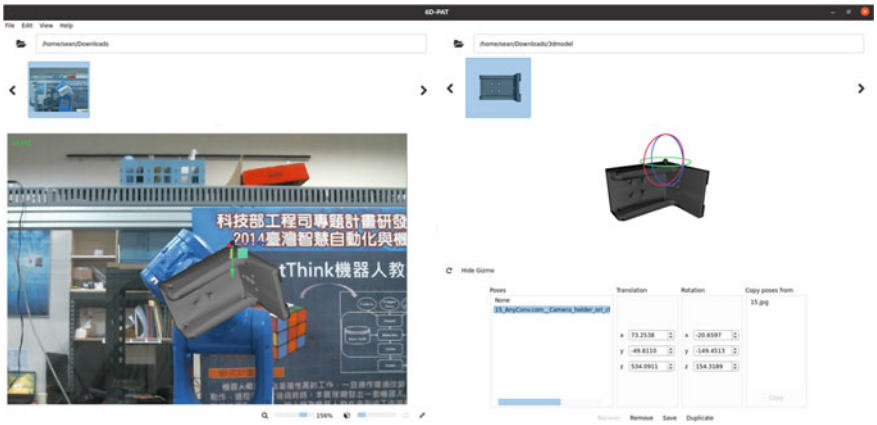

Fig. 2 6D pose annotation tool

$$ {}^{C}_{O}T = {}^{C}_{B}T\,{}^{B}_{E}T\,{}^{E}_{O}T \tag{4} $$

2.4 Projection of 3D Mesh Model on 2D Image

The purpose of this process is to create binary masks of the object. The object mesh model is required in this approach which contains 3D points of the object surface. After the object pose in the camera coordinate system is calculated, the mesh model will be rotated and translated within the 3D space according to the pose calculated in the previous step. The projection of each 3D point of the object in a 2D image plane can be computed using the triangulation method (Fig. 3).

In this process, camera intrinsic parameters are involved, which contain the camera focal length, and the optical center. In Eq. (5) below, X_c, Y_c, and Z_c are 3D points of the object represented in the camera coordinate system. f_x, f_y are focal lengths in pixels representing the distance from the camera frame's origin to the image sensor plane. c_x, c_y are optical centers in the image sensor plane represented in pixels. The computation in Eq. (6) yields the 2D pixel coordinate (u, v) projected from 3D points. In this procedure, segmentation masks (Fig. 4) and the object 2D bounding box location are recorded, which can be used to train an object detector or instance segmentation model.

$$ x' = \frac{X_c}{Z_c}, \; y' = \frac{Y_c}{Z_c} \tag{5} $$

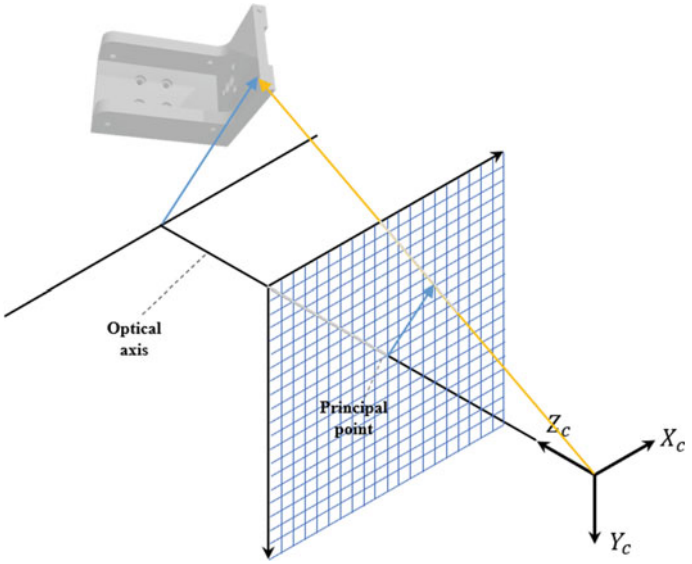

Fig. 3 3D mesh projection illustration

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \tag{6}$$

3 Experiment

3.1 Robot Movement

A sequence of robot poses was created before collecting the object pose dataset. We represented the target robot pose in motor pulse value instead of Cartesian representation. Pulse value directly describes the joint movement, which is more intuitive. We created different robot poses by adjusting the pulse value of the 4th, 5th, and 6th axes computed within certain ranges and followed specific intervals, as shown in Table 1. We used three layers of loop function with 4th-axis on the top, 5th-axis in the middle, and 6th-axis in the inner to create a list of pulse sets. Figure 5 illustrates the moving direction of each joint, highlighted in red.

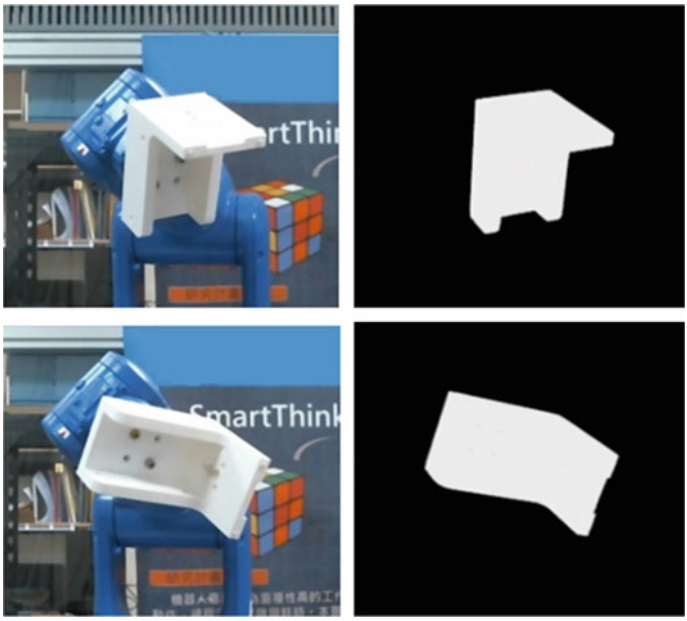

Fig. 4 Segmentation mask created by 3D mesh projection

Table 1 Rotation range and interval of axes

Axis	Min value	Max value	Interval
4th axis (R)	−40,000	40,000	4,000
5th axis (B)	−40,000	60,000	4,000
6th axis (T)	0	100,000	10,000

3.2 Training Data Collecting

Figure 6 shows the environment setup of the system. The camera was fixed in front of the robotic arm to capture the images of the object. The target object was attached to the robot end-effector. The robotic arm was operated to move the object to generate diverse poses of the object in 3D space as comprehensively as possible. The test object in this study is a jig used in the factory. The 3D model of the object is pre-designed, as shown in Fig. 7.

Figure 8 shows the data collection process. The PC sends a move instruction command to move the robot and capture an image with a corresponding robot pose when the robot arrives at the target position. The acquired robot pose is the input in (4) to compute the object's pose. With the object pose, the segmentation mask is created by 3D mesh model projection. We save the transformation matrix from object to camera, object binary masks, and images into the training dataset.

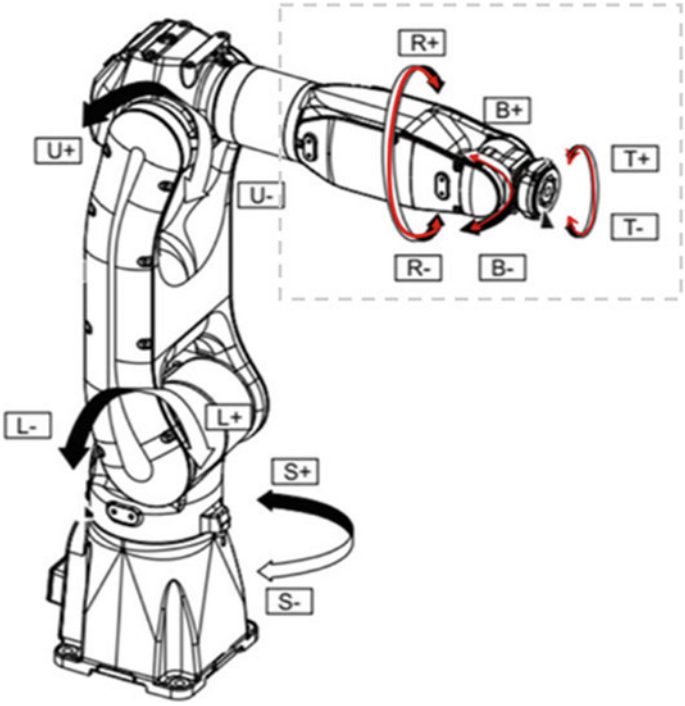

Fig. 5 Illustration of robot movement

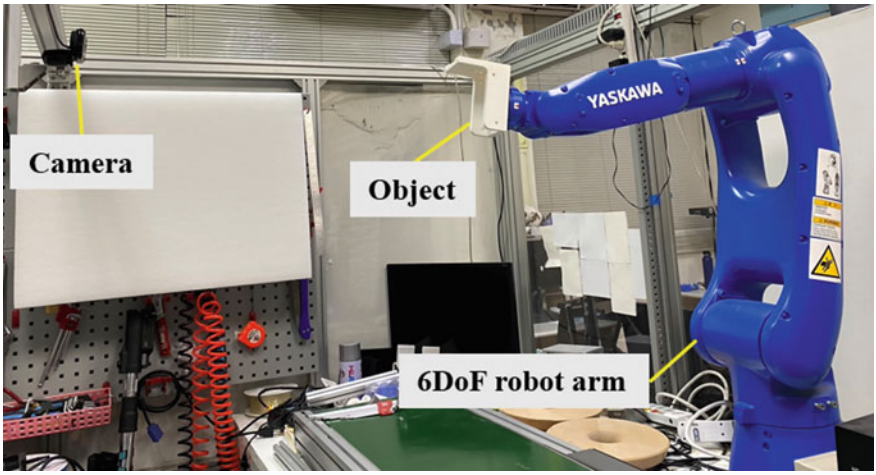

Fig. 6 Environment setup

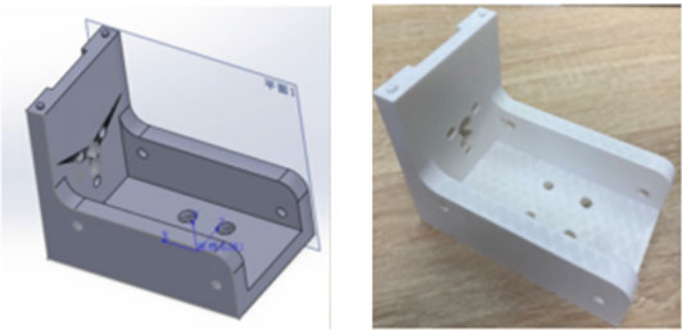

Fig. 7 **a** 3D mesh model of the object; **b** The actual 3D print object

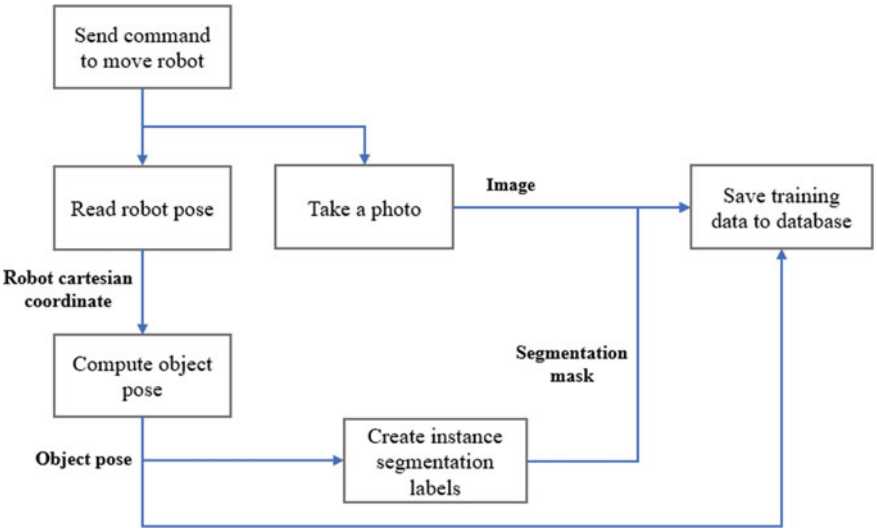

Fig. 8 Data collection process

Figure 9 shows the visualization of the front 800 object poses in the training dataset we collected. We transferred the object pose to camera views relative to the coordinate system of the object. The coordinate frame on the top of the object represents the camera coordinate system which contains the x-axis in green, y-axis in red, and the z-axis in blue. Since the robot movement was regular, relative camera views were uniformly distributed over the top of the object. We collected 3000 training data within 1 h with no humans involved.

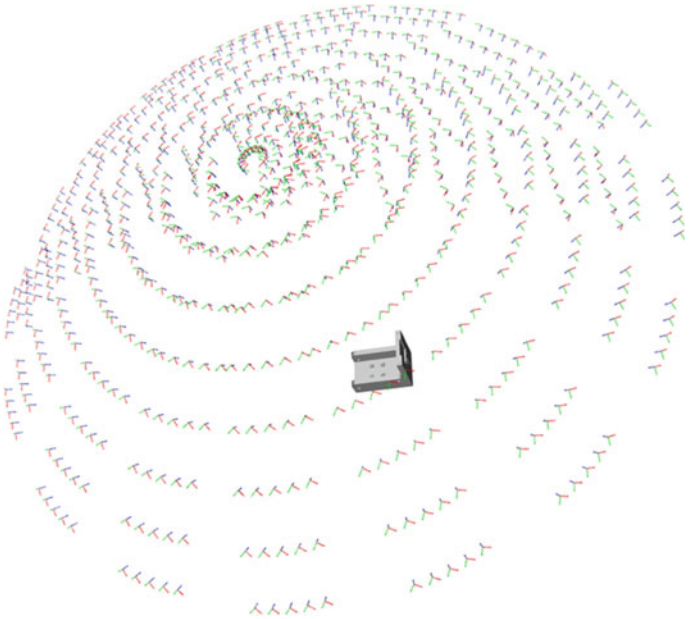

Fig. 9 Visualization of relative camera view

3.3 Object Pose Estimation Model

We implemented our custom dataset in a state-of-the-art two-stage object pose estimation method, Pixel-wise Voting Network [10], which predicts 2D object key points in images and computes the object pose through 2D-3D correspondences with a PnP algorithm. We split our dataset into two parts, 2,400 images for training and 600 images for testing, which were randomly selected from the dataset. We trained the key points detection network through 240 epochs.

We apply ADD metric in the evaluation which calculates the average distance between two converted 3D model points using the predicted rotation $\tilde{R}$ and translation $\tilde{T}$ and ground truth rotation R and translation T:

$$\text{ADD} = \frac{1}{m} \sum_{x \in \mathcal{M}} \left\| (Rx + T) - \left(\tilde{R}x + \tilde{T} \right) \right\|, \tag{7}$$

where $\mathcal{M}$ denotes the set of 3D model points and m is the number of points. It is claimed that the predicted pose is correct when the distance is less than 10% of the model's diameter. For symmetric objects, ADD-S metric [40] was applied, where the average distance is calculated based on the closest point distance in a 3D point set:

Table 2 ADD result in different threshold values

ADD threshold	ADD metric
0.1	0.9983
0.05	0.9
0.04	0.7983
0.03	0.6533

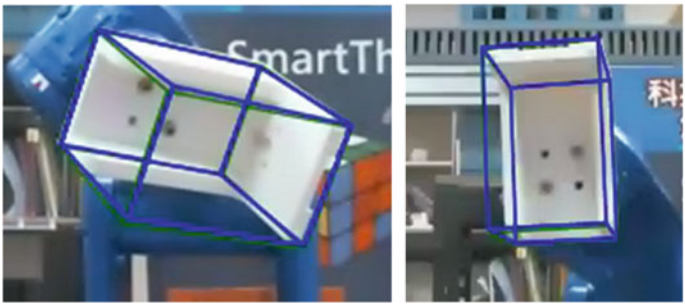

Fig. 10 A 6D pose estimation result

$$\text{ADD - S} = \frac{1}{m} \sum_{x_1 \in \mathcal{M}} \min_{x_2 \in \mathcal{M}} \left\| (Rx_1 + T) - \left(\tilde{R}x_2 + \tilde{T} \right) \right\|. \tag{8}$$

The result in Table 2 shows that even we decrease the threshold value to stricter conditions, over 90% of predictions meet the grasping condition. In this case, the threshold to the real distance is around 8 mm. Figure 10 shows the visualization results of two test images, where the green line represents the ground truth and the blue one is the prediction.

4 Conclusion and Future Works

The experiment in this study shows that the proposed object pose annotation system can automatically generate sufficient amounts of training data, including segmentation labels and object poses with respect to the camera frame. Although the annotation process still requires one manual labeling data, the rest of the collected data are automatically annotated using the known robot pose. It drastically reduces the data labeling time, which was performed by humans in tradition. The custom dataset generated by the auto-labeling system has been tested in existing pose estimation deep learning models. In the future, we will verify the pose estimation results in the real grasping scenario to demonstrate the feasibility of our training procedure. We also will discuss more methods to increase the generalization ability of the 6D pose estimation model in the aspect of data collection. In addition, data augmentation

can be implemented in training datasets, and we can compare the performance of different models.

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Application of Super Resolution for Optical Character Recognition in Low Quality Images

Mykola Baranov, Ivanov Serhii, Dmytro Shvetsov, and Yuriy Shcherbyna

Abstract Machine learning has become a very popular method in various branches of industry and has been successfully applied to a number of practical tasks. Optical character recognition, which is one of the most challenging task in computer vision, has made significant progress due to machine learning applications. Modern OCR systems can provide a high-accuracy predictions both for scanned documents and real-scene images. Despite such power, such models are still suffering from low-quality images, especially, in extreme cases of compressed images. A traditional approach to overcoming such deep learning model weakness is to extend the dataset in such a way as to cover such distortions. However, it requires model retraining and can not guarantee the same accuracy on the previous dataset. We tackle this issue from another perspective. In this paper, we discover how a super-resolution preprocessing step could help the OCR model to recognize images itself. Based on our custom synthetic dataset, we built a super-resolution system. We also performed a careful analysis of how loss functions should be used for text images. Finally, we showed that a custom-trained super-resolution system shows much better results in terms of restored image quality and text recognition accuracy.

Keywords Computer vision · Super resolution · Optical character recognition

1 Introduction

Optical character recognition is one of the most useful tools in the area of computer vision. It is applied in a lot of areas such as business process automation, document digitalization, license plate recognition, scanned document editing, text search on images, automatic scene-text translation, and so on. Such a scope of applications makes optical character recognition systems so valuable in modern life. Meanwhile, it is a very challenging task to build a universal optical character recognition system. A lot of existing models and systems are mainly focused on a subset of tasks, like

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scanned text or real-scene images. Generally, images that contain text can be divided into two groups:

– Scanned document
– Scene image

Scanned documents include both digital copies of text documents and photographs of text documents. Typically, such text images have controlled environments, lighting, distortions, and so on. In contrast to scanned images, scene images cover all real-life texts—advertisements, signboards, and last but not least, plaques. There are a lot of different distortions due to the noncontrolled environment. For example, it includes affine and perspective transformations, text overlapping, various fonts, text sizes, scales, colors, and other factors. Although real-life image text recognition is much harder, scanned document images are more valuable for practical purposes.

A lot of optical character recognition systems have been developed in recent decades. Some of them are focused on generic text recognition. Such models have a lot of capacity, which leads to a huge number of internal parameters (i.e., weight and biases). Very deep models tend to overfit data and perform purely on a validation set as well as inference time. Despite a lot of regularization techniques and augmentation approaches, large-scale datasets remain the most important factor in successful model training. Thus, generalized OCR models require not only a sufficient amount of data but a lot of computational resources both for training and validation. Meanwhile, modern trends bias computation to embedded devices rather than the cloud. From this perspective, the usage of cloud solutions is not the best option (in terms of traffic usage and response delay).

In this paper, we investigate ways to improve the existing OCR system without any internal change. In other words, we believe that the preprocessing step may be much easier and cheaper in comparison to baseline model retraining. Our contribution may be summarized as the following:

– We build a synthetic text recognition dataset.
– We explore how super-resolution may be exploited to improve the quality of low-resolution text images.
– We build a model that improves the quality of text images and show that our approach leads to significant text recognition accuracy improvements in comparison with original images.

2 Related Works

The key idea of deep learning models for optical character recognition lies in the usage of convolution layers along with recurrent layers [8, 12, 13]. Motivation for convolution layers is based on the image nature of input data—neighboring pixels are highly correlated, so there is no reason to use fully connected layers which draw

connections between each input. At the next abstraction level, text is also highly correlated in terms of characters. That's why recurrent layers are added on top of convolution features. State-of-the-art models, on top of the key idea described above, add additional features to improve performance of specific task or tasks. For instance, ASTER [12] suggests using spatial transform networks (STN) [4]. Extension of such an approach was suggested by MORAN [8]—this model mixes up spatial transforms and ASTER, so rectification is performs better. Most of the OCR models try to solve tasks directly in an end-to-end manner. In the case of low-resolution images, the goal of such approaches is to extract the best features to recognize the text. In the best scenario, image quality enhancement is achieved implicitly. But with some probability, the super-resolution task would not be solved in favor of overfitting. So, it makes sense to solve super-resolution tasks explicitly.

A super-resolution task means increasing the width and height of an image. The biggest challenge here is to find the missing pixels after upsampling. A naive approach suggests using interpolation methods (nearest, linear, cubic, bicubic, etc.). But such approaches tend to blur the image, so the result will not bring any new information—existing information will be uniformly distributed along new pixels. At the same time, humans can easily guess what the shape of a leaf should be after resizing it. It could be due to prior information which humans gain during life. Because that key idea was successfully transferred into deep learning, the super-resolutions method has been used in real-world applications. One of the promising approaches toward super-resolution is suggested by Generative Adversarial Networks (GANs) [5, 14]. Such models usually consist of a generative model and a discriminative one [2]. During training, the discriminator predicts whether generated images are fake or not, thus providing a gradient to the generative model. This is a common use of model architecture, especially if generated images should be visually similar to real ones. On the other hand, it requires a lot of computational resources to train since it requires training two models simultaneously. Also, it is hard to train such models because of the required balance between the models' performances. In contrast to GANs, there are approaches that exploit only one generative model. Usually, such models incorporate upsampling layers. To achieve high accuracy, various feature extraction techniques are used, such as the calculation of the feature covariance matrix [11], different skip connections [6, 11], frequency transforms [17].

3 Methodology

3.1 A Closer Look at Prediction Error Types

There is no perfect model that has been developed yet. Even human-level text recognition is not so perfect. It is very important to define a proper metric for deep learning models. Such metrics like character error rate or word error rate play an important role in model validation and model selection. The best KPI indicates the best models.

There is one more aspect of user-defined metrics. Training of a deep learning model task means optimizing user metrics. Usually, such metrics are not directly differentiable, so the loss function is optimized instead. But in practice, we cannot achieve a zero error rate. We carefully inspect different errors of model predictions. Generally, model errors could be classified as follows:

– Model errors
– Out of domain errors

Errors caused by weak models (either overfitting or underfitting) belong to model errors. This type of errors may be eliminated by a larger, more accurate model, better training process, upgraded loss function or regularization. This is actually a case where it is controllable for the researcher.

In spite of model errors being covered, most of the models fail; they are still uncovered. We classify this type of errors as "out of domain errors". While model errors can be tuned in some ways, out of domain errors are less controllable. This is due to the gap between the distribution of input images and the training dataset. In fact, there are a bunch of techniques for out of domain, but such a process is not easy to implement and transfer across different domains.

Existing OCR systems cover various different domains (like scanned documents, real-scene images, distortions, etc.). However, there is no system that reaches human-level OCR accuracy. For instance, low-resolution images can be easily confused by the OCR system while the text is still easily readable by humans.

In this paper, we tackle a way to improve model accuracy by incorporating an image preprocessing step. Namely, we focused on minimizing the gap between low-resolution image distribution and the training dataset. In the next sections, we show how a super-resolution preprocessing step can improve the Tesseract V5 [13] performance.

3.2 Dataset

Since in this paper we focused on the gap between inference and training dataset distributions, it is crucial to have a controlled environment and dataset. To achieve the best possible environment, we built a custom image-to-text dataset. Our datasets consist of 10,000 images. All images were synthetically generated. The original texts were taken from the "War and Peace" book by Leo Tolstoy. Here are the technical annotations of the dataset on Table 1.

All generated data was split into three parts: training, validation, and test subset in a ratio of $8 \times 1 \times 1$.

Based on our dataset, we build a low-resolution version of this dataset by downsampling images with bicubic interpolation and downsampling rate k. Samples of our dataset are presented in Fig. 1.

Table 1 Synthetic dataset technical annotation

Feature	Value
Image size	256 × 256
Image type	PNG
Font	Arial
Font size	16px
Linespace	1.5

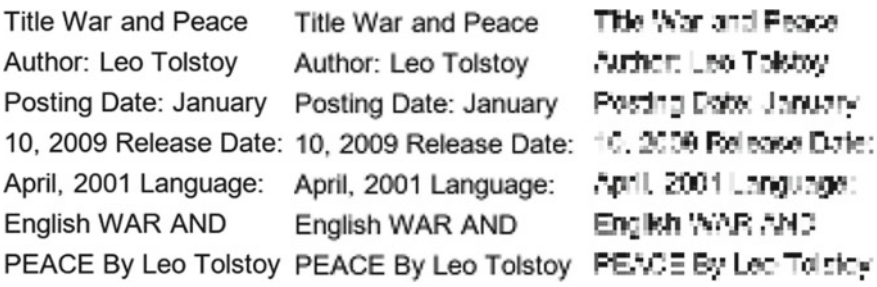

Fig. 1 Samples of our synthetic dataset: original sample (left), 2× downsampled (middle), 4× downsampled (right)

3.3 Super-Resolution Preprocessing Step

For the purpose of minimizing the gap between the inference dataset and the training dataset, we consider exploiting a super-resolution model as a preprocessing step. Namely, we incorporate a Pixel Attention Network (PAN) [20]. Such a model is near state-of-the-art on standard super-resolution benchmarks like Set5 [1], Set14 [18], B100 [9], Urban100 [3], Manga109 [10].

PAN model is based on N subsequent Self-Calibrated Pixel Attention (SCPA) blocks for feature extraction. Thus, we have:

$$x_n = f^n_{\text{SCPA}}(f^{n-1}_{\text{SCPA}}(\ldots f^0_{\text{SCPA}}(x_0)\ldots)), \tag{1}$$

where x_i—features extracted by previous layer f^{n-1}.

Having a set of extracted features, image upsampling is done by exploiting m subsequent Upsampling with Pixel Attention (UPA) layers, where m denotes a scale factor of the input image. This approach is merged with the classical bilinear image interpolation process in such a way that the output of the last UPA block is added to the up-sampled images. Namely:

$$I_{\text{SR}} = f_{\text{bl}}(I_{\text{LR}}) + f_{\text{rec}}(x_n), \tag{2}$$

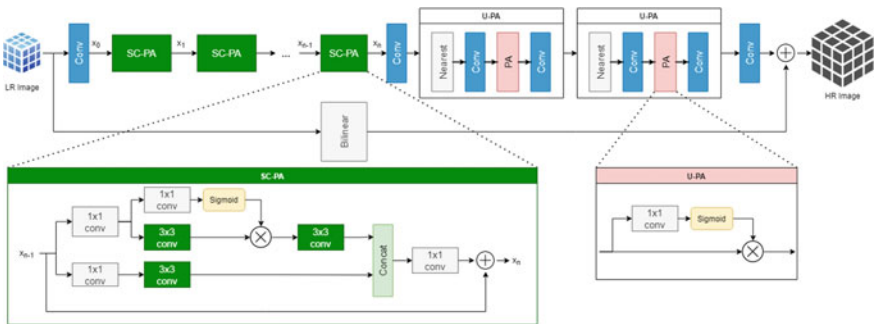

Fig. 2 Diagram of PAN model architecture

where

$$f_{\text{rec}}(x_n) = f^m_{\text{UPA}}(f^{m-1}_{\text{UPA}}(\ldots f^0_{\text{UPA}}(x_n)\ldots)) \tag{3}$$

Also, a classical set of CNN layers is used with the purpose of shallow feature extraction (Fig. 2).

Self-Calibrated Pixel Attention Self-Calibrated Pixel Attention is based on the well-known self-calibrated convolution block [7]. Such blocks tend to extract more useful features in comparison with classical convolution layers with arbitrary filters. The general structure of such a block consists of two group convolutions that which work in parallel and subsequent results are concatenated. Unlike classical group convolution, the upper branch of the SC block is responsible for calibration process (i.e., high-level feature processing). On top of that, a pixel attention mechanism was added, so the SC-PA blocks are able to interpret features according to their localization.

Pixel Attention Attention mechanism on convolutional layers gives us several ways to deal with attention on space features. Thus, we are able:

1. Channel attention (with output shape of $(C \times 1 \times 1)$)
2. Space attention (with output shape of $(1 \times H \times 1)$)
3. Pixel attention (with output shape of $(C \times H \times 1)$)

So, due to the pixel attention mechanism, our model is able to deal with 3-dimensionsl feature tensor of a given image. We achieve this by using a set of convolutional layers with K 1×1 kernels. Equation (4) provides a full details of our attention mechanism:

$$x_p = f_{\text{PA}}(x_{p-1}) \cdot x_{p-1} = f_{\text{act}}(f_{\text{conv}}(x_{p-1})) \cdot x_{p-1}, \tag{4}$$

where x_{k-1} and x_k stand for input and output vectors respectively. f_{act}—denotes activation function and f_{conv}—is defined as a convolution operation with 1×1 kernel.

Loss function In the super-resolution task, the most popular loss functions are a family of L_n functions. The classical case of L_n loss is the least absolute deviation function (L_1) which provides an absolute linear distance between the predicted and ground truth value.

$$L_1(y, \tilde{y}) = \frac{1}{N} \sum_{i=1}^{N} |y - \tilde{y}| \tag{5}$$

Originally, PAN model is built upon the L_1 loss function. Despite the near state-of-the-art result of the original model, we observe poor behavior on our low-quality text images. The root cause of such an issue lies in the semantics of L_1 function. By minimizing a linear loss function, we optimize only the absolute distance between ground truth and predicted pixels. Thus, we pay no attention to contrast and brightness. We found it critical for text images. Different levels of image degradation may have the same loss value (see Fig. 3). L_2 function not only pays more attention to the bigger errors, but also fails to understand the low-level semantics between ground truth and predicted image.

$$L_2(y, \tilde{y}) = \frac{1}{N} \sum_{i=1}^{N} (y - \tilde{y})^2 \tag{6}$$

We carefully investigated the issues of L_n metrics and found that the structure similarity index measure (SSIM) [15] seems to be the best choice for precise image upsampling or generating.

SSIM for pixel p is defined as follows:

$$\text{SSIM}(p) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1} \cdot \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2} = l(p) \cdot cs(p) \tag{7}$$

SSIM is one of the metrics of image quality that evenly pays attention to illumination contrast l and image structure cs. Average μ and standard deviation is obtained by using a Gaussian filter with a standard deviation of σ_G, G_{σ_G}. Such a metric can also be used as a loss function since it is differentiable.

SSIM loss function can be defined as:

$$L_{\text{SSIM}}(P) = \frac{1}{N} \sum_{p \in P} 1 - \text{SSIM}(p) \tag{8}$$

SSIM loss function now allows the model to generate pixel attention with respect to its neighbors. However, it still suffers from a non-generalized 'view' of pixel neighbors.

Multi Scale Structured Similarity Index (MSSIM) [15] can be treated as an improved version of SSIM since it pay attention not only to pixel surrounding but with respect to different scales.

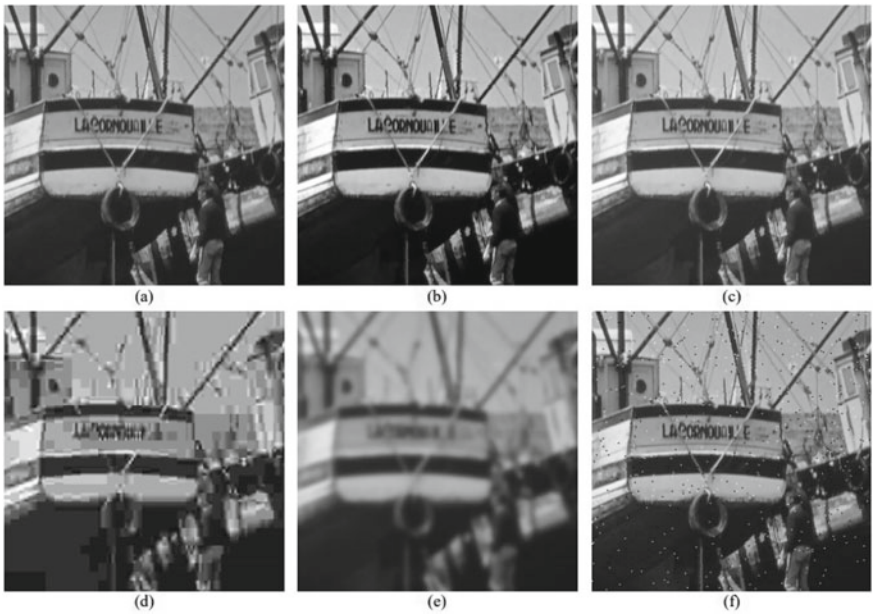

Fig. 3 Comparison of degradation of the ship image [15] with different degradation levels. All images have a L_1 loss value of 15. **a** Original image; **b** MSSSIM = 0.9168; **c** MSSSIM = 0.9900; **d** MSSSIM = 0.6949; **e** MSSSIM = 0.7052; **f** MSSSIM = 0.7748

$$\text{MSSSIM}(p) = l_M(p) \cdot \prod_{i=1}^{M} cs_j(p), \tag{9}$$

MSSIM metric can also be exploited as a loss function:

$$L_{\text{MSSSIM}}(P) = \frac{1}{N} \sum_{p \in P} 1 - \text{MSSSIM}(p) \tag{10}$$

According to [19] it makes sense to mix up a classical L_1 loss and MSSIM loss function for supper-resolution task. Thus, we obtain:

$$L_{\text{mix}} = \alpha \cdot L_{\text{MSSSIM}} + (1 - \alpha) \cdot L_1 \cdot G_{\sigma_G^M} \tag{11}$$

Evaluation metrics In addition to losses (7), (9) we use a peak signal-to-noise ratio (PSNR) as a metric of generated image quality:

$$\text{PSNR}(y, \tilde{y}) = 10 \cdot \log_{10} \left(\frac{\text{MAX}_I^2}{L_2(y, \tilde{y})} \right), \tag{12}$$

where y—ground truth image, $\tilde{y}$—noised ground truth image, MAX_I^2—maximum allowed pixel value of both images. L_2 is defined by Eq. (6)

Since in this paper we mainly focus on the optical character recognition task, we define an extra metric for text recognition besides the image quality metric. Here we define an average relative edit distance:

$$f_{\text{rel}}(t, \tilde{t}) = \frac{1}{N} \sum_{i=1}^{N} \frac{f_{\text{edit}}(t, \tilde{t})}{l_t}, \tag{13}$$

where t—ground truth text, $\tilde{t}$—predicted text, l_t—length of text t, F_{edit}—edit distance (also known as Levenshten distance).

4 Experiments and Evaluation

Super-resolution model evaluation We train our super-resolution model on a synthetic text dataset. Here is a test set evaluation result in Table 2.

Our experiment shows that our model reconstructs the input image much better in comparison to classic interpolation methods. Even in extreme cases of low-quality images with $\times 4$ scale, our approach can reconstruct text images with near human-level accuracy.

OCR evaluation Now let's move on to the OCR task. We predict text on the same test set using a Tesseract. Table 3 provides full evaluation metrics, both with and without the super-resolution preprocessing step applied.

According to metric (13), the OCR system works much better if the input image super-resolution was enhanced with the super-resolution method. The most dramatic improvements were obtained with $\times 4$ downscale distortion factor. As a result, our method improves tesseract text prediction on both $\times 2$ and $\times 4$ scales.

Table 2 Evaluation metrics on the test low-quality image dataset

Algorithm	Scale	PSNR	SSIM	MSSSIM
Bilinear	$\times 2$	17.5078	0.8622	0.9777
Bicubic	$\times 2$	18.9916	0.9055	0.9889
PAN	$\times 2$	**25.72**	**0.9784**	**0.9962**
Bilinear	$\times 4$	12.5833	0.6198	0.7873
Bicubic	$\times 4$	12.0794	0.6189	0.7804
PAN	$\times 4$	**16.5921**	**0.8504**	**0.9283**

The best score is highlighted with bold

Table 3 Comparison of Tesseract text prediction accuracy with and without the super-resolution applied

OCR System	Scale	SR	f_{rel}
Tesseract	$\times 2$	N	0.0654
Tesseract	$\times 2$	Y	**0.0437**
Tesseract	$\times 4$	N	0.9934
Tesseract	$\times 4$	Y	**0.313**

The best score is highlighted with bold

5 Conclusions

In this paper, we tackle a problem and investigate factors that cause prediction errors. Based on our custom synthetic text recognition dataset, we explore and show that there are specific types of errors that cannot be eliminated only with model training without new dataset collection. Thus, we tackle two fundamental problems which are somehow related to the few-shot learning area: increasing model performance without large-scale dataset collection and model retraining. Thus we shown input data is no less important than model itself. Such an approach gives us opportunity reuse exiting deep learning models with data from unseen distribution. Even more, it could be done without any changes to the model.

We focus on a modern OCR system since the OCR task is one of the most practical tasks in computer vision. The most powerful existing OCR systems are not publicly available and thus cannot be fine-tuned on custom datasets. We focus on a low-resolution image text prediction task as an example of an out-of-distribution prediction challenge. In this paper, we used OCR systems as an example of a predefined deep learning model. However, our approach can be easily extended to any other deep learning problem, even to not computer vision tasks. For example, image classification, object defections, panorama stitching, and others. Even more, preprocessing super-resolution step may be replaced with any other technique, thus we do not stick only to the computer vision area.

The super-resolution task is a well-known challenge, so we started with the near state-of-the-art PAN model, but it showed poor results on text upscaling due to specific features of scanned document text images, so we designed a custom loss function, which significantly improved the upscaled image quality.

Based on that result, we evaluated an open-source Google-powered tesserac t OCR system. Our approach dramatically increases tesseract accuracy on a $\times 4$ scale factor while still dominating with relatively small $\times 2$ scaling.

Such an approach to image preprocessing tasks may be extended to various cases like image denoising, rotation, transformation, image inpainting, and others.

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User Clustering in mm Wave Quality of Service-Based Non-orthogonal Multiple Access (QNOMA) for Vehicular Network

Syed Muhammad Hamedoon and Jawwad Nasar Chattha

Abstract Due to dynamic nature topology in vehicular network and exponentially huge amount of traffic, it is very difficult to provide services with high data rate to these vehicles. In a heterogeneous network, a V2I system with NOMA capabilities can achieve low latency and high reliability. In this paper, we focus V2I communication system in 5G. The performance of V2I is measured in terms of sum rate according to QoS requirement of different vehicles inside a cell. The intelligent transport system is required to cover the challenges of existing wireless networks. The most common problem in vehicular network is the requirement of data rate differently. In mm wave NOMA, the users which are closer to the base station received better rate comparatively to the other users. This become the bottleneck to meet the QoS demand for far user in mm wave NOMA. We solved this problem by using clustering technique to divide the number of users into different clusters. We proposed clustering scheme and compare with other two unsupervised machine learning techniques included K means and hierarchical. After clustering, SIC ordering is arranged according to their target rates of vehicles in QNOMA. In the end, we compare these clustering technique according to the data rate requirement of different vehicles. The proposed user clustering algorithm significantly improves the sum rate of the network according the QoS requirements.

Keywords Non-orthogonal multiple access (NOMA) · Quality-based non-orthogonal multiple access (QNOMA) · Fifth generation (5G) · Vehicular to Infrastructure (V2I) · Quality of service (QoS) · Successive Interference Cancelation (SIC) · Power Domain NOMA (PD-NOMA) · Base station (eNB)

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1 Introduction

In cellular communication, the fifth generation (5G) is widely used to evolve large number of applications which is used commercially and proposed sixth generation (6G) network to provide high intelligent communication in near future [1]. Due to rapid growth of traffic in wireless networks, non-orthogonal multiple access (NOMA) is widely used. The basic goal is to improve spectral efficiency and served multiple users to share the same resource blocks. This provides more advantages in massive connectivity and high data rates in mm wave NOMA transmission [2–4]. Recently, vehicular networks are emerging to improve traffic efficiency by employing intelligent transport system. The communication system used in Vehicular Ad hoc Networks (VANETs) is able to communicate with each other to reduce traffic accidents, congestion control, and achieve high data rates in network [5]. The application of NOMA to mm wave transmission has many potential advantages that attracts the research community [2–4]. The basic characteristics of mm Wave NOMA system has high directional transmission and higher capacity in order to make the users channel highly correlated. Vehicle to vehicle (V2V), vehicle to pedestrian (V2P), and vehicle to infrastructure (V2I) should fulfill everyone's requirement. The vehicle can communicate with the base station (Mode 3) or a decentralized system (Mode 4). Vehicle out of network coverage can also communicate another vehicle, which can act as a relay for out of network coverage. This can provide network infrastructure for a better V2X environment. With the enabling of ITS, the concept of smart cities, autonomous driving, easy navigation, traffic efficiency, and infotainment high quality of service (QoS) are all becoming a reality. NOMA technique is designed in such a way to allow several users to support multiuser transmission and to perform superposition coding (SC) technique at the transmitter side through share identical resource block. At the receiver side, the interference is introduced when superimposed signals are split up. The SIC implementation at the receiver helps the user to recover their own data without any corruption due to interference. In NOMA, the concept of non-orthogonality employs in power domain variation. At the transmitter side, the data is multiplexed and transmitted via a wireless channel by allocating the difference in power to the different users [6]. In this way, superposition coding at the transmitter side and SIC employed at the receiver side by utilizing the same spectrum. The receiver decodes the strongest signal first and treats other signal as noise and interference. Afterward, it eliminates the most powerful signal. This removal of unwanted signal continues until the desired signals are acquired by all the users [7]. The following is a summary of the paper's key contributions:

- We observe the problem related sum rate maximization in mm wave NOMA-based system for fixed user model scenario.
- We solved the complexity of SIC receiver by applying clustering schemes included proposed user clustering, K means and hierarchical for consider a user scenario cases in fixed user model. The users are assigned to the cluster on basis of their position from base station and selected clustering scheme.

– We proposed user clustering algorithm 1 for QNOMA which is based on quality of service requirement of vehicular users
– In the end, we compare the proposed user clustering algorithm with other clustering algorithm included K means and hierarchical for QNOMA.

1.1 Quality of Service-Based NOMA in V2I Communication

NOMA provides high achievable data rates and spectral efficiency in wireless system for promising 6G network. The achievable rates can be further improved in vehicular networks by applying NOMA principle. In heterogeneous environment of vehicular networks, all the devices have different QOS requirements some of the vehicles required high data rates for example emergency services. We proposed a quality of service-based NOMA in this paper, which uses cellular communications to enable vehicle networks. In basic NOMA principle, the SIC is implemented according to the channel correlation of users inside the cell due to which not achieve the desired multiplexing gains and fairness among users inside the cell. The ordering of users inside cell is according to the QOS requirement [8]. The N number of vehicles is located at different locations from base station. The vehicles U_1, U_2, …, U_N are located inside a cell from the BS at different distances d_1, d_2, …, d_N. The vehicles which are closest to the base station assigned more power comparatively to those vehicles which are farther away from the base station. In downlink NOMA, the SIC decoding order on the basis of the channel gains is $g_1 \leq g_2 \leq g_3 \leq$, …, $\leq g_N$. The strongest signal which have weakest channel is decoded first and then subtracted the from Y_n (t). This process is repeated until each vehicle decoded its own signal as shown in Fig. 1.

2 System Model

This section focuses on the downlink mm Wave NOMA-based system model as shown in Fig. 2, which comprises of a single BS with single antenna serves N single-antenna users. The clustering schemes are applied to create K clusters of users and apply NOMA to each cluster. With SIC, each user recovers their own signal by successively reducing interference from other low channel gain users in the same clusters. A single base station (BS) is served communication to $N = 8$ and $N = 12$ vehicular users inside a single cell. These users are located at different location from base station. The environment we consider is static which means user positions from the base station is fixed. The cluster's users are considered to be independently identically distributed (i.i.d.). The user model is defined as a normal variance distribution shown in Eq. 1 around the cluster center.

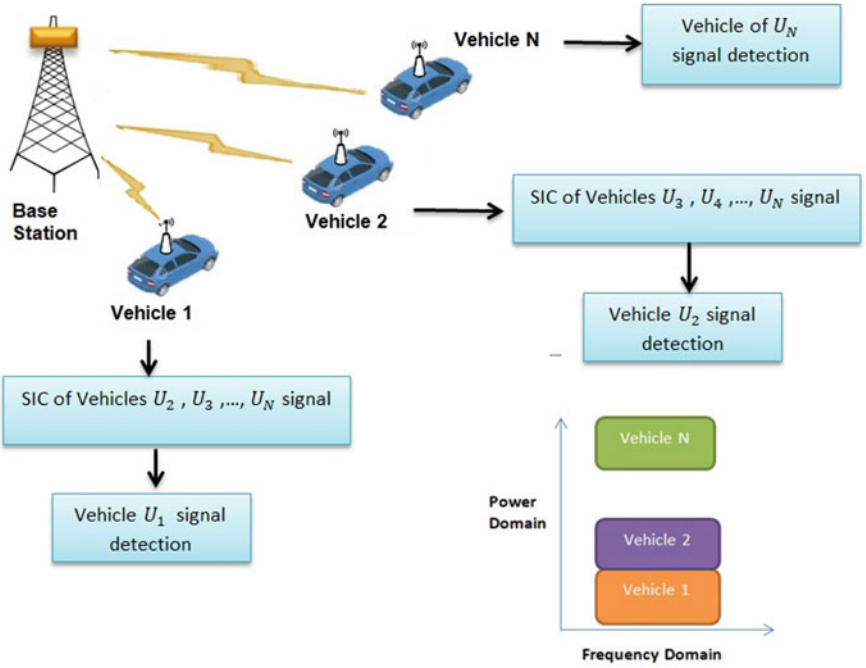


Fig. 1 QNOMA in V2X communication

$$f_p(x) = \frac{1}{2\pi\sigma_p^2} \exp\left(\frac{-\parallel x \parallel^2}{2\sigma_p^2}\right) \tag{1}$$

We assume the base station knows the channel state information of all the users. We have L numbers of users $U_1, U_2, \ldots, U_L$ that consider vehicles which are distributed inside the single cell as shown in Fig. 2. These users are placed at specific distances from base station $d_1, d_2, \ldots, d_L$. The users which are near to the base station have strong channel gain comparatively the other users. The channel gain for the the users inside a cell is $\left|h_{U_1}\right|^2 > \left|h_{U_2}\right|^2 > , \ldots, \left|h_{U_L}\right|^2$. The SIC decoding order is based on the channel gain sorting order. The channel gain is ordered in SIC operation according to the rates requirements $\left|h_{R_1}\right|^2 > \left|h_{R_2}\right|^2 > , \ldots, \left|h_{R_L}\right|^2$.

Let assume $X = \{x_i\}$ where $i = 1, 2, \ldots, N$. These are N dimension points into K cluster. The set of cluster is represented by $C = \{C_1, C_2, \ldots, C_K\}$. These clusters are made after applying clustering schemes which is discussed in Sect. 5. The superimposed message which is transmitted by the base station and received by the user in specific cluster C_K during downlink NOMA transmission is given by

$$Y_L^K = \left|h_{U_L}\right|^2 \sum_{n=1}^{L} \sqrt{\beta_{U_n}^K P_{U_n}^K} + \text{noise} \tag{2}$$

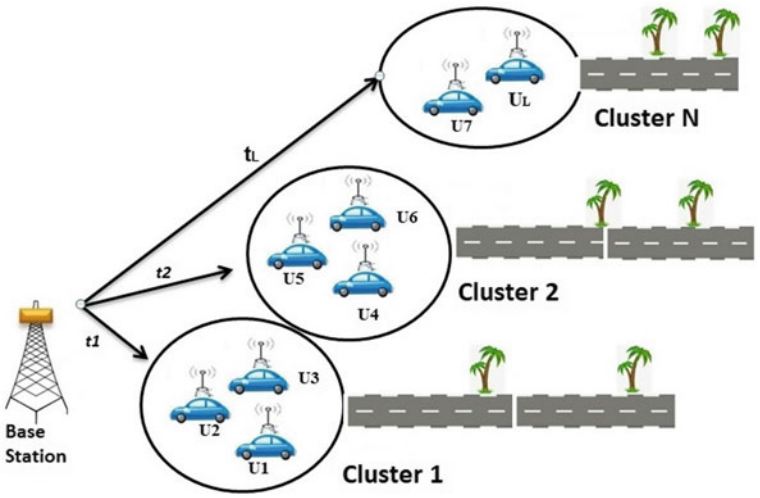


Fig. 2 System model for users clustering in mm wave NOMA

where Eq. 2 represent the received message at the vehicle L in cluster K during downlink NOMA transmission. In Eq. 2, $h_{U_L}^K$ denotes the channel gain of the vehicle user in specific cluster. These channel gains are sorted in SIC decoding order according on the basis of channel gain. In Eq. 2, $\beta_{U_L}^K$ represents the power allocation factor for all the vehicular user inside the K_{th} cluster which is splitting factor $\sum_{n=1}^{L} \beta_{U_n}^K = 1$ during NOMA transmission.

The signal-to-noise ratio of L_{th} vehicular user which comes last in decoding order of SIC is given in Eq. 3.

$$\gamma_{U_L} = \frac{\sum_{C=1}^{K} \left(P_{U_L}^C \beta_{U_L}^C \left| h_{U_L}^C \right|^2 \right)}{\sigma^2} \tag{3}$$

Similarly, the signal-to-noise interference ratio of the strong channel gain user which comes first in SIC decoding order is given in Eq. 4.

$$\gamma_{U_1} = \frac{\sum_{C=1}^{K} \left(P_{U_1}^C \beta_{U_1}^C \left| h_{U_1}^C \right|^2 \right)}{\sum_{C=1}^{K} \left(P_{U_L}^C \beta_{U_L}^C \left| h_{U_1}^C \right|^2 \right) + \sigma^2} \tag{4}$$

The achievable rate of L_{th} user in the k_{th} cluster is given in Eq. 5.

$$R_{U_L} = B \log_2(1 + \gamma_{U_L}) \tag{5}$$

Similarly, the achievable rate of the first user in the k_{th} cluster is given in Eq. 6.

$$R_{U_1} = B \log_2(1 + \gamma_{U_1}) \tag{6}$$

The overall sum rate of all the users inside K_{th} cluster is calculated by using Eq. 7

$$R_{\text{sum}}(K) = B \log_2 \sum_{n=1}^{L} \left(1 + \gamma_{U_n}^K\right) \tag{7}$$

In order to achieve sum rate, we need to follow some constraints which are mention in Eqs. 8, 9, and 10.
max $\mathbb{E}[R_{\text{sum}}(K)]$
s.t:

$$\sum_{n=1}^{L} P_{U_n}^K \leq P_{\text{Total}} \tag{8}$$

$$R_L^K \leq 2^R - 1; \forall k \tag{9}$$

$$2 \leq \sum_{k=1}^{K} C_k \tag{10}$$

The constraint mention in Eq. (8) represents the summation of each power of all vehicular users in specific cluster must be less than the total power received by the base station. The constraint mention in Eq. (9) shows that the rate achieved by the vehicular user in each cluster must be less than the total capacity of the BS. Equation (10) represents the minimum number of cluster must be greater than and equal to 2.

3 Proposed User Clustering

In NOMA, when number of users increased in coverage area the performance is degraded due to SIC complexity. This problem is solved by using clustering scheme to divide the number of users into different clusters. The clustering scheme is used to reduce the receiver SIC complexity at the base station in PD-NOMA. We proposed user clustering algorithm in which we cluster the pair of two users which have high channel gain difference. We group the two vehicular devices with the largest channel gains difference as one cluster after sorting vehicular devices based on their channel states. The users are present inside the cell with some distance from base station as shown in Fig. 3. The user which is near from the base station has strong channel gain comparatively the other users. When number of users required quality of service differently, the traditional SIC ordering is not desirable.

$$y_{U_1}^K = \left|h_{U_1}\right|^2 P_{U_1}^K x_{U_1}^K + \left|h_{U_1}\right|^2 P_{U_2}^K x_{U_2}^K + n_{U_1} \tag{11}$$

$$y_{U_2}^K = \left|h_{U_2}\right|^2 P_{U_2}^K x_{U_2}^n + \left|h_{U_2}\right|^2 P_{U_1}^K x_{U_1}^K + n_{U_2} \tag{12}$$

The received signal by the vehicular user y_{U_1} ,y_{U_2} for k_{th} cluster is represented in Eqs. 11 and 12. The expected reception of signals is represented by $x_{U_1}^K$ and $x_{U_2}^K$. The white Gaussian noise is represented by n_{U_1} , n_{U_1} with mean 0 and unit variance is added with this received signal. The $P_{U_1}^K$ and $P_{U_2}^K$ are the received power of the two vehicular user in each K_{th} cluster. In downlink NOMA, the user which have strong channel gain allocate weak power comparatively to the user which have weaker channel gain $P_{U_1}^K < P_{U_2}^K$. The received power by the two vehicular user inside K cluster should be less than the total power budget as shown in Eq. 13.

$$\sum_{C=1}^{K} \left(P_{U_1}^C + P_{U_2}^C\right) \leq P_{\max} \tag{13}$$

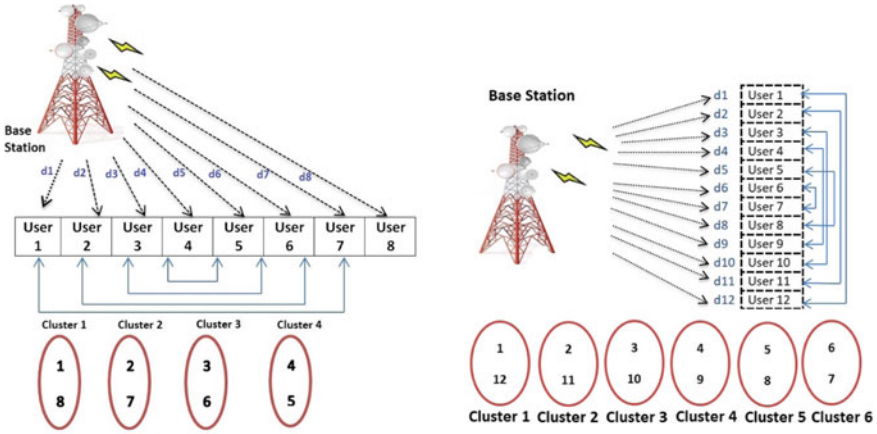
The clustering of vehicular users for $N = 8$ and $N = 12$ is shown in Fig. 3a and b. The pairing of users inside cluster C_k by using the principle of higher channel gain difference. In SIC decoding order, the users must be pair according to the proposed algorithm 1. The user which have strong channel gain must be pair with user have weaker channel gain in each cluster C_k and vice versa according to the rates requirements. In Fig. 3a, the principle of SIC is implemented on all the users U_N^K in k_{th} cluster. The SIC of ordering of all the users in K_{th} cluster for $N = 8$ from Fig. 3a is given by $C_1 = \{\left|h_{U_1}^1\right|^2 > \left|h_{U_8}^1\right|^2\}$, $C_2 = \{\left|h_{U_2}^2\right|^2 > \left|h_{U_7}^1\right|^2\}$,$C_3 = \{\left|h_{U_3}^2\right|^2 > \left|h_{U_6}^3\right|^2\}$, $C_4 = \{\left|h_{U_4}^4\right|^2 > \left|h_{U_5}^4\right|^2\}$.

Similarly, the SIC ordering for the users $N = 12$ from Fig. 3b is given by $C_1 = \{\left|h_{U_1}^1\right|^2 > \left|h_{U_{12}}^1\right|^2\}$, $C_2 = \{\left|h_{U_2}^2\right|^2 > \left|h_{U_{11}}^2\right|^2\}$, $C_3 = \{\left|h_{U_3}^1\right|^2 > \left|h_{U_{10}}^3\right|^2\}$, $C_4 = \{\left|h_{U_4}^4\right|^2 > \left|h_{U_9}^4\right|^2\}$, $C_5 = \{\left|h_{U_5}^5\right|^2 > \left|h_{U_8}^5\right|^2\}$, $C_6 = \{\left|h_{U_6}^6\right|^2 > \left|h_{U_7}^6\right|^2\}$

$$\gamma_{U_1} = \frac{\sum_{C=1}^{K} \left(P_{U_1}^K \beta_{U_1}^K \left|h_{U_1}^K\right|^2\right)}{\sum_{C=1}^{K} \left(P_{U_2}^K \beta_{U_2}^K \left|h_{U_1}^K\right|^2\right) + \sigma^2} \tag{14}$$

$$\gamma_{U_2} = \frac{\sum_{C=1}^{K} \left(P_{U_2}^K \beta_{U_2}^K \left|h_{U_2}^K\right|^2\right)}{\sigma^2} \tag{15}$$

The signal to interference and noise ratio of user U_1 is represented by γ_{U_1} in Eq. 14. Similarly, γ_{U_2} represents the signal-to-noise ratio of U_2 in Eq. 15, where $P_{U_1}^K$, $P_{U_1}^K$ is the power of U_1, U_2 for cluster k and $\beta_{U_1}^K$, $\beta_{U_2}^K$ is the power allocation factor of U_1, U_2 for k_{th} cluster and channel gain of user U_1 and U_2 is represented by $\left|h_{U_1}^K\right|^2$, $\left|h_{U_2}^K\right|^2$. The Gaussian white noise σ^2 is added as an interference in received signal. We can calculate the data rates of user U_1 and U_2 using the channel model, and they are as represented in Eq. 16 17.



(a) Proposed users clustering for 8 Users

(b) Proposed users clustering for 12 Users

Fig. 3 K means user clustering

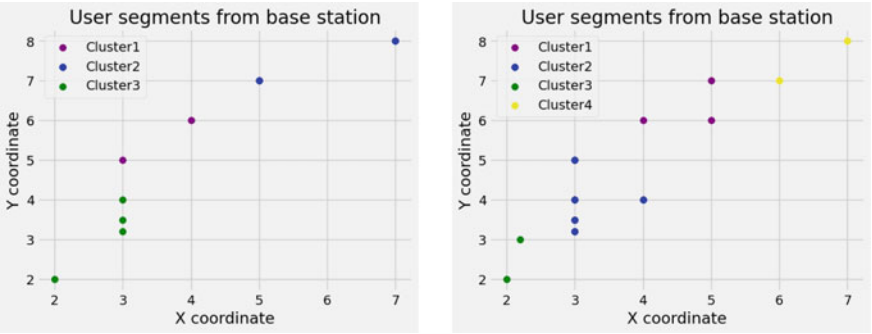
$$R_{U_1} = B \log_2 \left(1 + \gamma_{U_1}\right) \tag{16}$$

$$R_{U_2} = B \log_2 \left(1 + \gamma_{U_2}\right) \tag{17}$$

In QNOMA, the process of SIC ordering of users is performed on the basis of target rates due to which the desired quality of service meet. The SIC is performed on the basis of target rates R_1, R_2, …, R_n. The low rate requirement of user decode first and high rate requirement of user decode second and so on. The pseudo-code of proposed user clustering for QNOMA is mentioned in Algorithm 1

Algorithm 1 Proposed User clustering in QNOMA

1: Initialize the number of users $N = 8$ and $N = 12$ with distances from base station.
2: A base station is divided the single cell in to K number of cluster which is paired by two users.
3: Sort the channel gains of users inside the cell according to the rates requirement R_1^K , R_2^K, ..., R_n^k
4: Update SIC decoding order using step 3 and apply NOMA transmission for all the users inside K_{th} clusters
5: Repeat step 1 to step 4 until all the users are properly served by the base station
6: Measured sum rates of all the users inside each cell by using Eq. 7
7: Verify the results according to the defined rates requirements Q_1, Q_2, …, Q_n.
8: **END**



(a) Number of Users (N)=8 (b) Number of Users (N)=12

Fig. 4 K means user clustering

4 Machine Learning-Based User Clusterung in NOMA

Clustering is a class of unsupervised machine learning which is used to trained without being supervised using unlabeled dataset. The method of clustering mainly depends on the nature of dataset in feature space [9]. The procedure of cluster in downlink PD-NOMA is, at the beginning stage the vehicles report to the base station to their speed , location and QoS requirements. The base station executes an clustering algorithm to form the cluster and divide the users in to different number of clusters on the basis of distance. In this section, we discuss the unsupervised machine learning techniques included, K-means and hierarchical clustering method to partitions the number of vehicles inside the heterogeneous network and apply NOMA according to QoS requirements.

4.1 K Means-Based User Clustering

It is classical clustering technique that divides the dataset of n items into k a priori defined groups. The object which have minimum average dissimilarity to all other objects inside a cluster is known as medoid [10]. In this method, we can pick each representative cluster object grouped with other remaining object that are more similar. The method of partitioning is based on the notion of minimizing the total of the differences between each object and its matching reference point [10]. The final centroid is constructed as actual data points. The details of algorithm of K Mean is mentioned in [9].

The selection criteria for choosing number of cluster in k means by using elbow method. In this method, Within-Cluster Sum of Square (WCSS) is calculated for each cluster C_k. It is a squared distance between each point and the cluster's centroid. The plot resembles an elbow for the number of users $N = 8$ and $N = 12$. When we

examine the graph, we can observe that it abruptly changes at one point, forming an elbow. The graph then begins to close nearly parallel to the X-axis from this point that represents the optimal K value for the number of clusters. The number of clusters is computed by using elbow method for $N = 8$ is $k = 3$ and for users $N = 12$ the value of k is 4. This value of k is used to initialize the K means algorithm (Table 1).

There are different number of users $N = 8$ and $N = 12$ which is served by the base station in a single cell as shown in Fig. 4a and b. We assume the base station is placed at origin and clustering algorithm divide the number of vehicles in to k cluster according to their position x and y coordinate from base station. The K means clustering algorithm is used to make clusters the user on the basis of distance from the base station. In Fig. 4a and b, the number of users inside a clusters with different colors is represented. The clustering results generated by the K means are given in Table 2.

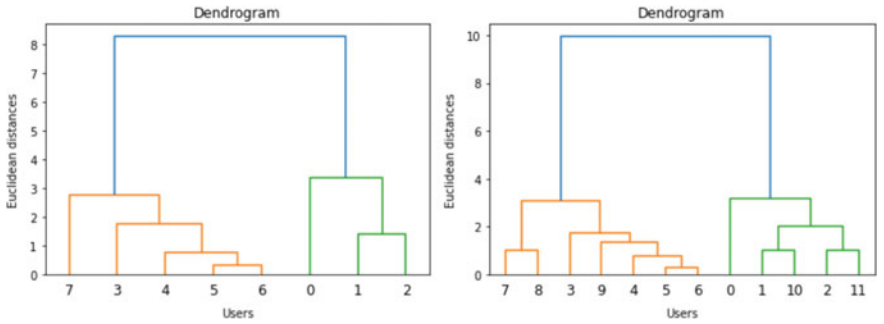
4.2 Hierarchical Clustering Method

It is unsupervised machine learning technique in which the clusters created by the tree-like structure known as dendrogram. The dendrogram's root node represents the entire data collection, whereas each leaf node represents a data object. The distance between each pair of objects or clusters, or between an object and a cluster, is commonly expressed by the height of the dendrogram [11]. In this method, the clustering starts with one object inside a cluster, and after that, a series of merge procedures are performed, resulting in all objects being assigned to the same group [11]. It is also called bottom-up approach. An agglomerative hierarchical clustering technique generates a sequence of data partitions, P_n, $P_{(n-1)}$, …, P_1. The approach links together the two clusters that are closest together at each stage. The clustering process in complete linkage, also known as farthest neighbor, is the polar opposite of single linkage. The distance between the two groups is calculated by measuring the distance between the two points that are the farthest apart from each other. $D(k, r)$ is calculated distance between the users inside cluster by using the complete linkage method as shown in Eq. 18.

$$D(k, r) = \text{Max}\{d\{i, j\}\} \tag{18}$$

where $D(k, r)$ is the maximum distance between the user i in cluster k with the user j in cluster r.

The dendrogram is represented for $N = 8$ and $N = 12$ for complete linkage in hierarchical clustering as shown in Fig. 5a and b. The two different colors in linkage group of users N are shown in dendrogram which indicates that this clustering scheme create two clusters.The clustering result generated on the basis of dendrogram is given in Table 2.



(a) Complete linkage when N=8 (b) Complete linkage when N=12

Fig. 5 Hierarchical user clustering

Table 1 Simulation parameters

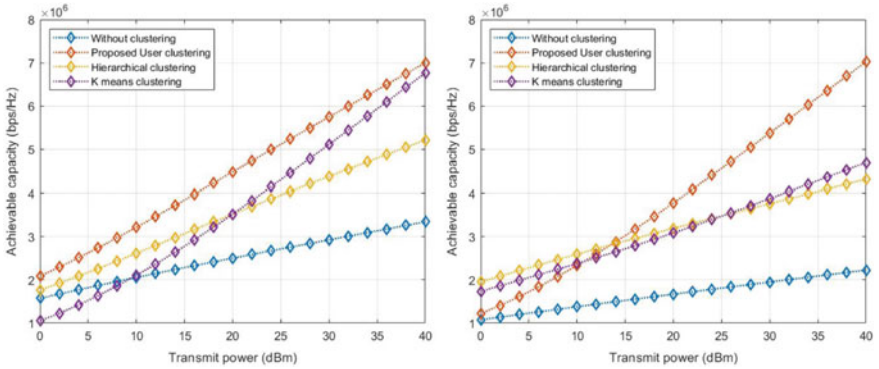
Parameter	Value
Number of users (N)	8, 12
Number of clusters (K)	2, 3, 4, 5
Path loss exponent	5
Bandwidth	10^6
Base station transmission power	0–40 dB
Noise power	−174 dBm

5 Numerical Results and Discussion

In this section, we observe the results by applying proposed and other user clustering schemes for NOMA and QNOMA by using simulation parameters which are mentioned in Table 1.

5.1 User Clustering Scheme Analysis

The user clustering scheme applies on the basis of information including vehicle position $P_{(x,y)}$ on xy plane and the distance from base station (BS). The users are assigned to the clusters by applying clustering schemes included proposed user clustering, K means and hierarchical. The comparison of user clustering schemes are shown in Fig. 6a and b. In without clustering scheme, when number of users increases, the overall performance of NOMA decreases due to complexity of SIC decoding order. The graphs shown in Fig. 6a and b provide better comparison of clustering algorithm which indicates that the proposed user clustering scheme performs well especially when number of user inside a cell increases. The proposed algorithm 1 optimizes the



(a) NOMA Achievable Rates for N=8 (b) NOMA Achievable Rates for N=12

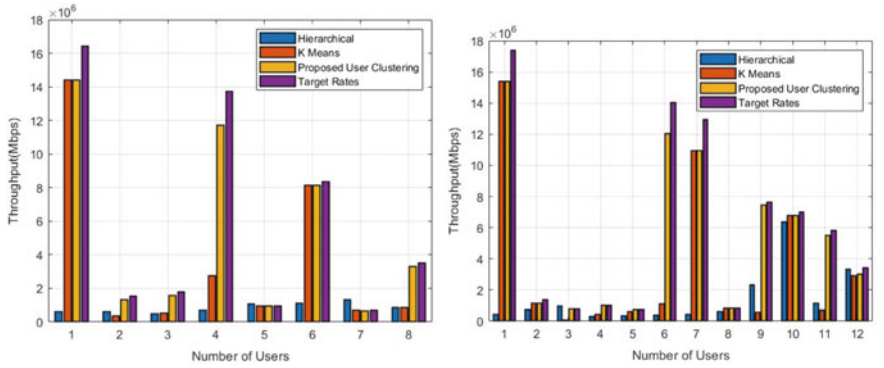
Fig. 6 Clustering schemes comparison for NOMA

Table 2 Clustering scheme results for QNOMA

No. of users (N)	Clustering scheme	Rate constraints (Q)	Positions of user in clusters
8	Proposed clustering scheme	Q1 = R2 < R3 < R4 < R1, Q2 = R5 < R6, Q3 = R7< R8	C1 = {2, 1}, C2 = {3, 4}, C3 = {5, 6} C4 = {7, 8}
	K means		C1 = {1, 2, 3, 4}, C2 = {5, 6}, C3 = {7, 8}
	Hierarchical		C1 = {1, 2, 3, 11, 12}, C2 = {4, 5, 6, 7, 8, 9, 10}
12	Proposed clustering scheme	Q1 = R2<R1, Q2 = R5 < R3 < R4 < R7 < R6, Q3 = R8 < R10<R9, Q4 = R12 <R11	C1 = {2, 1}, C2 = {5, 3}, C3 = {4, 7}, C4 = {6, 8}, C5 = {10, 9}, C6 = {12, 11}
	K means		C1 = {2, 1}, C2 = {5, 3, 4, 7, 6}, C3 = {8, 10, 9}, C4 = {12, 11}
	Hierarchical		C1 = {2, 3, 11, 12, 1}, C2 = {5, 4, 7, 8, 10, 9}

achievable rates of vehicular users $N = 8$ and $N = 12$ in K_{th} cluster during NOMA transmission as shown in Fig. 7. The simulation parameters are selected in NOMA according to Table 1.

So in this section we overcome this problem by proposed algorithm 1. Firstly, the users are assigned to the cluster according to the position from base station which reduces the SIC receiver complexity. Secondly, the users are assigned in SIC decoding order on the basis of target rates. Those users which require high service



(a) Throughput of Users N=8 (b) Throughput of Users N=12

Fig. 7 Clustering schemes comparison for QNOMA

requirement provide more power comparatively to the other users inside a K_{th} cluster. In Table 2, the system parameters of QNOMA are mentioned where the individual user rate constraints requirements in corresponding cluster SIC decoding order are mentioned. We assume some target rate according to rate constraints mentioned in Table 2 to verify the results of the clustering schemes. The NOMA principle is applied according to this Table 2 and generated the results as shown in Fig. 6.

The proposed user clustering scheme satisfied all the defined rate constraints as shown in Fig. 7, and the result summary for different clustering schemes of N users is satisfied Q constraints are mention in Table 2. When number of users increases to $N = 12$ the k means clustering satisfied some of the Q constraints as shown in Table 2 and Fig. 7. The results of hierarchical user clustering in QNOMA are not satisfied any Q constraints shown in Table 2 and Fig. 7b. We observe that the proposed user clustering scheme satisfied all the defined Q constraints as shown in Table 2 and Fig. 7b. The main reason is the created number of clusters by proposed user clustering scheme is larger than the other clustering schemes. The clustering of only two user on the basis of large channel gain difference is significantly improves the overall sum rate of the network. The graphs shown in Fig. 7a and b indicate that the proposed user clustering scheme follow the target rates requirement more closely as compare to the other user clustering schemes.

6 Conclusion

NOMA is one of the most emerging technologies used in vehicular network due to rapid increase traffic in smart cities the requirement of quality service varies from vehicle to vehicle. The main purpose is to share frequency spectrum among multiple users at the same time. The performance degradation in NOMA occurs when

number of users are increased due to SIC receiver complexity. The main problem in V2I vehicular network is to satisfy the demand of QOS parameters, i.e., data rates requirement for different vehicles. We observe that clustering scheme is very useful to increase the sum rate of the network as compared to without clustering scheme. We proposed algorithm for user clustering and compared with other two unsupervised machine learning algorithms included K means and hierarchical. The proposed algorithm performs more better and improves the sum rate of the network in NOMA. The other direction of our research is to address the quality of service requirements of the user, and we proposed the algorithm for QNOMA and compared with other two clustering schemes. The results indicate that the proposed user clustering algorithm significantly improves the sum rate and also meets the defined QOS requirement of the vehicular users in the network.

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A Techno-Pedagogical Framework for STEM Education Using Disruptive Innovations

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Abstract Research in Science, Technology, Engineering, and Mathematics (STEM) education has demonstrated a relationship between the use of information and communications technology and a better learning for students. Conventional teaching will not be able to meet the needed criteria for motivating and increasing the number of students in STEM related fields. The purpose of this research is to present an overview of a new learning approach using disruptive innovations such as Internet of Things (IoT), 3D printing, E-learning, Robotics, and Artificial Intelligence (AI) focused on children education based on a literature review. The proposed approach highlights the benefits for teachers and learners in kindergarten and formal primary education. This article proposes a review demonstrating positive results of disruptive innovations, using different technologies, focused on the improvement of STEM education. At the end of the work, a techno-pedagogical framework using disruptive innovations is presented.

Keywords STEM · Education · Disruptive innovation · Framework · Techno-pedagogy

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1 Introduction

The origin of the concept STEM can be traced to the 90 s when it was first introduced by the National Science Foundation (NSF) as Science, Mathematics, Engineering, and Technology (SMET) and later changed to STEM in 2001 [1, 2]. STEM in education began at the same time when the NSF included science and mathematics with engineering and technology in undergraduate and K-12 school education. However, in today's literature there is not an agreement on the included disciplines within STEM education and therefore it is difficult to identify what fields constitute STEM [3].

The NSF's list of approved STEM fields encompasses Chemistry, Computer and Information Science and Engineering, Engineering, Geosciences, Life Sciences, Materials Research, Mathematical Sciences, Physics and Astronomy, Psychology, and Social Sciences [4].

Developed countries have highlighted the importance of increasing the number of graduates with STEM skills to promote innovation, generate growth and withstand competition. Even though the progress has rapidly propagated these countries need to perform better [5].

STEM education can be promoted in the early years of children and play can be considered the foundation of STEM experiences during a child's learning process. With a greater understanding of play and its importance in STEM education as well as the intervention of adults as drivers, children will develop a better learning experience. Early years can vary from country to country, and they can be addressed in formal schooling for children aged 5–8 years [6].

Disruptive innovation is a concept coined in 1997 by Christensen [7]. At first the term was known as disruptive technology which referred to inferior technology that improved over time and became the new dominant technology. Later the idea of disruptive technology spread to non-technological variants such as business models and the concept evolved to disruptive innovation. To sum up a disruptive innovation is an innovation process in which products, services or technology are lower in position but attracted by low or new markets with certain advantages such as simplicity, convenience or cost that gradually replaces the mainstream markets [8].

Today some of the most potent disruptive innovations are Internet of Things (IoT), Artificial Intelligence (AI), Robotics, 3D printing, and E-learning. Practices in education will be highly affected by the applications of these disruptions in the field of Information and Communication Technologies. With tremendous growth of disruptive innovations some threats will emerge at the same time. Developments given by new technologies will provide great benefits but also drawbacks that must be considered [9].

2 Literature Review

One of the most common problems while integrating STEM activities into the educational curricula is the lack of a methodological approach that can motivate students. There have been some attempts to identify current trends in STEM education. The current state of integration of some disruptive innovations has also been implemented and there have been some initiatives to improve STEM through specific innovations. Most authors have worked through a systematic literature review to reach their desired results, some others conduct experiments. However, there is not a common framework in which a study on disruptive innovations is considered to engage students by taking key attributes of existing implementations. In the following section a literature review on STEM educations and its methodological approaches, trends, and experiments is given.

The authors in [10] proposed an educational robotics intervention using a programmable robot designed for children. They gathered information through different activities where kids played with the robot through sensory motor activities but did not engage with software programming. At the end of the research, they concluded positive results and a successful computational thinking engagement. Motivational factors were assessed and as consequence task engagement was found as a major characteristic which played a central role in children's attention. To obtain these results, the authors conducted an experiment with children in kindergarten level.

The work in [11] highlights the importance of integrating not only STEM but Science, Technology, Engineering, Arts, and Mathematics (STEAM) competencies into education. They proposed a methodological approach applying robotics and mechatronics. They conducted a literature review. In their conclusions, they mention that the application of robotics is common and in fact increases student's motivation; active methodologies such as project-based learning and challenge-based learning are helpful for STEAM integration; the tendency is for low-cost robots; the integration into education is simple if using active and collaborative methodologies; and teachers needs to be provided with support, because elementary education has its own characteristics.

The paper proposed in [3] also conducted a systematic analysis to find trends in STEM education. The authors stated that there is an upward trend in STEM publications, and these are mostly done in developed countries. They also point out that there is a major interest in teaching and learning in K-12 STEM education.

According to authors in [12], the implementation of STEM including applications such as robotics, game design, and computational modeling is still in an early stage and pedagogical design on enhancing equity was less researched.

Authors in [13] investigated STEM education in K-12 schools, pedagogical practices, and teacher development. They found that the most predominant approaches are project/problem-based learning, challenge-based learning, design thinking, inquiry learning, and games-based learning. However, teachers must be considered as a crucial part of the system and considered as curriculum developers and deliverers of the model.

3 Research Methodology

A systematic review of the scientific literature in the STEM education area was carried out following three stages: planning, conducting the review, and reporting the results as proposed by the authors in [14].

By following this systematic review at the beginning the search was based on personal knowledge to identify the needs such as the current state of the problem, the attributes or characteristics for inclusion and exclusion criteria, and the selection of sources.

To undertake the review the next research questions were proposed:

- What are the current trends in STEM education?
- What are the approaches focused on disruptive innovations for STEM education?
- What results have the authors obtained through the implementation of their proposals?
- Which are the key differences between STEM education models in developed and developing countries?

The systematic search procedure required a hierarchical approach as shown in Fig. 1. It began with a set of keywords containing all important concepts to be used in the search. Answers to the given research questions were proposed and a focus on knowledge was implemented to have a better impact on classification. An iterative approach was conducted and at the end of the search, terms were classified according to importance. The chosen terms were:

- First level criteria: STEM, Education, Children.
- Second level criteria: Computational Thinking, 3D printing, Robotics, IoT, AI, E-learning.

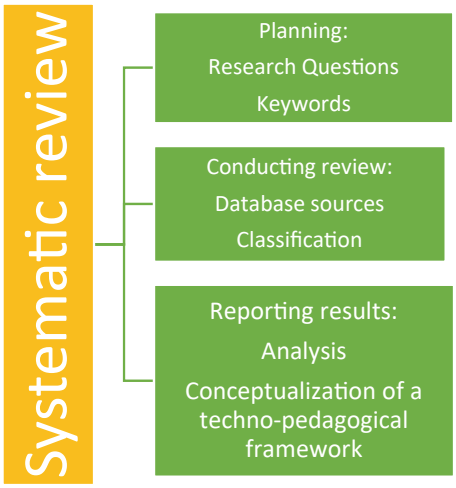

Fig. 1 Hierarchical approach for the systematic review

The sources used in this work were determined by the most popular databases: Google Scholar, IEEE Digital Library, SCOPUS, Springer Link, and Web of Sciences. However, after an iterative approach more databases were added such as MDPI, ACM Digital Library, SCITEPRESS Digital Library among others. There sources are considered reliable and some of them have a high impact factor, conference proceedings were also considered given the context.

This search was done mostly in the English language, which considered the universal language, and in Spanish, which is one of the most widely spoken language in Latin America. All studies considered for this work were published in the last five years. All works were published in prestigious and peer-reviewed journals or conferences. At least one term for each level criteria was considered.

All selected papers were double checked by examining them again. The papers were also classified according to its disruptive innovation in the context of STEM education and results.

4 Analysis of Data and Discussion of Results

The total number of consulted papers for this study is 268 distributed in five major databases. After applying the including and excluding criteria and removing duplicates, the number of results was reduced to 197. The following figure indicates the total number of consulted documents and their databases where they were obtained (Fig. 2).

During the conducting stage, the data found by searching using keywords obtained in the planning was classified by its disruptive innovation. The classification can be seen in Table 1. Papers were selected so that they were not included in more than one disruption. If one of those papers contained more than one disruptive innovation, then the most prominent technology was selected. Only 25 research documents were

Database	Consulted papers
Scopus	53
IEEE Xplore	62
Springer Link	28
Web of Science	24
Google Scholar	69
Others	32

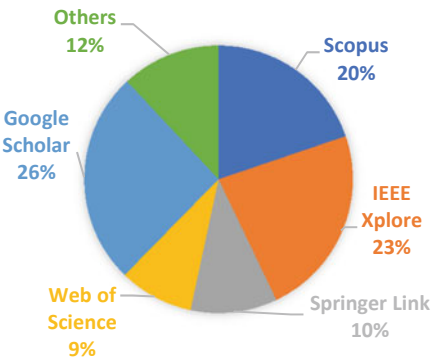

Fig. 2 Databases and consulted documents (total amount and distribution)

selected and divided into groups. When analyzing its content, it was possible to extract theoretical information and practical implementations in different scenarios.

There is no universal method for implementing disruptive innovations, but according to our results it is possible to follow a pattern by identifying key attributes of STEM education. It is important to run a pilot test and extend it with learned lessons. The commitment of teachers is essential, and the desired results can be shortened. As found in the literature review, first it is important to identify the characteristics in which children can be engaged and motivated. An active pedagogical approach is also necessary as can be seen in Table 2.

In the obtained results it was clear to note that authors make use of different technological innovations to handle STEM education. They also apply different tools, schemes, and methodologies. Nevertheless, they have agreed on engage students though active methodologies.

Each disruptive innovation provides a different approach. Robotics by itself is not a good indicator of learning, it needs to be accompanied not only with hardware but software. Artificial Intelligence was mostly used for verification or assessment of good practices, but it was not limited to that. Internet of Things allowed remote collaboration and storing of information. 3D printing showed positive results only if a makerspace was accessible. Some other disruptive innovations can be used but this work is limited to the ones that were studied in the revision of the literature.

Table 1 Disruptive innovations classified by topic

Disruptive innovation	References	Implementation
Robotics	[15–19]	Literature review, conducted experiment, workshop
3D printing	[20–25]	Conducted experiment, summer camp
Artificial Intelligence	[26–30]	Literature review, conducted experiment
Internet of Things	[31–35]	Case study, conducted experiment, literature review
E-learning	[36–39]	Case study, conducted experiment, camp

Table 2 Pedagogical approaches obtained from the review of the literature

Pedagogical approach
Project-based learning (PBL)
Challenge-based learning (CBL)
Problem-based learning (PrBL)
Play/Game-based learning (GBL)
Design thinking (DT) Inquiry-based learning (IBL)

5 Techno-Pedagogical Framework

In the discussion on STEM integration using disruptive innovations, the concept of a techno-pedagogical approach takes shape. Students and teachers need to work together to improve the system structure and the approach needs to be adaptable as the educational context or scenario changes. The conceptualization of this approach was obtained by an extensive literature review and the results obtained through observations and practices.

The approach must capture the students' attention but at the same time teachers must collaborate or interact with the system somehow to integrate activities and create an interactive pedagogical framework based on active methodologies and disruptive innovations.

Cross-disciplinary tasks involving Science, Technology, Engineering, and Mathematics can be expanded by implementing Information and Communication Technologies.

In Fig. 3 the proposed techno-pedagogical framework is shown. The proposed framework consists of a three-layered philosophy. Each layer focuses on fundamental concepts which in conjunction let enhance and amplify learning. On the external layer, the selection of a STEM related topic guarantees the uptake of the framework. The disruptive innovation selection introduces the technological approach, and the pedagogical methodology addresses the support and process for a better learning. The core values develop interest among student and serve as a pillar of commitment. It is important to mention that tools and equipment given the techno-pedagogical status are required when setting STEM education as a priority.

On the middle layer, the core values and the pedagogical methodology enables a deeper understanding of the framework. Assessment for the topic needs to be set up to measure the impact of the disruptive innovation and the obtained knowledge of the student in the STEM field. Preparation of a learning environment is also an important part of the process because according to the technological approach, there may be different tools and equipment to use. In this level is where the teacher serves as guidance and gives feedback.

On the inner layer, we have a student-centered learning which lets collaboration, creativity, and experience on STEM related fields. It has been proved that disruptive innovation increases the motivation of the student if supported by information and communication technologies.

6 Future Work and Conclusions

This work has demonstrated the importance of a techno-pedagogical framework to motivate student into STEM related fields. The framework focuses on disruptive innovations and pedagogical methodologies obtained by a review of the literature on STEM education.

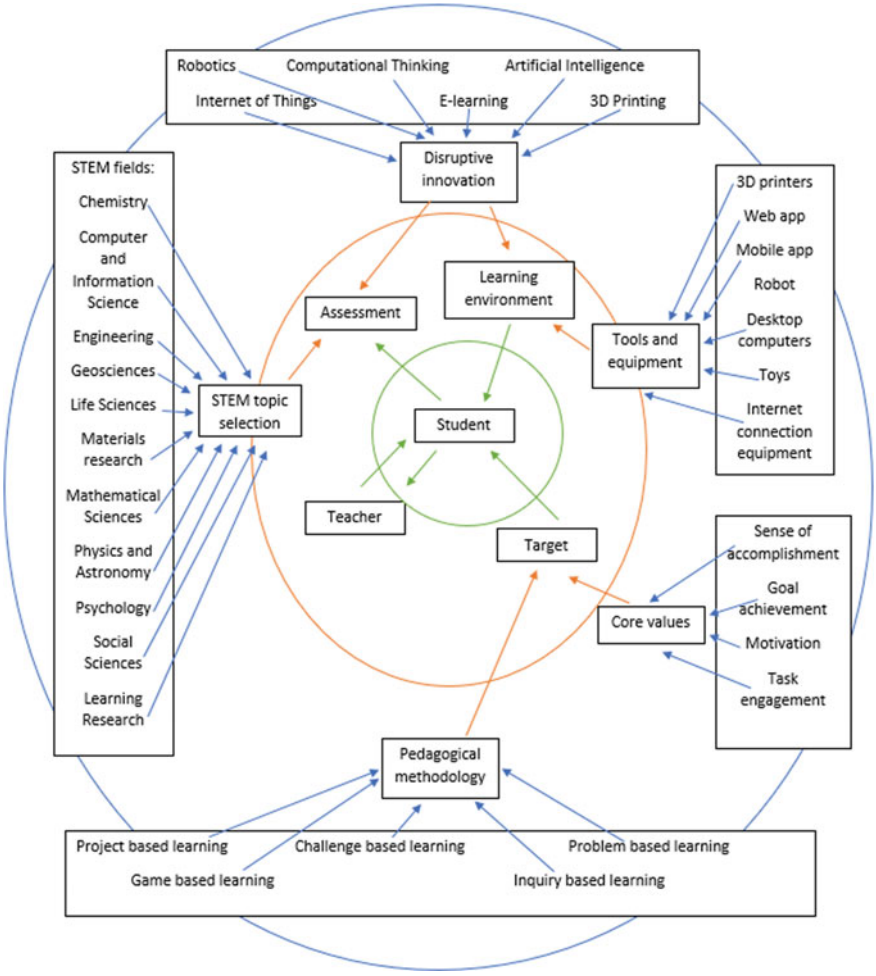

Fig. 3 Techno-pedagogical framework

STEM education consists of different technologies, methodologies, and tools in different environments. However, all approaches follow a pattern in which conventional teaching and learning are not present anymore.

The proposed framework based on the literature review is somehow limited because most of the consulted document did not consider a technique for calculating a sample size, and therefore the study can be improved. In a future work, the framework can be validated by implementing a conducted experiment in a practical situation among a group of children.

Even though the work focused on children, it could be extended for a broader coverage of age. STEM education is still struggling with integration into educational environments. It is important to engage student in these disciplines and that is why the

present paper has aimed to provide a basis for teachers and facilitate the development of disruptive innovations on education.

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Comprehensive Performance Evaluation of Mobile Networks in Macao Based on Field Test Data

Yide Yu, Yue Liu, Dennis Wong, and Su-Kit Tang

Abstract In this paper, we evaluate the 4G mobile network performance of network carriers in Macao by conducting three types of experiments: drive test, speed test, and application test, collecting field test data. The data is categorized into the objective network performance metrics such as RSRQ, CINR, RSSI, and RSRP, and the subjective metrics such as video freezing time and the perceived delay when using several popular applications. Based on the data, we conducted an evaluation. The result showed that good objective metrics may not necessarily generate good subjective metrics for the overall user experience on mobile applications, if the network coverage is not ideal. In this paper, we introduced max-min average normalization to subjective metrics such that the quantification of multi-type data becomes realistic.

Keywords Performance evaluation · Mobile network · Max-min average normalization · Network coverage

1 Introduction

With the advent of 5G, mobile operators aim to offer the best quality of experience (QoE) to their subscribers. However, due to the enhancing functionality of software and expanding computational abilities of hardware, a huge amount of mobile applications [1–5] can be supported on mobile devices. Even though the next generation IP network is hot in researching [6–9], the research direction tends to shift to mobile

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networking. One of the challenges is thus to evaluate the user's experience of the network from the perspectives of both the network carriers and the subscribers. In this paper, we comprehensively evaluate the user experience of 4G mobile network services of all network carriers in Macao by conducting three types of experiments: drive test, application test, and speed test to better evaluate and represent the subjective user experience. We designed an indicator based on the max-min average normalization to measure the overall subjective user experience.

Our motivation is to evaluate the network performance from the user experience on mobile application based on subjective and objective metrics. In reality, the network is subject to influence from the natural environment, and there are many random factors that make it impossible to judge network performance directly from objective data alone. In this paper, by combining the data from both sides, we go to a comprehensive judgment network which is a reasonable way. In this paper, related work is given in Sect. 2. As subjective metrics determines the user experience after min-max average normalization (described in Sect. 3), three types of experiments are conducted in Sect. 4. The results of the experiments are then discussed based on the field test data collected in Sect. 5. Finally, conclusions are drawn in Sect. 6.

2 Related Work

We investigated the methods of user evaluation metrics and the metrics of network performance separately. User evaluation is generally subjective, and each individual usually has their own criteria, while network performance metrics are generally objective and are monitored by devices.

User Evaluation Metrics There are some methods to measure user evaluation metrics by the survey and questionnaires.[10] (Net promoter score, NPS) introduces net promoter score for measuring the IT support satisfaction, [11] introduced the theory of CES (customer effort score, CES), [12] (customer satisfaction, CSAT) introduces the story about CSAT.

Reduced Dimension Because there are too many communication metrics, if we want to judge the network in a comprehensive way, we need to use the dimension reduction techniques. There are many dimension reduction options to choose from, such as [13] (principal components analysis, PCA), [14] (singular value decomposition, SVD), [15] (linear regression), and [16] (normalization).

Network Performance Indicators To evaluate the mobile network performance, some objective indicators as below are commonly used. RSRQ [17] (Reference Signal Receiving Quality) indicates the the reference signal receiving quality. It is a metric used to rank the signal quality. This measurement can be used for cell switching and cell selection decisions. CINR [17] (or SNR or SINR) provides information on how strong the desired signal is compared to the interference (or noise or interference plus noise). The following is an interval representation of CINR throughput. Received

signal strength indication (RSSI) [17] is an optional part of the wireless transmission layer that is used to determine the quality of the link. Reference signal receiving power (RSRP) [17] is one of the key parameters that can represent the wireless signal strength in LTE networks and one of the physical layer measurement requirements. It is the average of the received signal power over all resource elements (REs) that carry the reference signal in a given symbol.

There are also some other metrics to objectively measure network performance, see [18] for various measurements for network performance evaluation.

However, obtaining satisfactory values in these measurements does not always translate into a good performance evaluation. For example, a fast general upload and download speed of a network might not translate into a good performance evaluation of a popular application, as the network operator might have difficulty to maintain a fast connection with the servers of the application. Such a bad connection might badly affect the general performance evaluation if it is a popular application that users use most of their time, even though the network obtains excellent measurements for network performance evaluation in general. The goal of this paper is thus to develop metrics to measure the performance evaluation of the network objectively and subjectively.

3 Max-Min Average Normalization

The performance evaluation metrics are derived from their usage experience of various applications. We select the most popular application used in Macao out of five types of applications, namely YouTube, Facebook, TikTok, WeChat, and AoV. We design the testing items of each type of the applications, respectively, to simulate users' behaviors of usage. Due to the inconsistency of data units recorded for different applications, we designed a statistical formula to normalize the mean value for analysis in order to make an objective quantitative comparison, and the calculation formula of the indicators used in the statistical analysis is as expressed in Eq. (1).

$$y = \frac{\sum_{i=1}^{n} \frac{x_i - \min(x_1, x_2, \cdots, x_m)}{\max(x_1, x_2, \cdots, x_m) - x_i}}{n} \tag{1}$$

where y is the result of normalized summation, x is the value of one indicator of an application, and n is the number of all indicators of an application.

4 Experiment Design

Mobile Carrier We choose the four operators in Macao as the experimental subjects, which we denote by Carrier A, Carrier B, Carrier C, and Carrier D, respectively. They all have the capability to provide performance evaluation network services to its own subscribers.

Fig. 1 Macao Map. Macao is composed of four parts: Macao, Taipa, Cotai, and Coloane

Fig. 2 Drive test path information

Sampling The data we collected can be divided into two main categories: network performance data and performance evaluation data. Since locations of the base stations of operators are confidential so highly concealed, the data collection is based on the general accessibility of pedestrians and vehicles with normal mobile devices and standardized frequency scanner (Fig. 1).

Drive Test The driving route covers the 10 main roads in Macao (see Fig. 2). The data types are the operator unique identifier, the real-time terminal location, the time, the frequency band, the connected base station unique identifier, RSRP, RSRQ, CINR, RSSI, uplink(UL)/downlink(DL) throughput of multi-operators. The equipment used are the IBflex frequency scanner, mobile phones, the TEMS software, and the Huawei PHU software.

App Test The test is conducted in 4 locations throughout Macao, including Kiang Wu Hospital, Sino Plaza, Macao Polytechnic University, and Starwood Plaza. The applications tested are Youtube, Wechat, Facebook, Tiktok, and AoV. The types of data collected are performance evaluation related indicators (see Table 4). The devices used are mobile phones of the same brand and the same model, and SIM cards of different carriers.

Speed Test We selected 22 locations in Macao to perform the speed test, including Kiang Wu Hospital and Macao Polytechnic University. The data types include the real-time terminal location, real-time time, and UL and DL throughput (see Table 4). The devices used are mobile phones of the same brand and the same model, SIM cards of different carriers and Ookla Speedtest software.

Table 1 RSRQ descriptive statistics

Indicator	Statistical items	Carrier A	Carrier B	Carrier C	Carrier D
RSRQ	Maximum	−3.00	−3.00	−3.00	−3.00
	Minimum	−40.00	−40.00	−40.00	−40.00
	Mean	−10.69	−11.57	−10.22	−9.525
	Median	−10	−10.9	−10	−8.9
	Upper quartile	−12.2	−13.4	−11.8	−10.8
	Lower quartile	−8.3	−8.8	−8.1	−7.6
	Variance	13.2436	14.6819	9.30984	7.42045
CINR	Maximum	40.00	40.00	40.00	40.00
	Minimum	−30.00	−30.00	−30.00	−25.90
	Mean	8.525	5.556	7.908	8.922
	Median	7.7	4.7	6.8	8.5
	Upper quartile	2.7	0.2	2.4	4
	Lower quartile	13.9	10.2	12.6	13.5
	Variance	81.711	67.117	64.9307	53.7435
RSSI	Maximum	−16.3	−14.6	−16.6	−23.5
	Minimum	−105.3	−103.2	−89.8	−93.4
	Mean	−54.28	−50.74	−50.99	−57.97
	Median	−54	−50	−50.7	−57.5
	Upper quartile	−60.5	−55.9	−55.9	−63.2
	Lower quartile	−47.2	−44.5	−45.4	−52
	Variance	121.969	97.1761	75.6739	79.5698
RSRP	Maximum	−31.8	−29.4	−32	−37.9
	Minimum	−130	−130	−123.4	−111.7
	Mean	−72.76	−70.09	−69	−75.28
	Median	−72.4	−69.4	−68.8	−74.7
	Upper quartile	−79.6	−76.3	−74.6	−81.7
	Lower quartile	−65.1	−62.9	−62.7	−68.6
	Variance	145.111	124.51	92.1375	94.0807

Fig. 3 Heatmap of four carriers. Traverse all points of the drive test. If the four indicators of a point RSRQ, CINR, RSSI, and RSRP are excellent, the point is drawn on the map by latitude and longitude. Left to right are Carrier A, B, C, and D

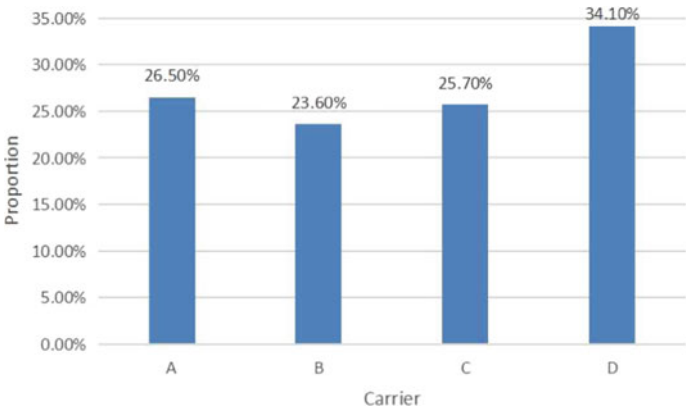

Fig. 4 Comparison of the upload and download speeds of the four carriers speed test

Table 2 DL and UL throughput of four carriers in Macao peninsula and Taipa

Area	Carrier	Download	Upload
Macao	A	182.6487	38.86458
Taipa	A	117.14	31.95583
Macao	B	43.66375	27.49542
Taipa	B	38.37883	22.06483
Macao	C	18.65593	13.28509
Taipa	C	19.36933	13.44633
Macao	D	10.74227	4.128056
Taipa	D	13.48617	4.389667

5 Result

5.1 Descriptive Statistics

As shown in Table 1, a small range from best to worst performance in all the four indicators. Carrier A has a small ratio of best to worst performance overall. Carrier B has the worst performance in RSRQ, CINR, and RSSI, and an intermediate performance in RSRP. Carrier C has a better performance overall with no worst case. Carrier D has the best performance in RSRQ, CINR, and RSSI, but a worse performance in RSRP. The performance of Carrier D is the best in RSRQ, CINR, and RSSI, but worse in RSRP.

Communication Performance We plotted the terminal locations with all-excellent indicators for the four operators on the map of Macao. As illustrated in Fig. 4, we found that the percentage of signals with all-excellent is the highest for Carrier D, followed by Carrier A, Carrier C, and Carrier B. Since the performance evaluation mobile network is designed and configured to cover the whole area of Macao, the distribution of signal strength and upstream and downstream rates in the whole area is relatively important. Figure 3 shows the distribution of operators with all-excellent performance indicators on the main streets in Macao. The same situation can be seen in Carrier C, where the distribution of hot spots is sparse. Carrier B has the least number of good indicators, but the distribution is even, and the coverage is

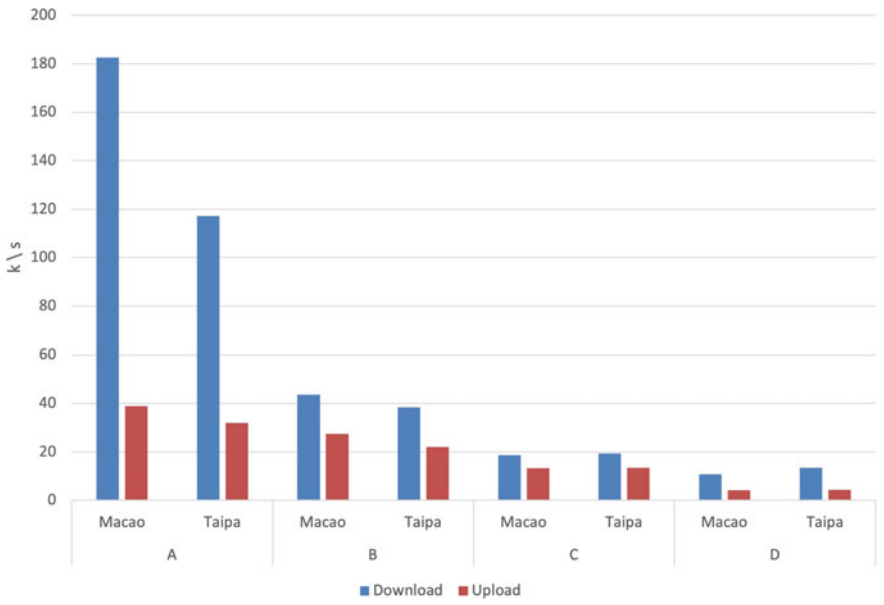

Fig. 5 Proportion of data with all indicators (RSRQ, CINR, RSSI, and RSRP) being **Excellent** to the total data

ideal. Finally, Carrier A, which ranks second in Fig. 4, has an average distribution of excellent indicators and excellent coverage. We assume that if the four indicators are all within the excellent tier (all-excellent), the service that user receives is excellent, so carrier A has the best overall performance.

Speed Test Result We divided Macao into two administrative regions: Macao peninsula and Taipa. We then conducted speed tests for each carrier to obtain the average upload and download speed in these regions (see Table 2). Figure 5 provides a simple comparison between the speeds of each carrier.

In Fig. 5, the upload and download throughput measured for Macao peninsula and Taipa are: Carrier A is the fastest, Carrier D is the slowest, and the rest two carriers are medium, and their download speed is much lower than that of Carrier A.

Performance Evaluation Using (1) to process all the data types recorded for 22 location (see Table 4), we got the application performance indicator for each carrier. The comparison between the indicators of all carriers on different applications is as shown in Fig. 6, and the exact values can be seen in Table 3. Since we have turned all

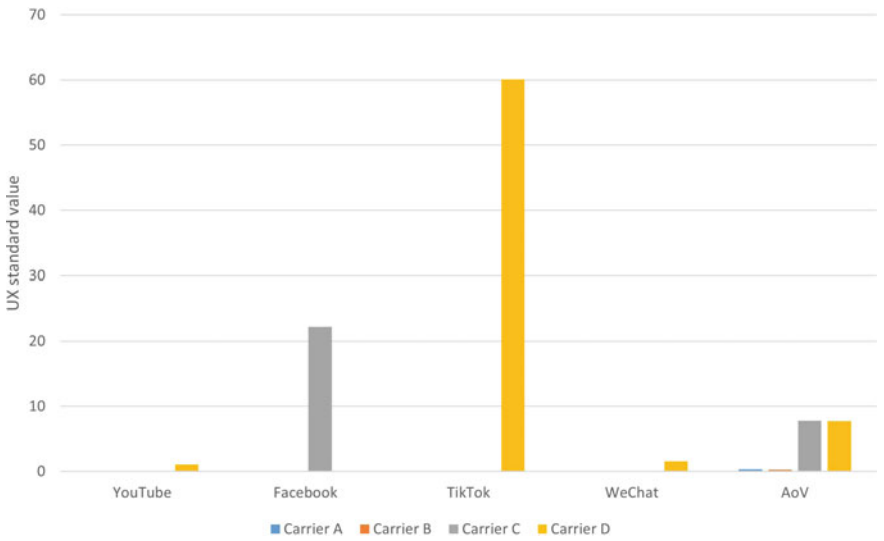

Fig. 6 Four carriers in application latency measurement index.

Table 3 Four carriers in application latency measurement index

Carrier	YouTube	Facebook	TikTok	WeChat	AoV
A	0.064556	0.01423	0.0197	0.02269703	0.359992
B	0.122226	0.023695	0.02476	0.02619552	0.302002
C	0.12431	22.23855	0.050463	0.0350426	7.780571
D	1.057815	0.041002	60.05665	1.54823704	7.729966

Table 4 App test item

App	Test item
YouTube	Whether to start video jams/spin length
	Check preset pixels (360/480/720/1080)P
	The number of times to play a 1-minute jam
	Whether to start the video when the lag/spin time (s)
	The number of times 1080P video lags of fast forward
	1080P video skipping play length of jams (s)
	The length of the fast forward of 1080P video jams (s)
	The length of the fast forward of 1080P video jams
Facebook	Sliding screen (20 video clips) jams/loads
	Quick browse (fast forward) length of jam (s)
	Quick browse (fast forward) length of jam
	Fast playback lag time
	Time to upload a 30-second clip (almost done) (s)
	Time to upload a 30-second clip (almost done)
	Time to upload a 30-second clip (Bar) (s)
	Time to upload a 30-second clip (Bar)
TikTok	Download about 30 s video length (s)
	Download about 30 s video length
	Upload 60 s video duration (s)
	Upload 60 s video duration
WeChat	Video message (30 s clip) (s)
	Take a look The number of times a pause occurs (sliding screen of 20 videos)
	Video message (30 s clip)
	Take a look + number of jams (slide 20 videos)
	Picture message (album backup picture)
	Picture message (photo album backup picture) (s)
	Voice call (smooth/lag)
	Image(smooth/lag)
	Voice(smooth/lag)
	Text message
	Voice message (about 10 s)
	Friend circle (20 pictures Post), unsuccessful uploads
	Text message (s)
	Voice message (about 10 s) (s)
	Number of times the video number is stuck (20 videos on the slide screen)
AoV	Number of delays/jams while playing
	Ping minimum during game play
	Ping maximum during game play

the indicators value into a fixed-order variable in the inverse order, all the indicators are as small as possible.

As shown in Table 3, Carrier A performed best on YouTube, Facebook, TikTok and AoV, and rank second in WeChat. It is considered the best operators in terms of subjetive user experience. Carrier B performed better in all categories, while Carrier C and D performed worse in general.

Because Carrier A has an even distribution of all excellent points on the map and the best performance in download and upload speed, these objective indicators demonstrate Carrier A which has the ability to provide the best communication services. Carrier A is the number one performer in four of the five most popular applications we surveyed. Therefore, with all things considered, Carrier A can provide the best performance evaluation service to users.

6 Conclusion

We have studied the field test data, collected from four mobile network operators in Macao. We also present the cumbersome subjective indicators in a concise manner, providing visual graphs and tables with an intuitive introduction. Even though the four indicator suggested that Carrier A is not doing the best, based on the high-speed uplink and downlink over ideal network coverage in Macao, Carrier A outperforms other carriers in terms of performance evaluation.

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Simulation-Based Testing of Foreseeable Misuse by the Driver Applicable for Highly Automated Driving

Milin Patel, Rolf Jung, and Yasin Cakir

Abstract With highly automated driving (HAD), the driver can engage in non-driving-related tasks. In the event of a system failure, the driver is expected to reasonably regain control of the automated vehicle (AV). Incorrect system understanding may provoke misuse by the driver and can lead to vehicle-level hazards. ISO 21448, referred to as the standard for safety of the intended functionality (SOTIF), defines misuse as usage of the system by the driver in a way not intended by the system's manufacturer. Foreseeable misuse (FM) implies anticipated system misuse based on the best knowledge about the system's design and the driver's behavior. This is the underlying motivation to propose simulation-based testing of FM. The vital challenge is to perform a simulation-based testing for a SOTIF-related misuse scenario. Transverse guidance assist system (TGAS) is modeled for HAD. In the context of this publication, TGAS is referred to as the "system", and the driver is the human operator of the system. This publication focuses on implementing the driver-vehicle interface (DVI) that permits the interactions between the driver and the system. The implementation and testing of a derived misuse scenario using the driving simulator ensure reasonable usage of the system by supporting the driver with unambiguous information on system functions and states so that the driver can conveniently perceive, comprehend, and act upon the information.

Keywords DSI · DVI · HAD · FM · SOTIF

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1 Introduction

In HAD, longitudinal and lateral vehicle guidance is controlled by the system. However, when the system reaches its operational limits, the human driver (HD), referred to as a fallback-ready user in SAE J3016 taxonomy [1], is expected to regain driving control within a reasonable amount of time. Whenever the system is not capable of handling a situation within its operational design domain (ODD), a take-over request (TOR) is issued by the system as a notification indicating that the HD should promptly perform the driving tasks.

Transition in automated driving (AD) is the process and period of transferring responsibility and driving control over some or all aspects of the driving tasks between HD and the system. Transition can be either activation or deactivation of a function or a change from one driving state to another as per [2]. According to the SAE J3016 taxonomy [1], the driver has no active role or driving responsibilities when the system is operating within its ODD. Engagement in non-driving-related task keeps the driver out of the loop, which leads to misuse when returning to manual driving (MD) in take-over situations [3].

To ensure smooth transition from AD to MD, the TOR must be presented through a well-designed interface. Therefore, the implications of driver-vehicle interface (DVI) design on the interactions between driver and the system, abbreviated as driver-system interactions (DSI), must be studied, so the driver can regain control over HAD while deterring misuse. Figure 1 depicts a pictorial representation of the incorporation of the driver in terms of interactions with the system and interface with the automated vehicle (AV). One of the key subjects in the SOTIF standard is FM, which is substantial consideration for human factors engineering [4]. It should be noted that this publication focuses on FM by the driver, and as part of the testing, human factors during transition in HAD are taken into consideration, not the other way around.

The factors for FM considered in this publication are driver's recognition judgment. Simultaneously, false recognition misjudgment, by the driver, are causes for FM. The aforementioned factors and causes addressed in this publication are referred to as human misuse process and guidewords, in the informative annex B of ISO 21448 [5]. The false recognition is analogous to the perceptual errors, where the driver's perception of the environment differs from reality. The misjudgment is akin to the decision errors, in which the driver decides on an incorrect action for the given situation [6].

This publication is structured as follows. Section 2 refers to description of a SOTIF-related misuse scenario. Section 3 outlines the strategy for implementing simulation-based testing of FM. Section 4 addresses the implementation using driving simulator and elaborates on results. Finally, Sect. 5 presents concluding remarks.

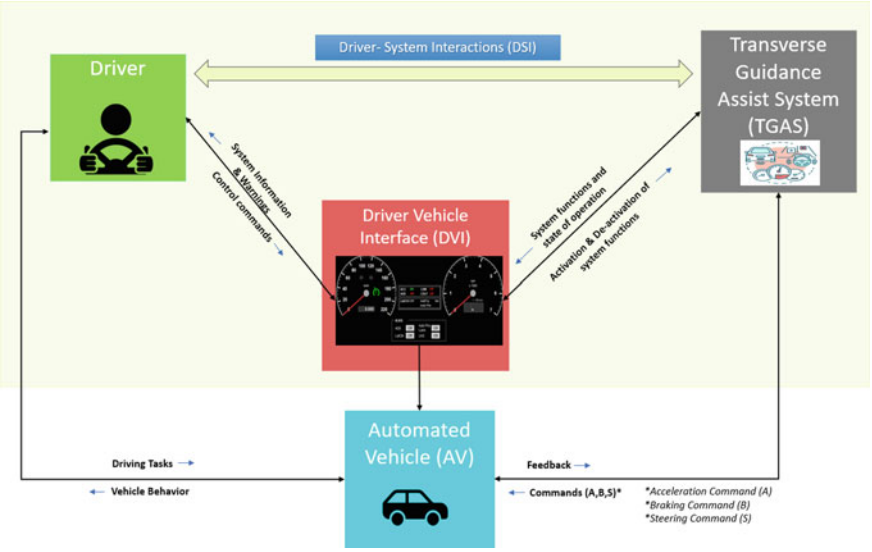


Fig. 1 Incorporation of the driver with the system and AV: interactions and the interface

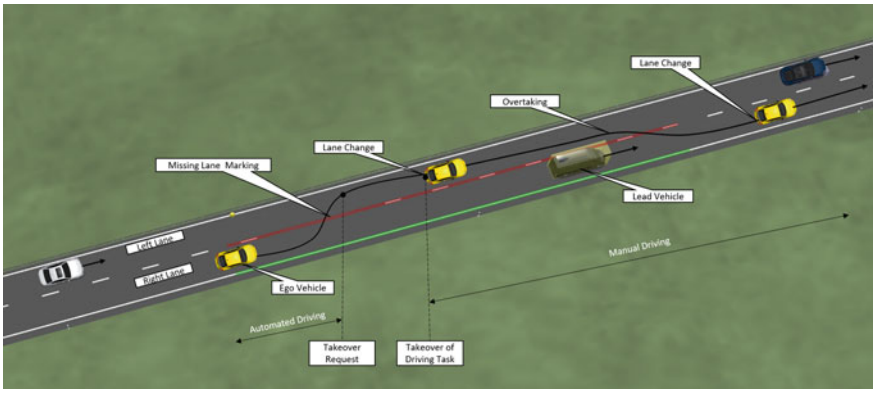


Fig. 2 Highway lane change scenario

2 SOTIF-Related Misuse Scenario

SOTIF-related misuse scenario can be derived from gained knowledge and brainstorming [5]. The methodology for systematically deriving SOTIF-related misuse scenario to support the safety analysis for the system is provided in the ISO 21448 [5]. The scenario shown in Fig. 2 is derived to expose the driver to a situation requiring transverse guidance that is formed by lateral and longitudinal maneuvering of the ego vehicle in a high-speed highway environment. Ego vehicle in the context of

Table 1 Description of SOTIF-related misuse scenario

Stakeholder	Foreseeable misuse (FM)		Driver system interactions (DSI)
	Factors	Causes	
Driver	Recognition	False recognition	Delayed take-over
	Judgment	Misjudgment	Take-over & perform under-steer
Environmental conditions	Potential SOTIF-related misuse scenario	Derived hazardous misuse scenario	
– Weather: clear – Light condition: daylight – Traffic condition: light traffic – Roadway surface and features: missing lane markings	The ego vehicle encounters a road with missing lane markings during automated driving on a two lane one-way highway and executing lane change maneuver from right to left lane. The camera sensor cannot estimate the location of the lane boundary due to a performance insufficiency. Ego vehicle starts to leave the lane and driver is notified to take control of the driving tasks by means of TOR	Driver fails to take over the control of the driving tasks, resulting in lane departure of ego vehicle	

this publication is defined as the AV equipped with TGAS. The entire scenario is divided into three maneuvers:

- Lane change from right to left lane
- Overtaking of lead vehicle from left lane
- Lane change from left to right lane.

Table 1 outlines the derived SOTIF-related misuse scenario considered in this publication conforming to an example methodology given in annex B of ISO 21448 [5].

The DSI that influence the vehicle-level hazard related to FM, namely lane departure, are considered for deriving a SOTIF-related misuse scenario. Take-over is defined as transfer of the driving control between human driver (HD) and the system [7]. Under-steer means the driver fails to provide adequate steering input for the ego vehicle to follow the lane.

3 Simulation-Based Testing

The strategy depicted in Fig. 3 describes the steps in methodical order to perform simulation-based testing of the SOTIF-related misuse scenario described in Table 1. The scenario and maneuvers are modeled using IPG CarMaker, as per the description given in Sect. 2. The TGAS performs AD of the ego vehicle by providing lateral and longitudinal control in the modeled scenario. When the system reaches its operational limits, it notifies the driver by issuing TOR. Driver take-over at operational limits and the corresponding TOR are not obligatory in HAD [8]. The system is expected to remain operational until the driver is able to regain control [6].

The driver might not be able to take over driving control within a specified take-over time and FM is expected, attributing false competencies to the system. It may lead to lane departure of the vehicle, addressed as a vehicle-level hazard. If the driver does not take over the driving tasks in the event of TOR, the system will transition to the AD with reduced functionality. Subsequently, a minimal risk maneuver (MRM) [9] is performed by the system to keep the ego vehicle in its lane and to automatically stop the ego vehicle on the side of the road in a safe manner [10]. The driver may be asked to take over at the end of the MRM.

4 Implementation and Results

The simulation-based testing is carried out using a driving simulator as illustrated in Fig. 4 allowing driver to control the ego vehicle in the virtual test environment.

The driving simulator is equipped with the hardware tools (Logitech G29—steering wheel, pedals, and gearbox) integrated with a simulation tool (IPG CarMaker). Likelihood that the driver can cope with the driving situation including operational limits and system failures is determined using the driving simulator. The driver-vehicle interface (DVI) as illustrated in Fig. 5 is designed to incorporate the interactions between driver and the system. The DVI design is in concordant with the design guidance provided in [11].

Based on literature study pertaining to the design of automated take-over requests in HAD from diverse aspects such as procedure [12], timing [13], and modality [14], the TOR is cued by a combination of an auditory alert and visual notification on the designed DVI. The HD does the take-over of driving control by pushing a button on the steering wheel of driving simulator. It is conceivable that the HD might engage in FM, especially if the HD is convinced that the HAD operates practically flawless [15] and will prevent vehicle-level hazard in the driving environment by choosing safe driving maneuvers [16].

A limitation of the current implementation is the usage of a static driving simulator, where haptic motion cannot be experienced. However, the implemented DVI make it easier to keep the driver's workload at an acceptable level by providing simultaneous auditory alert and visual notification to the driver with supporting information about the system functions and state of operation.

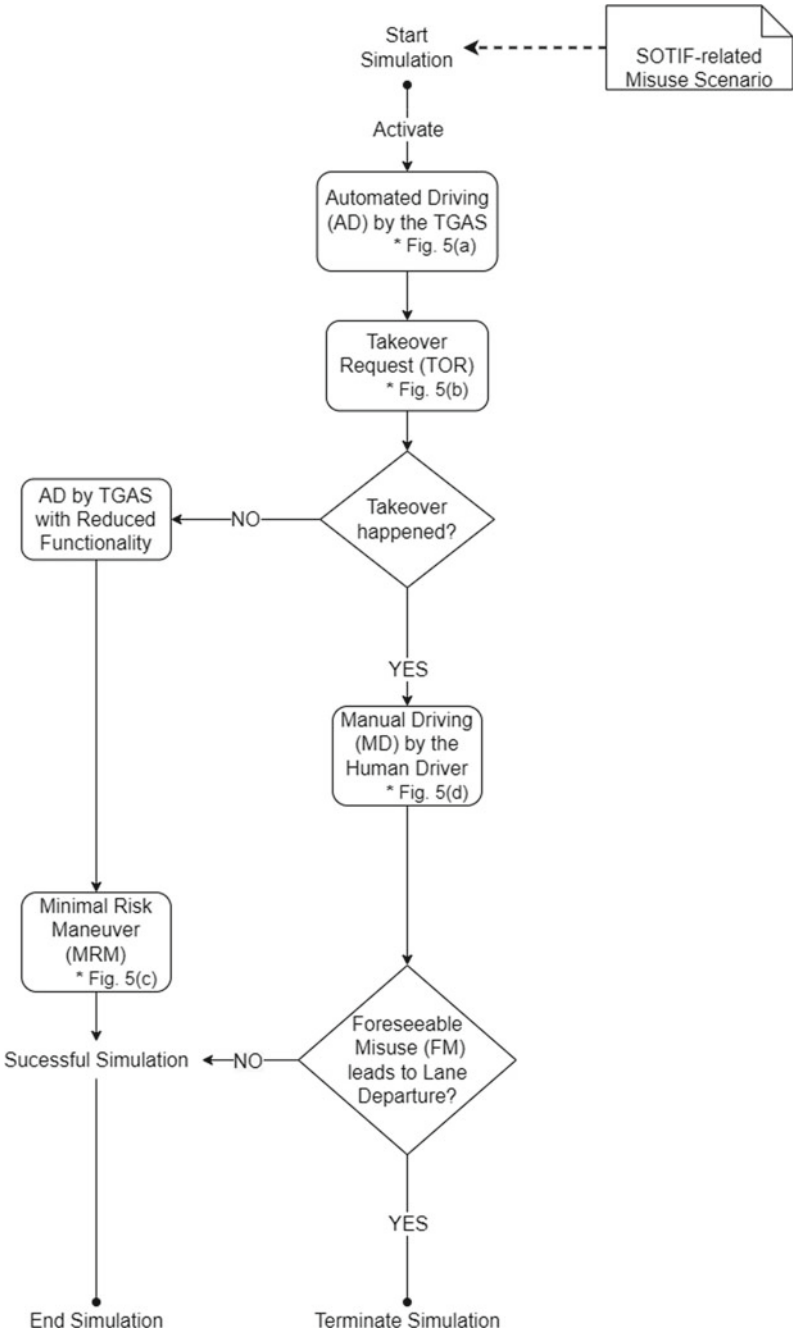
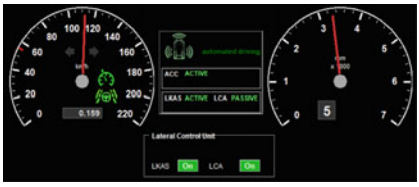


Fig. 3 Simulation-based testing

Fig. 4 Driving simulator



(a) Automated Driving (AD)

(b) Take-Over Request (TOR)

(c) Minimal Risk Maneuver (MRM)

(d) Manual Driving (MD)

Fig. 5 Implementation of driver-vehicle interface (DVI)

5 Conclusion and Future Work

When driving with highly automated driving (HAD), the human driver (HD) is allowed to engage in non-driving-related tasks. It is reasonable to anticipate higher likelihood of the system misuse [17]. The publication outlines the concept of foreseeable misuse (FM) emphasized in SOTIF standard [5] for a described SOTIF-related misuse scenario, illustrated in Sect. 2, applicable to HAD. An exemplary of the strategy defined for implementing simulation-based testing of FM resulting from

system-initiated transition between HD and the system is demonstrated in Sect. 3. It should be noted that the implementation shown in Sect. 4 is intended to demonstrate an approach for simulation-based testing of FM rather than to be a distinctive or optimal measure dedicated to mitigate FM. The relevance of this publication is that it adds to the understanding of the factors and causes contributing to FM by incorporating the concepts of DVI DSI and applies it to a SOTIF-related misuse scenario.

The fundamental premise is to incorporate and manage all driver and system interactions. The simulation-based testing approach is applied to investigate the factors and mitigate the causes responsible for FM by the driver. The incorporation of DSI and DVI to address FM is briefly described but has not been evaluated. A reasonable next step for future work will be to characterize and quantify the DSI, considering aspects of HD take-over in HAD. Analyzing the system specification for inappropriate interactions by the driver is a brainstorming task. One of the possible approaches for analysis is system-theoretic process analysis (STPA) which aims to identify the hazardous interactions in the absence of system failures [18]. Identification of factors contributing FM by STPA and effectiveness of the mitigation measures to prevent FM for the described SOTIF-related misuse scenario are suggested for future work. The implication of the proposed method is to exhibit how the concepts of DVI and DSI are interrelated with FM. Recommendations can be made on how, DVI design, TOR presentation modalities and driver improper interactions with system can be adopted to address the challenges of risks that could impact functionality of HAD.

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Natural Language Processing for Corporate Culture Assessment: Lessons Learned for Building a Strong Employee Value Proposition with GPTW Switzerland AG

Guang Lu, Timo Heroth, Cédric Lüthi, and Patrick Mollet

Abstract Demographic change is exacerbating the shortage of skilled workers in the global labor market. Companies have difficulties recruiting and retaining employees in future. Therefore, developing a strong employee value proposition (EVP) and, above all, a good corporate culture is crucial to attract potential employees. However, existing methods for creating and evaluating the EVP are manual and time-consuming. They require a thorough understanding of the company culture and can cost a professional consultant a lot of time to analyze the different cultural elements and values contained in various internal text documents. In this study, we aim to explore the feasibility of using natural language processing (NLP) for partially automated assessment of corporate culture. Together with our business partner GPTW Switzerland AG, we collected responses from over 50 companies to the EVP questionnaire *Culture Audit* and applied text embedding and topic modeling-based NLP techniques to assess corporate culture. The analytical framework contributes to a sound understanding of how cultural topics, and keywords are used and distributed in companies' *Culture Audit* responses. Our findings also highlight the current limitations and potential opportunities for NLP methods to complement the work of consultants in assessing organizational culture, particularly by harnessing the explanatory power of machine learning. Overall, this study could lead to a more synergistic and efficient use of data to provide organizations and their employees with a consistent, transparent, and monitorable employer brand.

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Keywords Employee value proposition (EVP) · Corporate culture · Natural language processing (NLP) · Text embedding · Topic modeling · Explainable machine learning

1 Introduction

The employee value proposition (EVP) balances employee satisfaction and performance in the work culture [1]. It can be used by employers as an effective recruitment and retention tool. This is particularly important in today's competitive labor market, including in the context of demographic changes that may exacerbate skills shortages. So far, most EVPs have been developed through a top-down approach led by management, HR or marketing representatives, while some recent studies have also considered the employee perspective [2]. Existing approaches suffer from a small data sample, potential bias from focus groups, and predefined dimensions for quantitative inventories [3]. In addition, a model-based EVP framework often results in similar EVPs between competitors, especially when surveys are based on closely related dimensions [4]. Regardless of these shortcomings in producing EVPs, traditional approaches to evaluating EVPs by analyzing open survey comments and qualitative audits are also ineffective. They depend on the experience of consultants and manual and time-consuming analysis. Therefore, this study aims to explore the feasibility of using natural language processing (NLP) to partially automate EVP assessment in order to provide additional and supportive insights in the assessment of corporate culture. NLP is a branch of linguistics, computer science, and artificial intelligence. We use NLP to gain the ability to "understand" the content of documents, including the contextual nuances of the language they contain. The technology helps extract the information and insights contained in the documents.

Automated analysis of text data to characterize EVP is in its infancy. In the last three years, many powerful pre-trained language models such as BERT [5], GPT-2 [6], and GPT-3 [7], as well as text analytic algorithms, have been developed that show promise for identifying the sentiments and communication styles underlying sentences. Various NLP techniques were applied to assess corporate culture in specific contexts and achieved initial success [8, 9]. Pandey and Pandey [10], for example, extended computer-assisted text analysis to the level of multiple words and provided guidelines for measuring organizational culture that meet content, external, dimensional, and predictive validity. Li et al. [11] used the word embedding model to create a cultural dictionary of five cultural values—innovation, integrity, quality, respect, and teamwork—and applied the model to 209,480 transcripts of earnings announcements. Their findings on the correlations between corporate culture and business outcomes, including operational efficiency, risk-taking, earnings management, executive compensation design, firm value, and deal closings point to the importance of culture in corporate mergers and acquisitions. Lu et al. [12] attempted to explain corporate culture in terms of the Big 9 culture values—agility, collaboration, customer, diversity, execution, innovation, integrity, performance, and

respect—based on mission and vision statements using NLP. The results extracted from the text embedding models, which ranged from the word to the sentence level, showed initial agreement with perceptions of company culture from external data sources such as Glassdoor Culture 500. Despite the above achievements, little has been done to assess corporate culture in the context of EVP using the description of management actions, which usually follow a predefined guideline to address the required cultural aspects, but may have very different styles from one company to another. We intend to develop an analytical methodology that draws on existing NLP methods to identify the critical intersection that constitutes EVP. Our work contributes to finding out whether current NLP methods can be used effectively in the EVP context, and what other methods are needed for a better explanatory power of the language models.

In this work, we collaborate with GPTW Switzerland AG, which collects a variety of data based on quantitative employee surveys and qualitative management audits from more than 100 organizations with around 30,000 employees. By analyzing this structured (e.g., ratings) and unstructured (e.g., comments) data, GPTW aims to help companies create a valid EVP to compete in the labor market. As a first step in applying NLP in the EVP context, we examined the responses of over 50 companies to the *Culture Audit* EVP questionnaire and found useful insights for building and evaluating an EVP. We proceed as follows. Section 2 presents the *Culture Audit* data we collected. In the following Sect. 3, our NLP analytical framework is described. In Sect. 4, NLP methods are applied to the data to gain insights into the corporate culture contained in the management audits. The advantages and limitations of the existing NLP methods are discussed in Sect. 5, and possible ways to improve the automated analysis results are also discussed. Finally, Sect. 6 summarizes our work and provides an overview of the research to come.

2 GPTW Culture Audit Data

The *Culture Audit* developed by GPTW contains five key questions that ask companies to align their actions to build a strong EVP with five cultural values: *trust*, *maximizing human potential*, *values*, *leadership effectiveness*, and *innovation*. For each question, GPTW offers specific storytelling guidance to help companies differentiate themselves from their competitors. The number of words per answer is also limited, ranging from 3,000 to 5,500. To assess the quality of companies' answers, GPTW applies a rating process based on structured criteria. The process includes two raters and a validation of interrater-consistency. For the culture value *trust*, for example, there are five different variables, as well as corresponding explanations to help with the assessment. We consider the explanations of these variables as the important criteria that GPTW would like companies to achieve in designing their strong EVP. Based on the assessment of each individual culture value, GPTW assigns an overall score that quantifies the strength of the company's EVP.

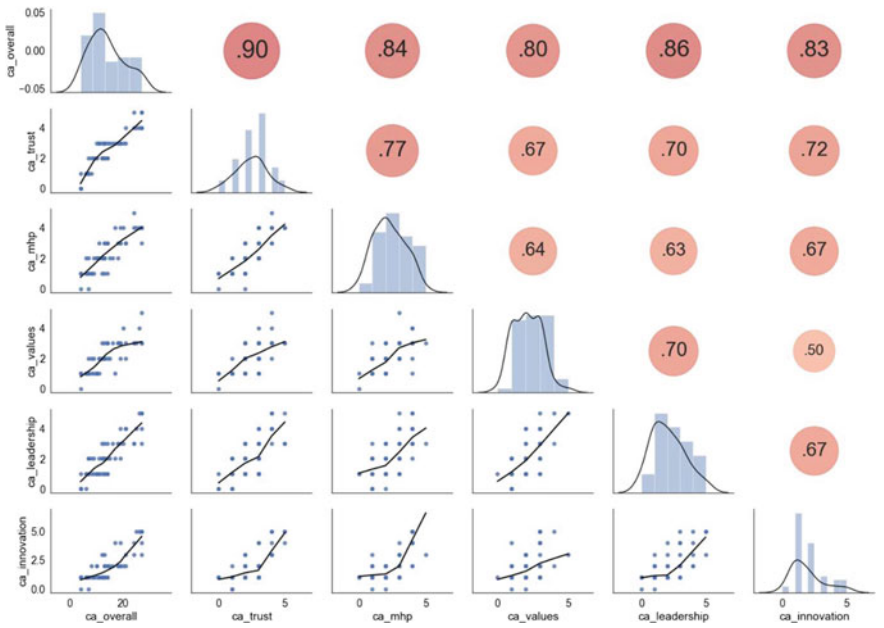

Fig. 1 Correlation between the culture scores based on the GPTW data

The *Culture Audit* data sample used in this study has been completely anonymized prior to the project to prevent organizations or individuals from being identifiable. The dataset includes responses from 54 companies of different sizes, i.e., small (20–49 employees), medium (50–249 employees), and large (more than 250 employees). The original responses are processed into a cleaned text to which we can apply English language models.

To get a first impression of the interplay between the different culture scores, Fig. 1 shows the correlation between the culture scores based on the GPTW data. This helps to understand which of the five dimensions is most important for the overall assessment of culture. On the one hand, the culture value of *trust* contributes most to the overall culture score and is almost coherent with it. If the *trust* score is high, the scores for the other culture values also tend to be higher and vice versa. This is consistent with GPTW's experience in evaluating *Culture Audit*, as responses to the culture value *trust* tend to cover the broadest range of topics and their interrelationships. On the other hand, the culture value *trust* correlates most strongly with the value *maximizing human potential*, while the culture value *values* correlates least with *innovation*. In general, the intercorrelations of the different dimensions are very high, indicating that we are measuring a single construct, culture. Most intercorrelations show low correlations at low scores, but high correlations at higher scores. This indicates that higher scores might be associated with better integration of topics.

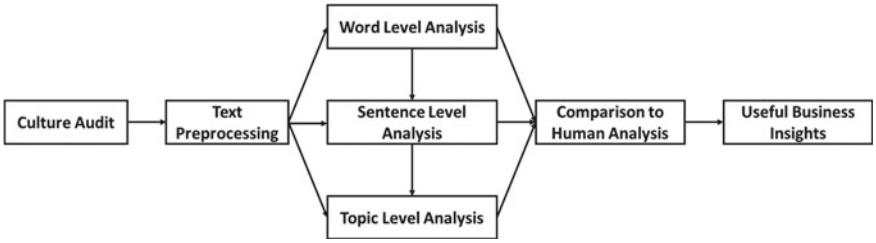

Fig. 2 NLP analytical framework

3 NLP Analytical Framework

We intend to analyze the *Culture Audit* data using an NLP analytical framework with three different levels. At the word level, we used a word embedding-based text analysis model to create a cultural dictionary to help capture the cultural elements in the management actions. At the sentence level, we used a sentence embedding-based text analysis model to code the content into different cultural dimensions and quantify the strength of cultural mentions in the text. At the topic level, we used structural topic modeling to extract the underlying topics of a particular culture and link these topics to meta-parameters such as rating values. We applied these analyzes to show some consistency with the consultants' evaluations and can contribute to a better understanding of the companies' EVPs. Figure 2 shows our NLP analytical framework.

To ensure smooth analysis of the *Culture Audit* data, we preprocessed the text using Python and the natural language toolkit (NLTK) [13]. We removed numbers, punctuation, stop words, line indicators, and words with less than three letters and lemmatised the remaining words.

To perform the word-level analysis, we worked on a model to measure corporate culture by creating scores based on corporate culture dictionaries [11]. This method combines a neural network-based machine learning approach with word embeddings, i.e., the Word2Vec model [14], to efficiently learn dense and high-dimensional vectors that can represent the semantic meaning of words. Once we have constructed such a vector for each word by examining its neighbors, we can theoretically calculate the association between each pair of words based on the cosine similarity of the underlying vectors and construct the culture dictionaries with words and phrases that are closely related to the individual culture values. The final culture score can be calculated based on the log-normalized TF-IDF values of the identified culture words.

Sentence-level analysis is possible with pre-trained language models such as sentence transformers [15]. Sentence transformers models can compute dense vector representations for sentences and paragraphs based on transformer networks such as BERT [5]. The text is embedded in the vector space in such a way that similar texts are close to each other and can be found efficiently using cosine similarity. In our

context, we used sentence transformers to encode the companies' responses and the evaluation criteria of a given culture value. We then determine the culture score by comparing the cosine similarity of the embedded texts. The results were compared with those obtained using the word embedding method.

We also compared the results of the word and sentence embedding models with human ratings of corporate culture to validate the current methods. Based on this, we applied a structural topic modeling method [16, 17] to identify meaningful culture topics that can be linked to corporate culture scores. This helps to improve the explainability of machine learning models and provide useful business insights [18].

4 Results

In this section, *trust* is used as an example because it is most closely linked to a company's EVP, as shown in Sect. 2. We adopted the word embedding-based text analysis model [11], which aims to create a cultural dictionary for the culture value *trust*. To do this, we first generated 21 seed words according to the study of Audi et al. [19], i.e., some words frequently mentioned in the context of *trust* in organizations. By using these seed words and training the word embedding model based on the companies' responses to the cultural dimension of *trust*, we were able to create a larger list of cultural words associated with *trust*. In addition, we determined a *trust* score by evaluating how often these words are mentioned in the companies' responses. Figure 3 shows the correlations between the length of the response, the GPTW culture score, and the word-analyzed culture scores based on cultural dictionaries of different lengths from 100 to 800. By varying the length of the cultural dictionaries, we want to find out whether it is necessary to create a long list of words in the dictionary to "cover" all the text in the companies' responses. On the one hand, it can be seen that document length correlates positively (0.6) with the GPTW culture score, indicating that GPTW focuses on identifying "stories" behind the explanation of culture. This increases the overall score and seems to be independent of company size. On the other hand, scores based on a dictionary length of 100 correlate least negatively with document length. Culture scores obtained with the word embedding method correlate negatively with GPTW scores regardless of dictionary length. These observations make sense considering that the space for explaining cultural aspects in the *Culture Audit* is limited, and the intention to produce a very long list of dictionary words to measure a culture value is pointless. They also show that GPTW puts more emphasis on "storytelling" than on simply mentioning a few buzzwords in the responses in order to achieve a higher score. The above also applies to the other culture value assessment.

We also checked the influence of the source text on the training accuracy of the word embedding model, as this may affect the synonyms found for the seed words. In the previous results, we only used the companies' responses to the culture value *trust* to train the word embedding model, where the amount of text was also limited and may have affected the training accuracy of the embedding vectors. Here, the

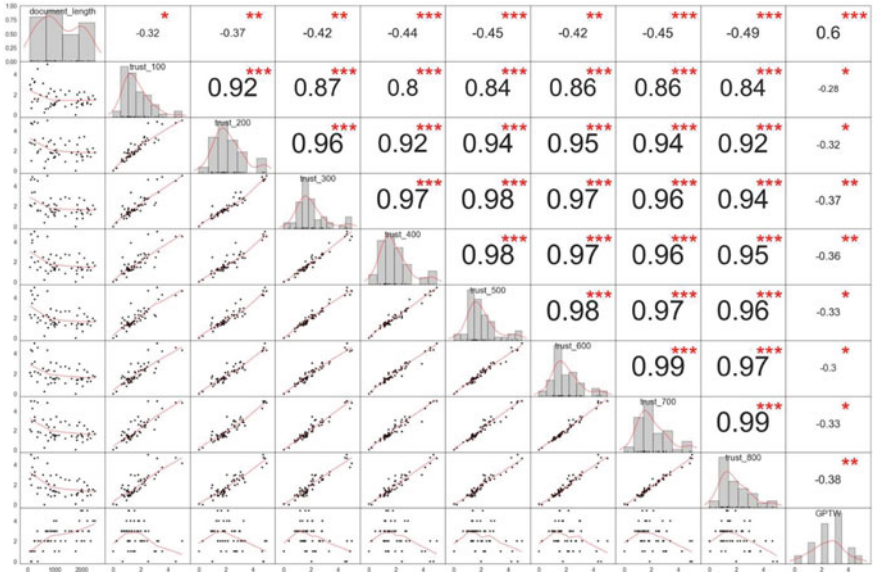

Fig. 3 Correlations between the length of the response, the GPTW culture score, and the word-analyzed culture scores based on culture dictionaries of different lengths from 100 to 800. The results are based on the culture value *trust*

companies' responses to all five cultural dimensions were linked together to train the word embedding model. In fact, the culture score based on the length of dictionary 100 shows a strong correlation between the results of the larger and smaller source texts ($r = 0.84$, $p < 0.001$), which means that the results obtained in Fig. 3 are valid.

Figure 4 examines how the culture score based on the sentence embedding model relates to that of the word embedding model and how it contributes to explaining the culture score assessed by GPTW. On the one hand, we know from Fig. 3 that the culture scores obtained with the word embedding model (compared to the sentence embedding model) correlate negatively with the GPTW scores, regardless of the length of the dictionary, with a dictionary length of 100 showing relatively better results. In other words, the more buzzwords considered for the dimensions (e.g., *trust*), the lower the score. This could indicate that the use of buzzwords alone does not improve the score, which could even leave a negative impression on GPTW consultants. On the other hand, the score of the sentence embedding model correlates slightly positively with that of the word embedding model and the GPTW score. This could indicate that describing the meaning of the topics (e.g., *trust*) in complete sentences (as opposed to synonyms) leads to a higher score.

Based on the results of the text embedding models, it is important to explore whether we can add some explanatory power to machine learning methods. In a real EVP assessment process, the consultants would not only like to get a final score for each company, but also some clues as to why the score are high or low. To this end,

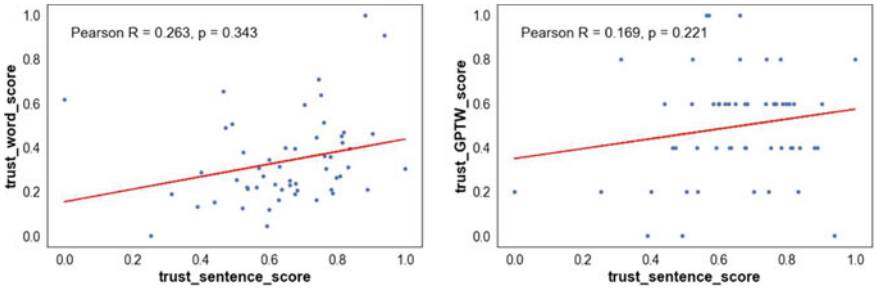

Fig. 4 Evaluation of the culture value *trust* based on the sentence embedding model and comparison of the result with that of the word embedding model and GPTW

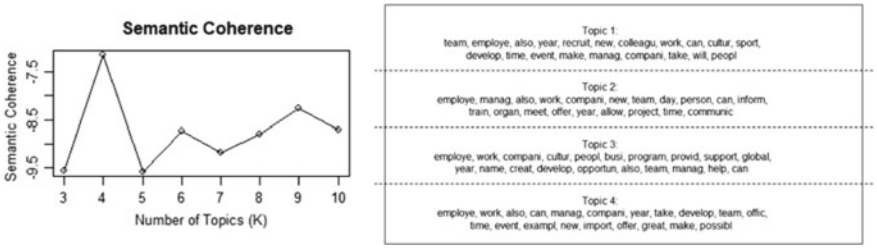

Fig. 5 Topics identified using the structural topic modeling method for the culture value *trust*. **a** Semantic coherence assessment to determine an optimal number of topics; **b** stemmed keywords extracted for each identified topic

we applied structural topic modeling to the cultural dimension of *trust* and assessed the underlying topics of the companies' responses and their correlation with the meta-parameters such as the GPTW culture score. As shown in Fig. 5, the results of the semantic coherence suggest that the companies' responses on the culture value *trust* could cover four topics. This suggests that companies tend to include different topics in their responses to the first cultural dimension. This assumption is supported by the GPTW consultants' impression that the four responses for the other cultural dimensions are mostly less content-rich. However, the distinctiveness of the four topics found is low, especially based on the extracted keywords alone. Possible explanations for this could be that these topics are well connected or that companies do not yet know how to address the different topics separately within the overarching dimension of *trust*. These findings can be used as a guide for the future design of the *Cultural Audit*. Nevertheless, the structural topic model revealed a relatively strong correlation (0.65) between topic one and the highest GPTW culture score with a low p value of 0.0189, implying that if the scope of topic one can be better defined, companies could reconsider or improve their management actions in that area to improve their EVP scores. The full results of the structural topic modeling for all five cultural dimensions are consistent with the above observations and arguments.

5 Discussion

In the above study, word-, sentence- and topic-level NLP methods were applied to the *Culture Audit* data to assess EVP strength in different corporate cultural dimensions. Overall, we did not find a strong positive correlation between the machine and human ratings. This could be due to the fact that the text embedding-based analysis focuses on "understanding" the words and sentences alone and determining how "close" these words and sentences are to the predefined cultural dimension, whereas the human assessment is more concerned with finding "stories" behind the text to support the explanation of EVP. However, the sentence embedding model seems more promising for the future, especially if we can better define the criteria used to assess culture. On the other hand, we found the use of structural topic modeling interesting to increase the explanatory power of the language models. This gives us a more transparent picture of what aspects the companies have discussed, and how these different perspectives can contribute to a stronger EVP.

Another way to improve the explanatory power of machine learning in EVP assessment is to include humans in the loop [20], e.g., in our context by integrating justifications for consultants' annotations on texts that represent good organizational culture and improving the training of a text classification model that can detect differences between texts. The model trained in this way cannot only classify the text into different categories, i.e., the culture scores, but also highlight parts of the text that might support the reasons for the text classification results. This makes the machine learning process more transparent and enables the consultants to better evaluate the EVP.

6 Conclusion and Outlook

In this work, we applied state-of-the-art NLP methods to evaluate the EVP of companies based on the *Culture Audit* data provided by GPTW. Analyzes were conducted at word, sentence, and topic level with the aim of partially automating the evaluation process. Overall, we conclude that the existing NLP methods generate results that only to a small extent match the human assessment of corporate culture. This could be due to the fact that the focus of NLP methods and human assessment do not entirely match, i.e., the former focus on the meaning of words and sentences, while the latter focuses on "stories". However, sentence embedding-based text analysis has shown promise once we can better define the criteria for a good culture value. In addition, our analyzes also suggest some guidelines that can help companies develop a stronger EVP and related management measures. Furthermore, it is important to extend the explanatory power of machine learning models through structural topic modeling or human-assisted text classification. This justifies the future research direction that could lead to a more reasonable and trustworthy assessment of corporate culture.

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A New Architecture for Diabetes Prediction Using Data Mining, Deep Learning, and Ensemble Algorithms

Adolfo Jara-Gavilanes, Romel Ávila-Faicán, and Remigio Hurtado Ortiz

Abstract It is a big challenge to diagnose diabetes in an early stage. This causes a health problem because it is a severe cause of death if it is not treated early or it can trigger many secondary diseases that impact the well-being of the patient. In this document, we present a new method to accurately predict this disease using data mining, deep learning, and ensemble algorithms. Data mining includes the processes of data preprocessing to make it more comprehensible and gaining insights from the dataset. This architecture is divided in 7 steps: First, the dataset is loaded. Second, the variables are analyzed to understand their value to predict diabetes. Third, the noise is removed from the dataset, deleting empty data. Fourth, the variables are transformed and scaled. Fifth, an exploratory analysis is made to explore the correlations between the variables. Sixth, the following predictive methods are applied: random forest, artificial neural network, and AdaBoost. Finally, results are presented and explained. To implement this method, we used a public dataset from kaggle called: diabetes dataset. This method achieved great accuracy, precision, and recall, which helps demonstrate the effectiveness of the method. Finally, this document could be the base for new research in this disease like trying to predict the type of diabetes the patient has, and it can be applied to different health problems. Furthermore, more predictive methods should be applied to try to achieve a higher accuracy.

Keywords Data science · Data preprocessing · Predictive analysis · Artificial neural networks · Random forest · AdaBoost · Diabetes

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1 Introduction

Diabetes is a very common disease nowadays. Every day the number of affected people by this disease sees a dramatic increase. The World Health Organization (WHO) [20] estimates that around 1.5 million people die from diabetes annually, and there are 422 million people that are affected by it [11]. These numbers increase every year. Most of the deaths occur when the patients are not diagnosed at an early stage. A great example of this occurs in Latin America, around 40–50% of patients are not diagnosed at an early stage [11]. Moreover, these undiagnosed patients could be affected in future with the following effects: greater propensity to have heart attacks, loss of nerves in the limbs of the body, limb amputation, blindness, among others [7].

Diabetes generally occurs when the body does not produce enough insulin or it is not used properly. Insulin's job is to carry glucose to the body cells to be able to have energy in it. The following 4 types of diabetes are explained:

- Type 1: It is caused by the lack of production of insulin.
- Type 2: It is caused by the inappropriate use of insulin [6].
- Gestational: It occurs pending pregnancy.
- Prediabetes: It is diagnosed when the levels of glucose in the blood are out of the normal range [7].

As it has been described, diabetes represents a worldwide health problem, therefore it is necessary to develop tools based on artificial intelligence and machine learning to deal with it and to prevent the increasing numbers of deaths every year.

Artificial intelligence and machine learning play a key role in the early detection of this disease. Many tools are based on them with the goal to help doctors make a decision about the patient. These tools make use of supervised or unsupervised learning techniques like: KNN, random forest, XGBoost, among others.

The goal of this work is to introduce an analysis method based on 7 steps that is capable of predicting diabetes. The fist step is to load the data. After that, an analysis is made to select the most important variables. Then, the noise is removed in the dataset. Afterward, the variables are transformed and scaled with the goal to obtain a better accuracy, precision, and recall. Then, an exploratory data analysis (EDA) is carried on with the goal to gain insights from the dataset; therefore, we can obtain some relevant information about what influences this disease, and to decide which variables are the most important for classifying this disease. Later, the following classifiers are applied to the transformed dataset: random forest, artificial neural network, and AdaBoost. Finally, the results are explained, and the best model is chosen. To reach this goal, a public dataset from Kaggle was used: "diabetes dataset" [19].

The most important contributions of this work are described below:

- A new architecture based in Data Science is introduced in order to obtain great accuracy, precision, and recall that can be coupled to other classifying problems.
- The classification task was carried out with 3 different classifiers to show the different results of each one.

- A group of experiments was made with a public dataset in order to compare the proposed method with other relevant methods.

Now, the structure of the article is explained. Section 2 presents the related works. Section 3 describes the methodology and the models used. Section 4 shows the experiments made, a brief description of the dataset and the quality measures. Section 5 introduces the results obtained from this method. Finally, Sect. 6 represents the conclusions of this work.

2 Related Work

In [5], the authors introduce a study based on the Pima Indians dataset. It contains 786 rows of data, and it was splitted into 90% for training and 10% for testing. In this study, the following classifiers were used: AdaBoost and an artificial neural network. The first classifier threw the best results obtaining 91.23% of accuracy and 89.48% of precision.

In [2], the authors present a study making use of a dataset recollected in a hospital in Sudan. It contains 318 rows of data, and it contains data from patients that suffered diabetes type 2. J48 was used to predict this disease, and it reached 70.8% of precision.

In [9], the authors performed a study with data coming from a diabetes hospital in Sylhet. It contains 520 rows of data. To predict diabetes, the following classifiers were used: support vector machines, random forest, decision trees, artificial neural network, and logistic regression. Among all of these classifiers, the artificial neural network achieved 96% of accuracy.

In [15], the authors carried out a research based on a dataset from Kaggle that contains 15000 rows of data with 8 categories. In this research, the following classifiers were used to try to predict diabetes: support vector machines, Naive Bayes, KNN, and gradient boosting. The last classifier obtained the best results obtaining 91.63% of accuracy.

In [10], the researchers present a comparative among the following classifiers: decision trees, Gaussian NB, LDA, SVC, random forest, extra trees, AdaBoost, multilayer perceptron, gradient boost classifier, bagging, KNN, and logistic regression; with the goal to predict and classify patients with diabetes. In this study, a pipelining classifier was used to improve the results obtained from each classifier. AdaBoost obtained the best results with a 98.8% accuracy.

The following Table 1 shows a comparison between the related works and our method. Thus, the differences can be appreciated easier. The order of the related works in the table are the same as they were explained in this section, and our method represents the last row of the table.

Table 1 Comparison between related works and the presented method

Author	Year	Dataset	Technique	Quality measure	%
Md. Kamrul Hasan et al.	2020	Pima Indians	Machine learning	Accuracy	95
Aishwarya Mujumdar et al.	2020	Sudan's diabetes hospital Jaber Abn Abu Liz	Machine learning	Accuracy	98
T. M. Ahmed	2016	Sylhet's diabetes hospital	Machine learning and deep learning	Accuracy	71
Juncheng Ma	2021	Unknown	Machine learning	Accuracy	96
Prakhar Saxena et al.	2022	Unknown	Machine learning	Accuracy	98
Adolfo Jara-Gavilanes et al.	2022	Diabetes dataset	Data mining	Accuracy	100
			Machine learning	Precision	100
			Deep learning	Recall	100

3 Methodology

In this section, the proposed method is explained. First, the classifiers are introduced. Then, the proposed method is presented. Finally, the parameters used for each classifier are explained.

3.1 Classifiers

The classifiers that are presented in this section were chosen for producing great results at classification tasks; therefore, they are optimal for detecting diabetes.

- Artificial Neural Network: It is a nonlinear statistical data model based on biological neural networks [1]. Its structure contains the following elements: inputs, neurons, layers of neurons, and the output. Neurons are in charge of receiving, processing, and transmitting information to their subsequent neurons. Weights are used to give more importance to some neurons. Therefore, ANNs are used to create predictive models [17].
- AdaBoost: It is a boosting model which generates stumps that are smaller than decision trees [16]. In the training phase, the first stump is created, and its error is calculated with the goal of using it to improve the next stump, and so on for the rest of the stumps [8]. Each stump has a weight based on the error value that they have, therefore if a stump has a lower error value, the higher its weight is for the final classifying decision. Those stumps are called "weak learners", and all of them are united to create a robust classifier.

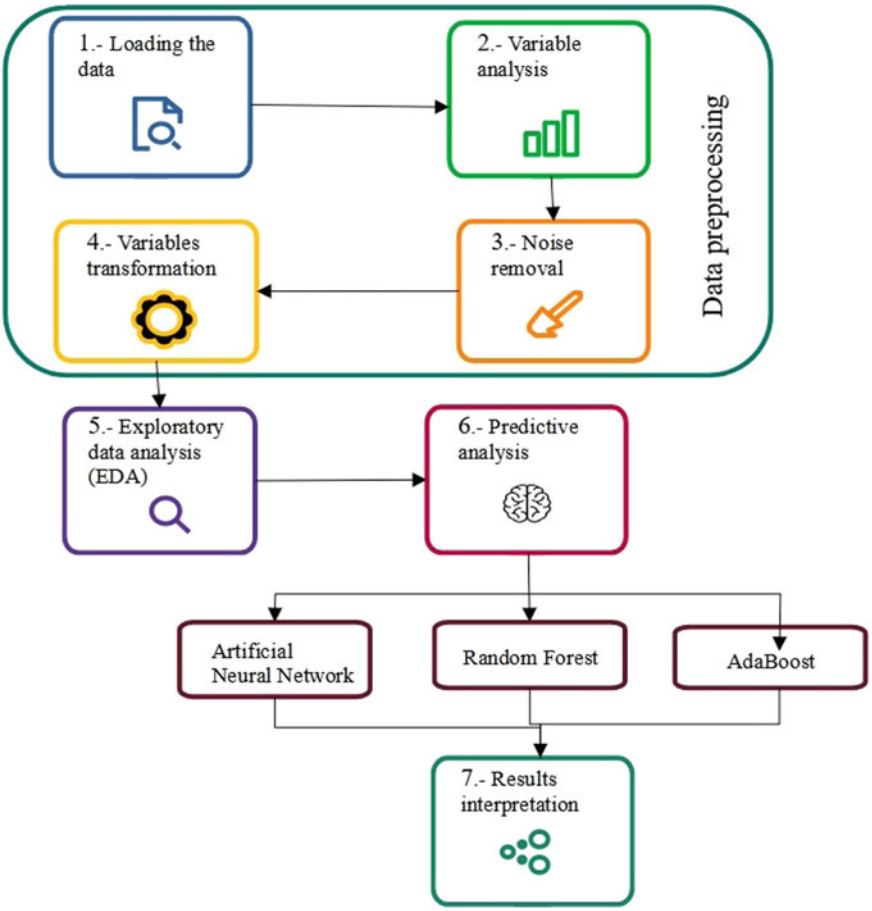

Fig. 1 Process of the analysis method

- Random Forest: It is a bagging technique frequently used for classification and regression tasks. This technique generates many decision trees which create a forest [18]. It is a bagging technique because it is the way to assure that every decision tree is different, therefore the classifier becomes more powerful for making predictions. This technique makes a final decision adding up every decision that a tree has made, and the most voted decision is the final prediction [21].

3.2 Proposed Method

Next, the steps made to reach the goal of this article are explained:

1. **Loading the data**: In this step, the dataset chosen is loaded for this method. It has the necessary information to reach the goal of this article and to apply the different classifiers.
2. **Variable analysis**: In this step, all the variables from the dataset chosen are analyzed.
3. **Noise removal**: This step plays a key role to replace all the empty data and therefore to obtain better results.
4. **Variables transformation**: This step is important to transform categorical variables to numerical variables and then normalized all numerical variables from the dataset.
5. **Exploratory data analysis (EDA)**: In this step, an exploratory analysis is made with the goal to gain insights from the dataset and to be able to understand the most important variables for the prediction task.
6. **Predictive analysis**: In this step, the different artificial intelligence and machine learning classifiers are trained and tested with the goal to compare results. The following classifiers were used: artificial neural network, random forest, and AdaBoost.
7. **Results interpretation**: This is the last step where the best classifier is chosen, and their results are explained.

4 Experiments

To be able to reach the goal of this article, a public dataset was used. It contains 2000 rows of data, where 34% of them are patients diagnosed with diabetes, while 66% of them are patients without diabetes.

Following, the variables from the dataset are described in Table 3.

Table 2 Dataset description

Dataset	Diabetes dataset [19]
Number of variables	9
Number of observations (patients)	2000

Table 3 Variables description

Variable	Brief description
Pregnancies	Pregnancy status
Glucose	Blood glucose level
BloodPressure	Blood pressure
SkinThickness	Skin thickness
Insulin	Blood insulin level
BMI	Inclusion body myositis (IBM) mainly affects men
DiabetesPedigreeFunction	It is a function that rates the probability of having diabetes based on genetics, i.e., the family history of diabetes
Age	Patient's age
Outcome	Whether or not the patient has diabetes (0: no, 1: yes)

Table 4 Classifiers parameters

Classifier	Parameters
Artificial neural network	Epochs = 10, 15, 20, 25, 30, 35, 40, 45, 50
	Optimizer = adaptive moment estimation (Adam), adaptive gradient algorithm (AdaGrad), root mean square propagation (RMSprop)
	Learning_rate = 1e−1, 1e−2, 1e−3, 1e−4
	6 layers density
	Layer 1, 2, 3, 4, 5:32, 64, 96, 128, 160, 192, 224, 256, 288, 320, 352, 384, 416, 448, 480, 512
	Layer 6:1
AdaBoost	Tree_depth = 2, 3, 4, 5
	Boosting = True
	*n*_rounds = 100, 50
Random forest	*n*_tree = 100, 200, 300, 400, 500

4.1 Chosen Parameters for Classifiers

After the data was loaded, and the variables were analyzed, the noise from the dataset was replaced making use of the average of the variables. Then, a *K*-Fold technique is implemented to reach better results. The values of k are 5, 7, 10. Thus, we can compare which value is the best for each classifier. Following, Table 4 presents the parameters used for each classifier.

4.2 Quality Measures

Following, the quality measures implemented to evaluate the classifiers are explained.

1. Accuracy: It refers to how close the actual value has been to the predicted value [4].

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{True Positive} + \text{True Negative} + \text{False Positive} + \text{False Negative}} \tag{1}$$

2. Precision: This measure refers to the percentage of interests on the given corpus, with which we can obtain the measure of quality in the classification tasks [3].

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \tag{2}$$

3. Recall: This measure helps us determine the percentage of hits that the classifier has achieved [14].

$$\text{Recall} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \tag{3}$$

5 Results and Discussion

This section presents the results of the steps explained in the methodology section. Moreover, the best classifier is chosen, and its parameters are showed. Finally, a figure making use of a multidimensional scaling technique is applied to represent the data in a 2D scale.

5.1 Data Preprocessing

After the dataset was loaded, an analysis on the dataset variables was carried out with the goal to understand them and to classify them between categorical and numerical variables. Then, the empty data was replaced with the average of the variable where it was found. Thus, the final size of the dataset ended with the same amount of rows of data.

5.2 Exploratory Data Analysis

Once the data preprocessing step is finished, the next step is to realize an exploratory data analysis (EDA). This step has the goal to gain insights from the dataset and to

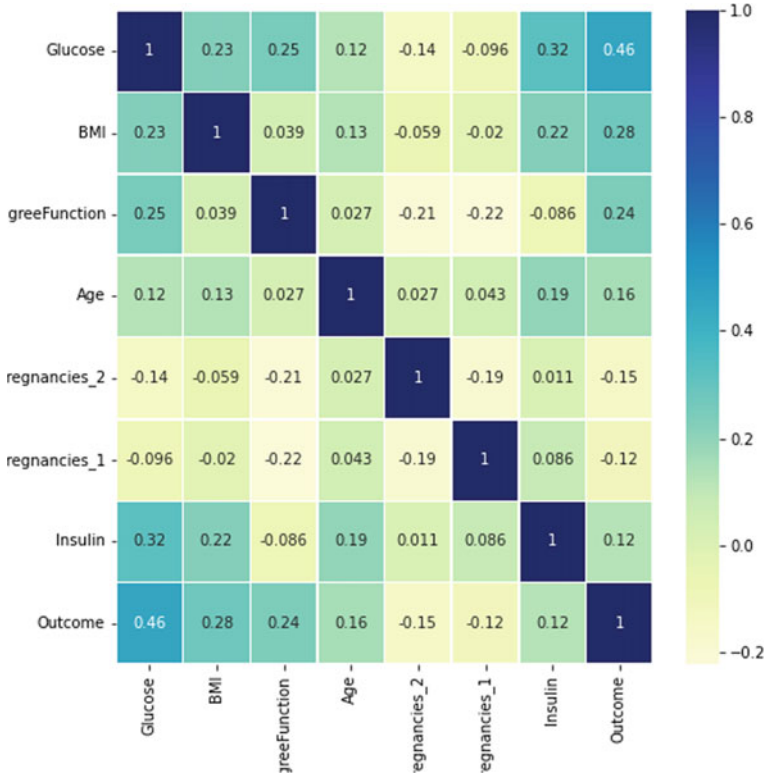

Fig. 2 Heat map of most relevant correlations

analyze the most correlated variables with respect to the variable to be predicted. As it can be seen in Fig. 2, the most correlated variable is glucose. This means that the higher the blood glucose level a patient has, he is more likely to have diabetes. The next variable is BMI. It is an inflammatory muscular disease that affects the body cells. This hinders the normal functioning of the cells; therefore, there is a defective glucose absorption. The last variable is DiabetesPedigreeFunction. It is a function that determines the odds of a person having diabetes based on the family member's history of this disease.

5.3 Classifiers Results

The results obtained by each classifier are shown after the classifiers were trained and tested with the different dataset partitions. Table 5 shows the results yielded by each classifier.

Table 5 Classifiers results

Classifier	Accuracy	Precisión	Recall
Artificial neural network	0.865	0.8965	0.8523
AdaBoost	**1**	**1**	**1**
Random forest	0.9899	1	0.9714

Bold Values represents adaboost is the best model of Classifiers results

Table 6 Final parameters for each classifier

Classifier	Parameters
Artificial neural network	Epochs = 15 Optimizer = Adam Learning_rate = 0.01 6 layers (352, 352, 256, 192, 256, 1) Activation functions (relu, relu, relu, relu, relu, linear)
AdaBoost	K = 10 Tree_depth = 3 Boosting = True n_rounds = 50
Random forest	K = 10 n_tree = 500

The best results of each classifier were reached by the parameters showed in Table 6.

As it can be seen in Table 5, the best classifier was AdaBoost which obtained 100% of accuracy, precision, and recall. It had 50 boosting iterations and 1801 stumps. To reach these results, the k value was 10.

Figure 3 shows the variables that are the most important for the AdaBoost classifier. The most important one is DiabetesPedigreFunction, which is related to the odds of a person having diabetes based on the family member's history of this disease. Then comes glucose and BMI which have almost the same level of importance at the moment to predict this disease.

5.4 Data Dispersion

Figure 4 shows a 2D representation of the dataset. A multidimensional scaling (MDS) technique was used to accomplish this task. MDS is a dimensionality reduction technique, which means that multidimensional data is transformed into a lower space, while keeping the crucial information [12, 13]. This was done with goal to observe how the data was distributed. As it can be seen, many data points overlap; therefore, it is more difficult to classify and make the right predictions.

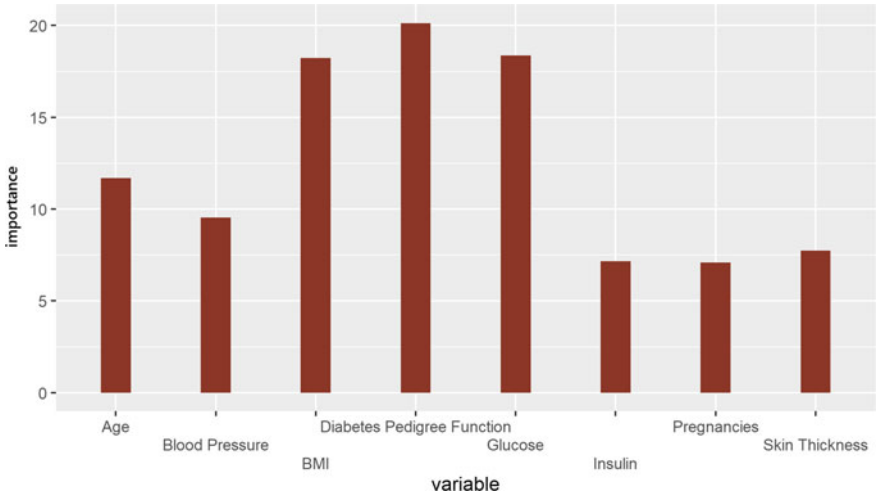

Fig. 3 Importance of variables in the AdaBoost classifier

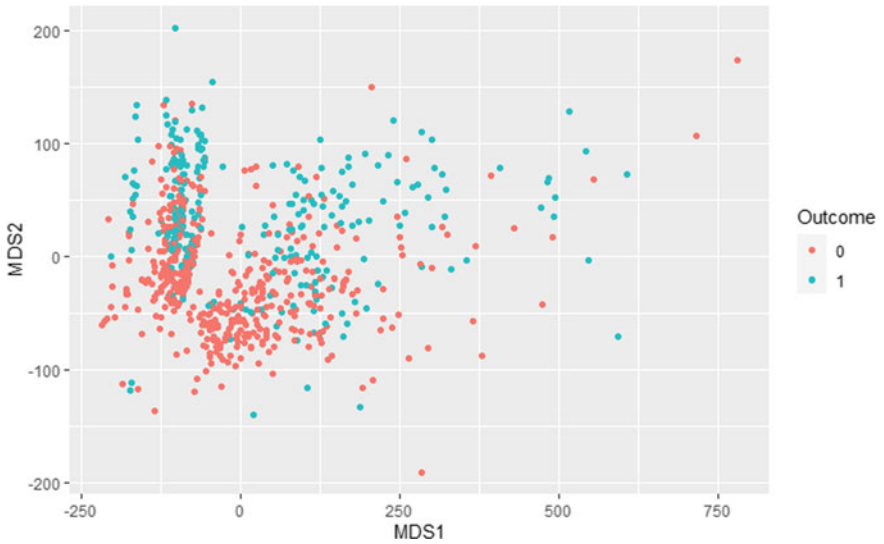

Fig. 4 2D representation of the dataset

To perform the MDS technique, the following parameters were used:

- Number of components: 2 (to use a 2D graph).
- Metric: metric MDS.
- Relative tolerance: 1e−3
- Maximum number of iterations: 300.
- Distance metric: manhattan.

6 Conclusions

After analyzing the results, the proposed method has reached the goal that was settled at the beginning of this work. First, during the data preprocessing phase, we were able to classify the variables and to replace all the noise and empty data within the dataset. Moreover, the data from the dataset was transformed into numerical, and then, it was normalized. After this phase, an exploratory data analysis (EDA) was made, and the most correlated variables were found: glucose, BMI, and Diabetes-PedigreeFunction. The following classifiers were trained and tested, where the best of them was AdaBoost. It reached 100% accuracy, precision, and recall. In addition, the most important variables for this classifier were presented, and it is worth pointing out that they differ from the most correlated variables.

This study has some potential limitations that are:

- The size of the dataset is not big enough to be able to gain more insights and reach higher accuracy with the other classifiers.
- Besides, the dataset should be more diverse in terms of where it was collected, it means that the data should be gathered from all the world to be able to generalize this method. There could be a bias based on the location where this data was gathered.
- The class to be predicted was not equally distributed; therefore, an oversampling technique should be applied in order to balance the class.

This method has proven to be effective for the task to solve for the following reasons:

- It is important to preprocess the data to convert it to numerical and then normalize it to achieve higher results.
- The exploratory data analysis step helped us to gain insights from the dataset; therefore, we understood how was the behavior of the data.
- The three classifiers were trained and tested with different hyperparameters with the goal to select the best ones.
- The AdaBoost classifier reaches the best results, but it can be trained and tested with different hyperparameters.

As it can be seen, this proposed method reached higher results than the ones in related work; hence, this method could be the baseline for future work. As future work, we propose the following lines:

- This dataset can be used to apply different classifiers like: XGBoost, J48, CatBoost, Regresión Lineal, among others.
- The proposed method can be used in other datasets related to health problems.
- To apply an oversampling technique, in case to work with the same dataset, in order to balance the class to be predicted.

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Content Moderator Startle Response: A Qualitative Study

Timir Bharucha, Miriah E. Steiger, Priyanka Manchanda, Rainer Mere, and Xieyining Huang

Abstract Commercial content moderators review user-generated content (UGC) to ensure the posts meet platform policies, guidelines, community standards, and regional laws. While the majority of posted UGC is deemed acceptable, a large amount of content remains, which is classified as non-compliant and may include gore, violence, suicide, child sexual abuse material (CSAM), and pornography, to name a few. Because of this, content moderators have a greater prevalence of their nervous system activating a startle response, which can impact emotional, psychological, and physiological processes. Prior research on content moderators has failed to explore moderators' initial reactions to content from the start of employment through tenure as the subjection to material and habituation increases. This study takes an in-depth look at moderators' experiences from recruiting, through training, and production to better understand the content moderators' startle response and factors that enable startle habituation. The current study sample consisted of 78 total respondents—38 content moderators in the Philippines employed by TaskUs Inc. and 40 in Estonia employed by Sutherland Global Services. Employee tenure ranged from 0 to 6 months. Succeeding our analysis, transparency, understanding, and preparedness were major themes identified as the critical factors found within both companies when exploring the activation of the startle response and facilitation of habituation following content exposure. These themes were prevalent in the employment life-cycle's recruiting, training, and production phases.

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Keywords Commercial content moderation · Startle response · Startle habituation · Well-being · Resilience · Employee life cycle · Recruiting · Training

1 Introduction

Content moderators surveil and examine user-generated content (UGC) on various social media platforms in an effort to confirm that user posts comply with the set terms, policies, guidelines, community standards, and applicable regional laws [23, 27]. They are considered to be the front-line decision-makers, a task that can be cognitively and psychologically taxing [9]. These platforms heavily rely on moderators to act as a protective barrier and sponge for non-compliant and potentially harmful material to safeguard the end-user experience [7]. While the vast majority of posted UGC is deemed acceptable and safe to be published on the platform, a heightened volume of non-compliant media remains in circulation and necessitates specialized review [27]. Examples of this media can take on various forms of media (e.g., audio, pictures, video) depicting gore, violence, murder, suicide, child abuse, sexual violence, and animal abuse [23, 27]. Although the exact number is unknown, it is estimated that over there are over 100,000 moderators working worldwide processing this media [7]. Because of the extensive, indispensable, and mandatory human intervention in-depth exploration into the experiences of content exposure is warranted.

In addition to the graphic nature of the content, moderators experience and must manage work and procedural complexities. They are asked to meet high quota demands. According to research, moderators are required to review 800–1000 social media posts per day [19]. Process time for the content averages 20–30 s, increasing with content complexity [19]. The assignment of material varies, with some queues consisting of specific and steady, yet egregious content such as pornography or violence. While other queues are more unpredictable and sporadic with randomization of harmless or benign, and graphic or disturbing content populating in a single day directed by algorithms [25].

The intricate requirements of the occupation and quantity and frequency of exposure to egregious content leave the population in a vulnerable state as moderators are at an increased likelihood of activating the startle response in comparison to the general population. The startle response is an unconscious protective mechanism initiated by abrupt or fear-inducing stimuli. This response is activated in as little as 14 ms following the triggering event leaving little time or opportunity for processing [11, 16, 18].

When left unattended, repeated or over-exposure to graphic and disturbing content increases psychological and emotional distress [27]. A startle that is not successfully processed may lead to the activation of the fight or flight response [18]. This response hinders an individual's cognitive and dexterous operations for up to 30 s, leading to reductions in decision-making and performance [12, 18, 28]. The response has also been found to bring about the negative emotions of fear and nervousness [11].

According to prior research, the startle response, or reflex, is significantly activated when exposed to unpleasant visual stimuli [14, 22]. Investigation into this phenomenon is mandatory as this visual review is one of the primary functions of the content moderators' occupation. Furthermore, reviewing egregious, charged, and emotion-inducing images brought about similar psychophysiological responses as if the individual were encountering the experience first-hand in real life [3]. In other words, at times due to the emotional response moderators may not be able to differentiate their reality from the content being reviewed. For these reasons, it is critical for researchers to better understand the experiences of moderators reviewing graphic content.

On the other hand, recurrent subjection to the provoking stimuli can lead to startle habituation, or the diminishment of behavioral and psychophysiological reactions to the activating stimuli [8]. As the novelty of the attention-gathering stimuli decreases during autonomic emotion regulation, emotional responses diminish (i.e., habituation, [8, 21, 29]). The habituation process is thought to be a form of learning and filtration as the individual becomes knowledgeable in delineating between threats and non-threats the impact and triggering of the startle response tends to decrease [29]. In the moderator content, it is important to understand factors that facilitate habituation and decrease startle response. Increased habituation has the potential of decreasing the development of adverse mental health effects.

The study was examined through the lens of Schacter and Singer's [24]. Two-factor Theory of Emotion which asserts that emotions are composed of two factors: physiological arousal and cognitive appraisal. The theory postulates that when an individual experiences an emotion, physiological arousal takes place [24]. The Two-factor Theory of Emotions is a manner in which to explain the impact of the stress–strain relationship [2]. The fundamentals of Socio-Physicochemical theory propose that physical and emotional components are stimulated by situational circumstances, even more so during extreme instances such as violence or terror [2].

Overall, there is a paucity of evidence-based research on content moderator startle response and subsequent habituation. Sarah Roberts [23], Andrew Arsht and Daniel Etcovitch [1], Newton [5], and other prominent content moderation scholars have successfully highlighted the experiences of moderators concerning work environments, and job requirements, processes, and procedures to the larger audience. The researchers, however, have been unable to empirically explore the psychological impact of the occupation due to the difficulty of accessing currently employed moderators and the strict non-disclosure agreements enforced by social media platforms and third-party vendors [7].

Moreover, the available research on commercial content moderation primarily focuses on automated moderation, artificial intelligence, and algorithms, which overshadows the vital human element and the effects of processing potentially harmful media on moderators [4], Chandrasekharan et al. [6, 10]. The few studies that do exist on the experience of content moderators primarily explored prolonged exposure to content and the probability of developing adverse mental health effects [1, 13, 26, 27]. These studies have failed to address content moderators' initial reactions to

content, and the subsequent development of habituation. These topics have garnered minimal attention. This study looks to fill these critical gaps in the literature.

With the ever-increasing popularity, growth of social media platforms, changing global content trends, and the vast number of individuals it requires to safeguard a platform, it is evident that further exploration into the content moderators' experiences and reactions to the media is critical. This exploration provides a rare glimpse and insights into the way that commercial content moderators process various types of content from benign to egregious in their day-to-day from the beginning of employment to 6-months of tenure. We aim to expand the knowledge base of moderator experiences and, specifically, to better understand their startle response and the development of habituation. In other words, we look to better understand initial physical, mental, and emotional experiences to egregious content and the process and factors for adjustment. The research provides a unique perspective on a possible avenue for the reduction of potential psychological harm such as secondary traumatic stress, compassion fatigue, and secondary traumatic stress. Through a better understanding of the startle response and factors facilitating habituation organizations providing moderation services may take a more preventative standpoint and provide resources that may reduce long-term harm.

2 Methods

2.1 Participants

The sample consisted of 38 content moderators in the Philippines employed by TaskUs Inc and 40 in Estonia employed by Sutherland Global Services, both content-moderation service providers. Employee tenure ranged from 0 to 6 months. The content moderators were assigned to categorized queues made up of various media types (images, video, audio, and text) with a varied level of graphic content ranging from benign to graphic. Categorized queues require the review of specific and reoccurring content with minimal deviation in assigned themes.

2.2 Procedures and Data Collection

All study procedures were compliant with the code of conduct, legal regulations, and ethical guidelines of TaskUs Inc and Sutherland Global Services and held to the highest regard. It is important to note that, throughout the entire duration of the study, the research teams at both companies remained independent entities that did not report directly to departments that may oversee content moderation employees (e.g., operations). As a result, the research teams were not invested in particular outcomes of the study and could therefore evaluate the data objectively. That is, special efforts

were made and taken to minimize conflict of interest. To further ensure the ethics and objectivity of this study, an external independent researcher and licensed counselor from a Carnegie R1 institution independently reviewed the study procedures and data.

To gather candidates, the researchers distributed a flier detailing the study and requested participants through both companies' employee email distros. Employees were explicitly informed that (1) participation would be completely voluntary; (2) their continued employment or performance review would not be contingent upon their participation; (3) their responses would be stored securely and not shared with anyone beyond the research teams (e.g., not with their supervisors); and (4) their participation would not be associated with monetary compensation. For employees who indicated interest, the researchers met with all volunteers to discuss the purpose of the study in greater detail. All interested participants were sent a link that contained the consent form. The form included the introduction and purpose of the study, risks and benefits, procedures, confidentiality statement, voluntary nature of the study, participant rights, and contact information of the researchers, and a 27-item, open-ended questionnaire (see details below). After the study, participants were thanked, debriefed, and provided with mental health resources. No adverse outcomes (e.g., mental health deterioration) were observed as a result of participating in this study.

2.3 Questionnaire

This study used a 27-item questionnaire comprised entirely of open-ended questions. Prior to analysis, questions were placed into the following domains: Training; Production; Current Cases; and General Experiences. Participants were given a prompt or question and were able to type in responses.

Training. These questions pertained to participant reactions to training for content moderation. These included questions about their thoughts ("Tell me your initial thoughts in your first few weeks of training"), feelings ("What were some of the emotions you experienced during training, what caused those feelings, and what was occurring at those times?"), and after-effects ("How did the exposure to graphic content impact the rest of your workday and your day after your shift ended?").

Production. During production, content moderators review UGC. This set of questions focuses on the transition from training to the application ("What are some differences you can identify between the jobs/cases you encountered in training versus now in production?"); and changes from training content to the real-world application ("How have your thoughts, feelings, physical sensations, and reactions about the content changed since moving from training to production?").

Current Cases. Participants were asked a set of questions about their reactions to the most recent queue of UGC. These questions focused on how difficult the moderation process is ("What makes a job/case easy to review? What makes a job/case difficult

to review?"); how moderators adapt to UGC ("What has helped you adapt or become more comfortable with the content?"); and the effects of content moderation on performance ("What is your average time completing a job in general, and what is your average time completing a graphic job?").

General Experiences. Participants were asked several questions about their overall experience with content moderation. Here, questions related to pre-expectation versus the reality of their job role ("In what ways was this job similar and different to what was explained to you during the recruitment process? What were some things you did not expect to experience?"); reactions to the job ("Tell me about the time you had to take a break from work due to the material? Please describe the content and what you were thinking and feeling (emotions and physical sensations)," "What types of material are you worried about encountering (or used to be)?"); strategies to mitigate the effects of the content ("What skills, techniques, or resources did you use so you could move back into your workflow?"); and participants' sense of adjustment ("I am curious if you feel you have adjusted to the work? What are your thoughts on adjustment, what assisted you in adjusting to the work, and how long did it take to adjust?").

3 Results

3.1 Analysis

The study was conducted through the lens of the Two-factor Theory of Emotion (Schacter & Singer, 1962) and via a bottom-up, deductive, thematic content analysis. The thematic content analysis approach is appropriate for survey data and when attempting to understand the phenomenological experience of participants. As we did not enter the study with a hypothesis, we let the results manifest from the data (i.e., a bottom-up approach).

Thematic Content Analysis. Participant responses were de-identified and uploaded to MaxQDA for analysis. We followed the traditional steps used in thematic content analysis [15, 17]: familiarization, coding, generating themes, reviewing themes, and defining themes. Familiarization refers to reviewing, understanding, and becoming comfortable with the responses. We then examined the data closely and assigned codes to specific responses or portions of responses. Following that, we grouped the coded data into categories. After carefully reviewing the coded responses and associated categories, we then began the process of identifying themes. This involved condensing similar categories into broader, generalizable themes. These themes were then reviewed by comparing them to the responses to ensure that the themes were supported by the data. Finally, we appropriately labeled and defined the themes that emerged from the data. The total process took approximately one month.

A number of themes were identified through the content analysis. This section presents a stratified explanation of each theme as it pertains to training, production, current cases, and general experiences collectively across both companies. Table 1 provides a list of identified themes.

3.2 Training Themes

Concerning the training phase, respondents reported overall enthusiasm, curiosity, and preparedness for managing their roles. Within this stage, a range of emotions was identified when addressing first exposure to media; however, generally, respondents remained neutral and stabilized. Ways of adjustment conveyed included the training department's capability to teach relevant fundamental learnings. Specific themes that surfaced are outlined below.

Learning Enthusiasm. When asked about their initial thoughts in the first few weeks of training, new hires stated, "excited to learn new things," "curious about the things we will encounter," and "you're being taught the things you have never heard before, so it was really neat to me," with a large majority of participants endorsing the sentiment of excitement regarding the opportunity to learn new information and work as content moderators. For example, one moderator responded, "enthusiastic about the world I am about to discover!" In addition, moderators deemed their work meaningful and purposeful by safeguarding social media; yet, this specific theme emerged at a greater frequency when working in the production phase versus onboarding with the company.

Readiness. Exploring thoughts, emotions, and physical sensations associated with first exposure to egregious content, some moderators indicated no impact as they had prior experience viewing similar media in their personal lives. As such, they were prepared for the sensitive media coming into training. "I have exposure in my personal life and stuff I seen on social media, so it was an easy transition for me." Another went on to add their preferences for horror movies. "I really like scary movies, and that have graphic contents. Because I watched a lot, it helped me with this work." Prior work experience was also found to increase preparedness, "I came from another similar job so nothing new in that way."

Looking at the process of moving out of training and into production, most participants indicated no adversity and a smooth transition as they felt ready and eager but anxious. "Because of training, I could manage my response, emotions, and thoughts of the content I am reviewing." Furthermore, candidates emphasize no difference in types and severity of content from training to production. "Almost all content was discussed in training, and production only had slight differences, so the change was not hard for me."

Leaving the training phase, content moderators appreciated the experience and in-depth instruction provided by the trainers, which included clarifying protocols for actioning the correct tags on material when reviewing cases and removing ambiguity.

Table 1 Themes, definitions, and exemplars

Themes	Definition	Exemplar
Transparency	Open, honest, and intentional communication detailing the true nature, content exposure, and risks associated pertaining to the role and requirements of a content moderator	"During my recruitment process, they already told me that I'll be doing as a content moderator handling disturbing content, so before I enter the training I am prepared for the job"
Preparation	Developing a thorough understanding and expectations pertaining to workflow, processes, protocols, content exposure, and managing exposure response	"Because of training, I could manage my response, emotions, and thoughts of the content I am reviewing"
Learning enthusiasm	Curiosity and excitement about expanding worldview and understanding novel roles and responsibilities of moderation work	"Excited to learn new things," "curious about the things we will encounter," and "you're being taught the things you have never heard before, so it was really neat to me"
Readiness	Moderators' perception they are capable of psychologically managing their workflows and assignments	"Excited to learn new things," "curious about the things we will encounter," and "you're being taught the things you have never heard before, so it was really neat to me"
Process ambiguity	The inability to distinguish how to act on specific material correctly	"Production has content that is more diverse in the topic than in training. I believe it should contain more examples"
Habituation	Ability to positively adapt to a repeated threatening stimulus by diminishment in physiological or psychological responses	"I get a little startled with the unexpected before, but now it does not affect me as much"
Hindrance to habituation	Factors that delay or impede the moderators' ability to positively adapt to a repeated threatening stimulus	"Daily stress and fatigue can tear down mental fortitude due to random changing protocols and shifts schedules it deteriorates your ability to focus and process graphic content."
Sense of purpose	Belief that the work conducted is essential in protecting the end-user and safeguarding the platform, which results in a positive outcome	"I take pride in what I do no matter how hard it may be at times, I look back on the purpose why I do this job. And it is fulfilling"
Programmatic intervention employed	The environmental and psychological resources offered and utilized by moderators	"Actually, because of all the wellness and interaction, I'm quite all good"

They felt training created a foundation that could be relied upon when facing adversity or uncertainty. "For me the training was really good. I learned a lot and in the times I'm having confusion I go back to the materials to help me."

3.3 Production and Current Case Themes

While transitioning from training to production, the first signs of startle response and habituation were found when moderators were responsible for maintaining specific metrics, and the content volume increased. Questions related to production and current case themes overlapped and are combined as one section related to emerging themes. Further, some individuals reported a conflict between what to anticipate and reality, with inconsistency between training and production relating to content protocols and severity. This resulted in increased process time with greater cognitive load. However, protective factors materialized in the form of finding a sense of purpose that allowed moderators to cope with the changes.

Process Ambiguity. Although most respondents indicated a high appreciation for training as it assisted in solidifying a fundamental understanding of the job, including processes, procedures, and type of content to expect, a select few desired more from the process once in the flow of production. The moderators expressed concern regarding the largely theoretical approach of training, which provided insufficient hands-on opportunities within training.

Respondents found training decks outdated and lacking in edgier, diverse examples as a reference instead of the more assorted level of severity found in production. "There are lots more variations in content and more intense in production than training." Likewise, the training modules were defined as black and white, meaning the review, violations, and decision-making was more evident than the subjectivity of content in production. "Production has content that is more diverse in the topic than in training. I believe it should contain more examples."

Even with these discrepancies, the moderators conceded the impossibility of covering all potential scenarios and media in training, as material populated in the queues is unpredictable and ever-changing. Therefore, moderators focused on areas within their control, such as knowledge of policies, procedures, and wellness interventions instructed. "You cannot learn everything in training, having experience in production is needed to get used to the content and job." Although, participants correspondingly requested discussions surrounding updates to policy and workflow changes.

Sense of Purpose. The development of a sense of purpose solidified the self-affirmed necessity of the moderator's role and aided in the adjustment to content. Respondents saw themselves as protectors and defenders charged with keeping social media a safer place and reducing societal harm by removing controversial media. Additionally, the moderators believed that they could bring justice to those afflicted by reviewing the content. "I take pride in what I do no matter how hard it may be at times, I look back

on the purpose why I do this job. And it is fulfilling." Another moderator responded I always think about the reason I am doing it.

Habituation. The participants endorsed habituation and adjustment to egregious content, with the majority reporting the habituation timeframe ranging from 2 to 4 weeks. In this context, habituation did not imply a lack of impact for unexpected or severe content but rather a decrease in emotional, psychological, and physiological responses. For example, one participant stated, "I get a little startled with the unexpected before, but now it does not affect me as much."

Although there are still instances when unanticipated content populates, leading to startle/shock, evidenced by an increased heart rate, sweating, and momentary cognitive impairment, the moderators report feeling more accustomed to and ready for the exposure when working in specialized queues. They describe an increased capacity to manage the response and process the information when working with categorized content with clustered concepts. "By the time I moved to production, I am used to viewing sensitive content, though sometimes I am still shocked at the media but doesn't affect me much. I am able to handle it." Another content moderator added, "I could feel myself gradually becoming used to the job and content. Training, recruiting, and wellness really helped make me ready."

Hindrance to Habituation. The primary factors that disrupted or slowed adaptation were associated with the workflow. This included keeping up with the fast-paced environment of changing policies and trends. Stress, fatigue, and cognitive overload were associated with these frequent updates. In an effort to manage change, some moderators reported continuing work-related activities during scheduled breaks. "Daily stress and fatigue can tear down mental fortitude due to random changing protocols and shifts schedules it deteriorates your ability to focus and process graphic content."

Concerning content, new, unexpected, intensely egregious content and subjects or topics moderators were not trained to action altered their ability to adapt. Unfortunately, due to the ever-changing world and current trends, training and established procedures cannot always anticipate or account for everything a content moderator may face. When this occurs, moderators rely on their established forms of support for assistance: wellness staff, managers, trainers, and teammates.

3.4 General Experience Themes

Questions that fell within the "General Experiences" section are listed separately as they address the recruiting process's influence on adjustment. Respondents disclosed they were provided adequate information related to the role requirements and risks involved with moderation work, allowing them to conduct self-research on moderation and make an informed decision on whether the role is suitable for themselves. Further, this section identified specific interventions, techniques, and coping strategies self-reported by moderators to adapt to their unique work tasks.

Transparency. When in the recruitment process, numerous moderators reported an overall positive experience. They regarded the recruitment team as clear and accurate with their descriptions of the job requirements and the potential exposure to sensitive content. These individuals felt as if they were informed enough to grasp the nature of the job thoroughly. One moderator responded, "During my recruitment process, they already told me that I'll be doing as a content moderator handling disturbing content, so before I enter the training, I am prepared for the job."

Conversely, a subgroup of individuals indicated a lack of transparency and the use of coded dialogue from the recruiter. The respondents stated that the recruiters used words like "confidential, sensitive media, or graphic" when referencing the content exposure leading to a subjective understanding. Furthermore, there was a failure in fully conveying the time exposed to and spent reviewing graphic content. The subjectivity, diverse interpretation of terms, and high-level overview left some feeling unprepared or unaware of the actual reality of work. One participant wrote, "The interviewer disclosed I will be viewing sensitive medias but not much more detail." Another responded, "I didn't expect that I had to view so much graphic media." Concise explanations throughout the recruitment process assisted in the transition to training.

Preparation. After accepting the job offer but before starting training, a few employees researched on their own to fully understand the day to day and requirements of a content moderator. This personal quest for knowledge was said to be a key differentiator in increasing readiness. However, other respondents regarded the content and the potential impact on them as unsettling. After initial exposure to graphic content, disgust, shock, fear, anger, and sadness were the most expressed emotions. Physical sensations included the body tensing, palpitations, perspiration, headaches, and an inability to focus. Moderators reported a disconnect between feelings of preparedness, perceptions of expectations, and the actual reality of content exposure and its impact. This disconnect led to a desire for more transparency and preparation early on.

Due to the ever-changing trends in media, even those tenured in the job reported randomized content populating within their queues that fell far outside of their general categorization. This resulted in a startle activation and required a break from the material. The average duration of time necessary for recovery following the startle reflex lasted 30 s. However, when the startle response was unattended, the fight, flight, or freeze response activated, resulting in a need for "five to ten minutes" to return to baseline functioning. The most prevalent media reported that led to startle response included violent acts, harm to others, and child sexual abuse material, as evidenced by replies such as, "…if it's too bloody or too gory to watch." "It's when I saw child abuse, I needed to pause for a few minutes and just listen to music to divert my attention."

Programmatic Interventions Employed. Aside from generalized operational practices, participants emphasized the importance of the psychological health and safety

programming facilitated by TaskUs and Sutherland Wellness & Resiliency Departments in adjusting to the nature of content moderation. The program provides wellness resources such as psychoeducational training, skill-building groups, individual sessions, e-learning courses, monthly outreach, and recommendations for tooling and breaking strategies/interventions based on research findings. These resources are strategically developed to assist the moderator in reviewing and processing all content levels.

Employees stressed the importance of engaging in wellness training where they could acquire and develop the mastery to help them in times of crisis. Skills and exercises learned from the wellness and resiliency departments that facilitated a return to baseline after startle activation were communicated by the respondents as "physical activity," "breathing exercises," "meditation," "stretching," and "communicating with coworkers." One moderator stated, "Actually, because of all the wellness and interaction, I'm quite all good." Access to the Wellness & Resiliency program was said to be a vital asset assisting in the transition period from training to production, and content moderators interviewed called for more wellness initiatives to be placed in the recruiting and training phases.

4 Discussion

This study addresses a gap in the literature and increases the understanding of moderators' initial experiences with content, startle response activation, and startle habituation. Previous studies on startle response pointed to the emotional, cognitive, and physiological impairment the phenomenon could have on the individual in response to adversarial or unexpected stimuli [12, 18, 28]. This unconscious and protective response was identified in the experiences of content moderators.

Participants in the study were able to identify instances when their startle reflex became activated. This occurred when they were exposed to unexpected graphic media. Disgust, shock, fear, anger, and sadness were emotions they experienced. Physical sensations included body tension, palpitations, perspiration, headaches, and an inability to focus. These responses impacted both well-being and workflow.

Participants identified a reduction in behavioral and psychophysiological reactions over time and described an increased ability to manage and process graphic media. Key elements that reduced the prevalence of startle response included open and transparent conversations from recruiters when describing content exposure and duties of the job to potential moderators. This was supported by prevalent themes such as preparation and enthusiasm. Those candidates who fully understood the reality of the job described an easier transition into training and entering production. Additionally, when in training, content moderators greatly benefitted from in-depth instruction and examples that were diverse in topic and severity; this was evidenced by the following themes: sense of purpose and readiness. Conversely, some individuals felt unprepared as the theme of process ambiguity surfaced in responses.

When in production, most individuals reported impact by content exposure, yet the majority noted adaptive adjustment to their work as evidenced by the theme of habituation. Themes of factors that either harm or facilitate habituation were noted. For instance, the theme of hindrance to habituation indicates that specific environmental influences may be a barrier to adaptive adjustment. Still, programmatic access and a sense of purpose substantially facilitated habituation. Specifically, the psychological health and safety programs and initiatives assisted employees in processing and managing content when in production.

5 Implications and Recommendations

This study suggests a need for further research exploring content moderators' responses to graphic content and the development of interventions or strategies to facilitate habituation. The results of this study support the necessary creation of strategic initiatives throughout the employment life cycle. This includes increased transparency, understanding, expectations, and requirements of content moderation. Each phase will also greatly benefit from the implementation of well-being-focused interventions.

In the recruitment process, recruiters should be as detailed as possible, describing the distinct nature of the occupation. This includes verbally detailing examples of content that the candidate has the potential to be exposed to (i.e., giving detailed examples of content to be reviewed). Lastly, recruiters should emphasize the availability of wellness support, both internally and externally available.

When considering elements and structure of training, wellness resources, and coping, strategy integration is necessary throughout the training processes. Further interventions should center on acclimation to the rapid pace and change of their work tasks and environment. When illustrating examples of content, gradually increasing the graphic nature of the material can lead to greater moderator preparedness, expectations, and ability to process such content. Further, extending the duration of training allows the content moderator exposure to a variety of media, topics, procedures, and policies and decreases the pressure and cognitive overload experienced while learning.

In production, we recommend rotating teammates' dedicated content queues. This increases expectations and preparedness for unavoidable content, reducing the possibility of shock and surprise. Next, moderators should be offered flexible content breaks to be used when the individual is experiencing a startle. This allows the content moderator time to step away and recompose themselves. Operation leaders should emphasize the importance of mental health as moderators may worry about not meeting metric standards and protocols.

6 Limitations and Future Research

No study is without its limitations. While this study's conclusions are derived from participant responses, those responses came from survey questions and not live interviews. This approach was taken for this foundational endeavor to increase participation and facilitate the study across geos spanning many time zones. We were able to gather 78 participants which is considered a large sample for a qualitative study [20]. Future research on the lived experiences of content moderators should incorporate semi-structured interviews to forth expound on participant responses. Consistent with all studies using self-report methods, it is possible that self-report bias may exist in all surveys and interview methodologies. We note that employers interviewing employees is another limitation but would like to highlight that the comments and information are not universally positive. We expended great efforts to honestly uncover the moderator's true experiences. Several steps were taken to limit its potential impact on study findings. For instance, participants provided responses via survey without a live observer. To further encourage honest responses, participants were informed that their data would be secured, not shared beyond the research teams, and ensured the individual participant would not be identifiable.

Second, results were acquired from two companies located in different countries. The current study does not address the cultural differences pertaining to either the country of origin or the company itself. The differences may have influenced how individuals interpret and adapt to the content and address the potential risk of moral injury when reviewing material that falls outside of their accepted cultural norms. We advise future researchers to look into these key factors.

Future research should also focus on biofeedback and content moderation. The industry and academics will greatly benefit from biofeedback research in the form of skin conductance and heart-rate variability. This may provide objective and quantitative data that supplement the current findings derived from subjective and qualitative data. Following the emerging theme of hindrance to habituation, future research should explore whether programmatic psychological interventions are a moderating variable to the identified adverse environmental factors.

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Maturity of Web Services in the Application to Smart City Conception. Case of Optimal Path Finding Services, SSTypes Library, and www.GoMap.Az Project

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Abstract Existing Maturity Models have limitations and describe the problem quite roughly. Information and Communication Technologies (ICT) play a leading role in Information Society and Smart City (SC) development. The Societal Patterns Evolution Model (SPEM) and the Simple Learning Motivations Hierarchy Model (SLMHM) were designed to build a detailed model containing societal and technological components (Gakh in A look at evolution of teams, society, smart cities, and information systems based on patterns of primary, adaptable, information, and creative society, pp 701–704, 2022; Gakh in A look to model of society and teams development based on initial formation, primary, adaptable, information, and creative society patterns, 2022). This paper describes the application of SPEM and SLMHM for the case of practical realization of Optimal Path Finding Service (OPFS) and SSTypes library (https://github.com/dgakh/SSTypes) within the www.GoMap.Az project (https://www.gomap.az). The model allows one to asses these software products, their maturity, impact on the society and economy as well as their shortcomings. The scientific value of the research is concluded in the presentation of a new unique and well-designed maturity/development model. The practical value of the research is concluded in the description of an example of realized products, of a new tool allowing the evaluation of the success of ICT projects and their impact on SC and societal development.

Keywords Maturity model · Smart city · Sustainable development · Web services

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1 Introduction

At the 17th Conference on Computer Science and Intelligence Systems FedCSIS 2022 a paper named "A Look at Evolution of Teams, Society, Smart Cities, and Information Systems based on Patterns of Primary, Adaptable, Information, and Creative Society" was presented. Considered patterns correspond to the development stages (presented in the further text as the Societal Patterns Evolution Model or SPEM), 16 levels of the Simple Learning Motivations Hierarchy Model (SLMHM), and corresponding ICTs were discussed. A match of society's development level and relevant ICT is considered a success factor in ICT project implementation [1]. ICT projects are essential in the realization of SC conception [2]. Smart City (SC) is a socio-technical phenomenon [3].

The project www.GoMap.Az (will be referred to as GoMap in the further text) [4] is the implementation of a web portal providing online geoinformation services covering for the moment of this article writing areas of three countries: Azerbaijan, Georgia, and Armenia. The portal includes Optimal Path Finding Service (OPFS) and runs using the SSTypes library. Part of the SSTypes library is presented as open-source software named SSTypesLT (the authors will refer to both libraries using the name SSTypes) [5]. These software products were designed to comply with the concept of SC. The study of this compliance is very interesting from point of view of both—science and practice.

This paper presents analyses of mentioned software products' maturity according to SPEM and SLMHM. Current research covers a gap concluded in the lack of literature in the sphere of holistic modeling of modern socio-technical systems, such as SC.

2 Theoretical Background and Research Questions

2.1 Prerequisites

The main prerequisites for this study were: OPFS within the GoMap project [4]; SSTypes library [5]; SLMHM [6, 7]; study of development patterns of society, SC, and Information Systems [1, 8].

OPFS is developed using C/C++ as a module that can be compiled into the Dynamic Link Library (DLL), to Microsoft Windows Service, or to command line application with TCP/IP interface implementing a subset of HTTP. The code is platform-independent, so OPFS can be compiled to run on any operating system where C/C++ and Boost library [9] are implemented. The solution includes the C# wrapper that allows using OPFS directly from the C# code.

The SSTypes library is implemented on C# in order to speed up data sanitation and processing. The library contains types that are fully compatible with C# built-in types, such as *int* and *double* but provide additional functionality. OPFS uses part

of SSTypes rewritten to C/C++. The studied literature, in addition to the above, included an analysis, first of all, of papers on Maturity Models (MMs) of SC, software, quality, etc.

2.2 Maturity Models

There is no single generally accepted formulation of what SC is, but the role of ICT in the implementation of the SC concept is huge [2]. ICTs are an important tool for the transformation of industrial society into an information and knowledge society [10]. SC can be considered a socio-technical system [3]. The ability to apply MMs, SPEM, and SLMHM was discussed in [8].

The studied MMs include: SC Development MM [11], Software Capability MM (SW CMM) [12], Knowledge Management MM (KMMM) [13], ISO 37xxx standards relating to the establishment of SC operating models for sustainable communities [14], ranking SC models [15, 16], the SC Maturity and Benchmark Model [17], three MMs which holistically approached a city [18, 19], information governance MMs [20], ISO 15504 [21], COBIT 4.1 Process Maturity [21], Asset Management Maturity Scale, the Capability MM [22], Portfolio, Program, and Project Management MM (P3M3), the People Capability MM, Testing MM [22], enterprise content management [23], Capability maturity levels for research data management [24], EIM MM [25], Records Management MM [26], Crosby's Quality Management Maturity Grid [12], the model of Business-IT Alignment Maturity [27], the foundation for ongoing process improvement [28, 29], Business Process MM [29], the risk MM [30].

Maslow's Theory of Human Motivation [31, 32] is proven and effective in many cases across many disciplines, including business, management, marketing, parenting technology, education, and psychology [33, 34]. However, there is incompleteness observed in the model and its criticism [33-36]. SLMHM was developed to avoid the disadvantages of Maslow's Theory [6] and was corrected to be compliant with the Plan-Do-Check-Act cycle that makes it applicable in management [7].

2.3 Research Questions

The maturity of OPFS should be evaluated by taking into account their contribution to SC. As a result, this research addresses the following research questions:

- **RQ1**: To what extent does the OPFS contribute to the SC?
- **RQ2**: How mature of the OPFS can be evaluated?
- **RQ3**: To what extent SPEM and SLMHM can be used to evaluate the maturity of real software products?

3 Research Methodology

This research was carried out according to the recommendations given in [37]. The research used a methodology similar to the methodology for creating an education development strategy [6], namely, the identification of the main components of the system and the creation of a model for their development and their interaction. The research was based on an expert evaluation of mentioned software products according to the SLMHM and SPEM. The expert evaluation was used due to the absence of clear methodology (SLMHM and SPEM are young models), unstructured input and high calculation volumes need [6]. At the same time, an Artificial Intelligence tool that is aimed to implement such evaluation is under development [38]. The method of acquiring knowledge was rationalism. Both inductive and deductive reasoning was used.

This research relates to the following three levels of abstraction: (1) *Theory*. SPEM and SLMHM are two combined theories [1]; (2) *Concepts*. Building blocks of SPEM and SLMHM, first of all, the patterns and levels; (3) *Indicators*. Actual features of considered software products juxtaposed with the patterns of SPEM and levels of SLMHM. The patterns of SPEM and the order of SLMHM level can be considered variables.

4 The Model

4.1 Components of the Model

To create a model for the development of mentioned software products based on SLMHM, the following components of the system should be taken into account (It is more convenient to consider the model as a system). The environment is not finite nor limited, which is why the presented system has no boundaries but is considered as a system [39]): (1) *Developers*. This category includes developers of software, hardware infrastructure, and data; (2) *Staff*. This category includes persons who operate the system; (3) *Users*. These are both people and other systems who use the GoMap services; (4) *Environment*. In general, this includes everything that does not belong to the previously listed components, although in the strict sense of each component, all other components can be related to the environment to some extent. Gakh [6] contains a description of a similar approach and the environment for the development of education, which allows for a better understanding of it.

Multiple Criteria Decision Analysis (MCDA) approaches can be used with SPEM and SLMHM. Such approaches can be useful to get a quantitative evaluation of software products and their impact on the economy and society [40, 41]. In this case, other components can be used. But it makes the model and calculations huge and out of the scope of this paper.

SLMHM Levels

The following text outlines analyses of GoMap, OPFS, and SSTypes library for the time of writing this article:

Level 1.1. Desire. Market research showed the enormous benefits to the country that can be derived from the implementation of the OPFS and GoMap. The advertisement gave the population information about the availability of OPFS and its capabilities. Available similar services such as Google Maps [42] are designed for global use, which excludes the implementation of the desired local features. The implementation in GoMap of the functionality required for Azerbaijan is both fast and cost-effective.

Level 1.2. Intention. The initiator of the GoMap project was the Ministry of Culture and Tourism of Azerbaijan. The project was implemented by SINAM Company [43]. The public and private sectors participated in the implementation of the project.

Level 1.3. Feasibility. The main problems in the implementation of the GoMap project were technical problems associated with the collection and processing of a large amount of data and the in-house development of online map software.

Level 1.4. Action. The implementation of the GoMap project included, first of all, the collection and structuring of data and the development and running of the online map software.

Level 2.1. Evaluation. In the GoMap project, the evaluation was provided by the following methods: the development was evaluated by tests and feedback from service personnel and users; the maintenance personnel was assessed by failures of hardware, networks, and means of standard software such as operating systems and database management systems; users were assessed through focus group surveys; environmental risks were assessed, including an assessment of the needs for OPFS and competing products on the market.

Level 2.2. Improvement. In the GoMap project, the improvements were ensured by the following methods: development was improved by debugging, upgrading algorithms, and code refactoring; maintenance personnel was improved by updating system software; improving interaction with the users was carried out by informing them about the new capabilities and functionality of the product; environmental risks were mitigated by improvement of their assessment.

Level 2.3. Alternatives. In the GoMap project, the alternatives were ensured by the following means: various programming languages; web and mobile applications; proprietary and open-source software; multiple feedback paths for users have been created; provision of 3 languages—Azerbaijani, English, and Russian in data and user interface; alternative business processes and products (GPS tracking resource www.yollar.az and AzNav car navigator); SSTypes library alternative capabilities.

Level 2.4. Innovations. The GoMap project as a whole is an innovation. Innovations have also emerged at the level of system components. The innovative data collection procedure made it possible to create an electronic map in the shortest possible time. The use of Postgre SQL was an innovative approach in Azerbaijan. The GoMap OPFS is an innovative solution. It was developed in-house based on the modified A* algorithm taking into account traffic rules and actual traffic jams. The

SSTypes library is an innovative solution, allowing, among other things, to perform text-number transformations up to 4 times faster than the standard approach [5].

Level 3.1. Reward. GoMap project is open for integration with other systems through open Application Programming Interface (API), REST, JSON, and XML. Integration includes connection to other systems, e-government, taxi services, and so on giving them the benefits of online maps and the Street Addressing System.

Level 3.2. Optimization. The interaction of the GoMap project as a whole with other systems is not optimized. It is necessary to accumulate innovations and the parallel development of user systems, which is currently beyond the scope of the project. The SSTypes library was developed to optimize GoMap modules.

Level 3.3. Synergy. In the GoMap project, OPFS was tightly linked to the Street Addressing System. The SSTypes library is the best example of technology achieved synergy within the scope of the GoMap project: its types can be used instead of and together with built-in C# types; the structures have the smallest footprint. But a synergy between the GoMap project and external systems has not been achieved.

Level 3.4. Extraordinary. In the GoMap project, the level of extraordinary has not been reached. At the same time, the SSTypes library can be considered extraordinary within the scope of the project.

Level 4.1. Information. Strongly speaking in the GoMap project the level of information has not been reached. At the same time, the publication of scholarly articles and presentations at scientific conferences have begun. A process that can relate to this level is information about the traffic jams being generated automatically and entered into OPFS.

Level 4.2. Streamlining. Receiving, transforming, and using real-time traffic data is an example of streamlining. The usage of a subset of JSON and HTTP in OPFS is an example of streamlining within the project scope.

Level 4.3. Expansion. In the GoMap project, the level of expansion is not sufficient. However, one example of the expansion is the inclusion of Georgia and Armenia in the project as well as plans to add other countries in the future.

Level 4.4. Totality. The expansion leads to the pervasive use of OPFS everywhere and in all areas of human activity. It should be taken into account that this level is theoretical, not achievable, and serves to set and formulate development goals. The goals of the GoMap project can also be represented by its pervasive use everywhere and in all areas of human activity.

5 Discussion of Findings

5.1 Technical Findings

GoMap, OPFS, and SSTypes were modeled separately. OPFS and GoMap portal were considered together in many cases, and SSTypes library was considered separately. GoMap portal includes several services as alternatives, so it satisfies SLMHM Level 2.3, Alternatives. OPFS provides only one functionality but in different ways.

SSTypes significantly differs because it does not provide any service, rather it is a building block for other products. It can satisfy Level 2.3 only within the scope of these products. SC is a socio-technical system [3]. Assurance that the societal level is the same or higher than that of implemented ICT solutions is a recipe for success [1].

OPFS can reduce transportation cost and gas emission, helps emergency services to reach target sites, increase comfortable navigation, and so on. OPFS benefits many of the 17 United Nations Sustainable Development Goals [1, 44]. Observation shows that level of GoMap OPFS is higher than the level of users (for example, drivers in rural areas prefer to ask about the right path of locals, rather than use navigators). It leads to problems with the self-sufficiency of the services and needs inside support. At the same time, the service is an example of technology benefiting SC and is a step to the realization of SC conception.

The structures and functions of the SSTypes library effectively fit into the C# language and interact with its fundamental structures and functions (Int32, Double types, Nullable value types, etc.). It is also fully integrated with C# and C++ modules and provides exceptional performance and footprint. The library transforms data taken directly from the source. So, one can claim that within the project the SSTypes library satisfies SLMHM Level 4.3, Expansion. SLMHM Level 4.4, totality is not achieved in many practical cases. So, the SSTypes library could be an example of a software product that satisfies the maximum SLMHM Level but is within the scope of one project.

SLMHM Level 2.4, Innovations is quite a high level, although it is just the 8th level of 16. It is the final level of the Adaptive Society Pattern (ASP) [1]. ASP relates to reactive approaches to changes and solving known problems. The main aim of ASP is to achieve adaptation to changes and sustainability as result. Sustainable development requires the development of the Information Society Pattern (ISP) and achieving SLMHM Level 3.4 [1]. GoMap achieved SLMHM Level 2.4, Innovations. The higher levels are also achieved to some extent. Section “The Model” shows that achievement of SLMHM Level 3.1 and higher depends on users and external systems as significantly as higher the level. SLMHM Level 3.3, Synergy, requires tight communications with users (and external systems).

GoMap OPFS is used within the scope of the project. The ability to implement these services as web service, windows service, and DLL (as well as UNIX/Linux utility) allows one to strongly affirm that OPFS satisfies SLMHM Level 3.3, Synergy. But they are not achieved SLMHM Level 3.4, Extraordinary, because GoMap project has services that were not affected by OPFS. If one considers OPFS within the scope of SC, it satisfies SLMHM Level 2.4, Innovations as well as GoMap project does.

6 Conclusions

The contribution of OPFS to SC can be evaluated using SPEM and SLMHM. For OPFS implemented in GoMap, one can say that it satisfies SLMHM Level 2.4, Innovations, and belongs to ASP [1]. This evaluation determines how mature the service is. Thus the research questions RQ1 and RQ2 are answered. SPEM and SLMHM were used to evaluate the maturity of real software products for the realization of SC conception. The assessment was carried out by the expert evaluation qualitatively. Quantitative evaluation requires huge calculations and processing of nonstructured data. Speaking strongly, there is no methodology for quantitative evaluation according to SPEM and SLMHM at the moment of this paper's writing. If such a methodology existed, it would require a large amount of computation and the use of Artificial Intelligence technologies. The research question RQ3 is also answered. SPEM and SLMHM are young models presented in a theory. This research is the first study of an actual case. These facts highlight the scientific and practical value of this research.

The practical advantage of the work is concluded of structuring of the practical achievements according to qualitative levels and patterns. The structure in its turn showed advantages and shortages of ITC solutions and allowed the engineers to plan their future development. GoMap project and its OPFS have achieved the SLMHM Level 2.4, Innovation, and need future development in ISP [1]. SSTypes Library achieved SLMHM Level 4.3, Expansion which means that its current development is concluded in the inclusion of additional functionalities and penetration to as many solutions as possible.

The time complexity of the proposed technique requires significant effort to gather data and a tool to perform necessary calculations. Integration of data gathering into project management can simplify the data gathering. AI tools can simplify calculations. Expert expectations concluded in getting benefits from the method for projects with a budget of USD 1 million or higher.

6.1 Disadvantages of the Research

The scope of this paper did not allow presenting of more detailed analyses. It could be considered a disadvantage. Another disadvantage is the absence of a methodology of quantitative assessment according to SPEM and SLMHM. At the same time, the order of level is a quantitative indicator. Expert evaluation could be considered as a subjective appraisal although this research was carried out based on 14 years of experience of GoMap project development. The lack of sociological study could also be considered a disadvantage. But within the scope of this research, marketing studies carried out by SINAM company give enough information to implement the initial analyses presented in this paper.

6.2 Future Research

As it was mentioned before, the disadvantages of this research are the absence of a methodology, the high volume of calculations, and the requirements to process unstructured data. Future research, first of all, should include: (1) studying other cases and performing as deep analyses as possible; (2) developing an AI tool to help analyses based on gained experience; (3) developing the methodology to assess the software products and ICT projects as a whole within SC scope.

The development of an AI tool is already started as an open-source project. The first project aimed to evaluate cases in the sphere of education [6, 38]. Because this research is based on the same approaches that are used in [6], the project will contribute to the evaluation of software products and ICT projects also. Assessment of societal structure is also an exciting research direction. Such research is in the field of sociology. Combined ICT and sociology research promises very interesting outcomes.

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Modification of Dijkstra's Algorithm for Best Alternative Routes

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Abstract Dijkstra's algorithm (DA) is classified as a basic strategy for searching minimal routes from one point to another and found useful in several applications, such as in network routing protocols, setting of irrigation lines, and road transportation networks. This algorithm minimizes the time and distance covered in a mission-critical venture such as a road and fire accident rescue mission. However, the shortest-path-finding technique, as proposed by Dijkstra, may take the longest due to several constraints, such as queues formed from roadworks, bandits, kidnapping, or accidents, thereby making the shortest path inaccessible. This study aimed to develop a Modified Dijkstra Algorithm (MDA) for finding alternative routes moving from location A to another location B when the shortest route is inaccessible. The objectives of the study were to design a variant of Conventional Dijkstra's Algorithm (CDA); implement and evaluate its performance. The study used a 40-node graph with varying weights and arbitrary source nodes with designated destination nodes. Both CDA and MDA were implemented in a Python environment. The probabilities of the existence of alternative routes to the shortest path were derived using a random number generator. The comparative evaluation of both algorithms was carried out and the results were depicted using tables, graphs, histograms, and ogives. The average distance covered, number of routes, and probability cost was used as lead indicator for evaluation performance. The findings deduced that the MDA model provided alternative routes better than the CDA, especially when the minimal route is impassable, and proffered a better means of navigation whenever the shortest path is under constraints for safety and accessibility. This study recommends Modified Dijkstra's Algorithm model to be used in Courier and logistic services, transportation systems, and as well as in engineering companies.

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Keywords Alternative routes · Dijkstra's algorithm · Shortest route · Cost matrix · Probability cost · Random number

1 Introduction

The shortest route is concerned with determining a route with the least distance connecting two specified nodes. The nodes are referred to as source {initial} and destination (specified), respectively. In this study, however, the focus is on the algorithm, which notes the shortest distance from one point to another using data structures. It is, however, observed that traversing the shortest paths may be more time-consuming than taking longer routes in some situations. This may be due to certain extraneous factors which have not been considered in the conventional Dijkstra's algorithm. Such factors include unexpected limitations or hindrances on the identified shortest path that make it impossible to traverse the shortest route faster than longer ones. The shortest route is an essentially pragmatic consideration, especially in the general transportation system and urban transportation in particular. Therefore, this study considers such external variables when applying Dijkstra's algorithm and hence, deduce it results in a variation of the conventional Dijkstra's formulation, thereby solving the problem. The computational complexities of DA and its variant proposed in this work would be computed to determine the variation's penalty and establish whether the variant's introduction is worth its computational perspective resources. The shortest-path computations are said to be one of the challenges in graph theory, given a graph with parameters on its nodes and edges to determine the shortest path among nodes [1]. Edsger Dijkstra developed DA in 1959 [2]. It employs greedy techniques for solving single-source shortest problems (SSSP) having nonnegative with a minimum number of edges [3]. It frequently chooses from the unselected nodes, node v, closest to source s declaring the path with minimum distance from s to v once the edges of v can be scanned to reach the desired destination [4].

Dijkstra uses either a directed or non-directed weighted graph, having distance and priority queue, of which all its components are modified to solve different problems [5]. Vertices and edges in a graph can have different representations; the distance can have a different purpose with varying dimensions. The priority queue can have non-identical contrast relaxation. It can also find the minimum path costs from the initial point to another destination by putting to stop the algorithm once the minimum route is reached. DA is also applicable to finding the minimum path from one city to the other, making the nodes represent cities and the driving distance between pairs of cities be the edges linked together by a road. The minimal route that can be obtained from one location to another seems to be a significant challenge in a routing network. Many applications and products were established to proffer solutions to these difficulties by developing different algorithms. In routing network, challenges such as handling cities crisis and drive guide systems are unavoidable, so there is a need for prompt intervention [6–8], and it can be corrected through the modification of Dijkstra's algorithm.

Scientists and travelers face many problems with tour schedules. As a result, application software has evolved and been launched to combat similar problems by providing a structured road network route. The past scholars showed their different shortest-path algorithms in solving a valid road network route; somehow, the problem still exists. Hence, introducing a new shortest-path algorithm will enhance and provide alternative routes for transporters and road users over the road network [9].

2 Conventional Dijkstra's Algorithm (CDA)

The minimal route from an initial node to other nodes could be found given a source node in the graph. Two sets of vertices are preserved with a given source as root, one set is contained with vertices, and the other set comprises vertices yet to be contained. There is a need to search for a vertex in a different set, mainly from the set not yet included, representing the shortest distance from the initial node at any algorithm stage.

Conventional Dijkstra's algorithm achieves a time complexity of $0(n^2)$, and its advantage is that it does not need to explore all edges, mainly when the cost or some of the edges are huge. Its disadvantages are that it deals with only nonnegative directed or non-directed weighted edges in a graph, and applies only to connected static graphs, which perform a brute-force search known as a greedy algorithm concept.

The minimal route from the initial point to the other specified point could be done using the designed graph transposed. The distance predecessor and status are labeled on each node. The node's predecessor stands for the node that comes before the given node in the minimum route from the source, and the node's distance represents the minimum distance. A node's status could be long-term or short-term. When a node is made long-term, it is already contained in the shortest path. If necessary, short-term nodes can be renamed, but nodes that have been made permanent (long-term) cannot be renamed.

Some steps are involved in finding the shortest path in Dijkstra's algorithm which is stated thus:

1. Put the distance from the initial node to 0 and the remaining distance to infinity.
2. Put the current node to the starting location (source)
3. Name or label the current node as visited
4. Put the distance from the starting point to the adjacent node at the minimum of its current distance. The sum of the weight of the edge from the current node and the distance from the source to the current node for all nodes adjacent to the current node.
5. From the set of unvisited nodes, randomly set one as the new current node on the condition that there exists an edge to it such that it is the least of all edges from a node in the set of unvisited nodes. To reiterate: The new current node must be unvisited and have the shortest cost edges linking it to a visited node. This is

achievable by looping around all adjacent unvisited nodes to those visited nodes, retaining the node with the shortest cost edge.

6. 3–5 should be repeated until all nodes have been identified as visited.

2.1 Related Studies

Dijkstra's algorithm (DA) helps to solve optimization problems by considering node weight when computing the shortest path. It has a computational complexity $0(n^2)$. Dijkstra's algorithm has several advantages: obtaining the minimum path for every pair of nodes, between two nodes through several specific nodes, and from a given vertex to all other vertices [10]. Author [11] simulated a logistic system using the Dijkstra's algorithm. The technique experimented on an instance of 60 nodes. From the computational results, Dijkstra's algorithm gave 100% accuracy in solving the travelling salesman problem (TSP). The work by [12] modeled logistic companies' efficient delivery of items as a classic travelling salesman problem. They obtained an optimal solution using a modified Dijkstra technique. The Dijkstra's algorithm was modified to recognize the priority of some clusters of routes based on their distance and weight. In some instances, the experimental outcome of the method yielded a comparative efficiency of 478% and a computation time of 48.1%. This showed that the modified method with priority outperformed the state-of-the-art Dijkstra technique.

The author [13] concluded that the shortest-path search is an important basic tool for various applications of graph techniques, especially online social networks. Even then, managing today's social networks computationally is a great task. Spanning trees are simple to create, close-packed compared to real graphs, and extend across machines to allow queries to be parallelized. Six sizeable social graphs from Renren, Facebook, and Orkut were used to show its scalability and efficacy, the biggest of which has 43 million nodes and 1 billion edges. Strategies for incrementally updating Atlas as social graphs shift over time were defined; 35 regular snapshots of a Facebook network were used to capture graph dynamics and demonstrate the efficiency of Atlas. It was tested on numerous graphs application, generating similar results.

Authors [14, 15] proposed an improved self-adaptive genetic algorithm based on the genetic algorithm principle by encoding the chromosomal model. They changed the encoding parameters to boost the genetic algorithm. Their results also showed that the enhanced genetic algorithm DRSP-GA obtained better global optimization solutions that quickly adjust to newly introduced transportation than the A* Algorithm and DA for the shortest-path problem. Authors [16] identified critical events on the critical path using the critical path method (CPM) so that resources could spend minimal time determining the outcome. The critical path was calculated using three parameters and updating the Dijkstra's algorithm [17] conducted an experimental study to ascertain the effectiveness of human strategies in solving the vehicle routing problem (VRP) compared to heuristic techniques. Motivated by the need to know

the usefulness and limitations of human decision-making, especially in completing TSP-related tasks such as clustering and route building, the discrete choice model was developed to evaluate the underlying motivation of participants in their choices of some attributes during the tour building process of clustering and route finding. The work was based on three (3) hypotheses. A total of 112 respondents, aged between 18 and 32, participated in the experimental study, most novices in routing. The costs of the attributes by each participant and instance were also evaluated using multinomial logistic regression. The analysis also included splitting the clustering and routing performance to independently compute the optimal solution. Humans' performance was then compared to the nearest neighbor's performance. Their findings showed that while humans often could not generate optimal solutions, they typically performed better than the worst cases of these heuristics and worse than their best cases, irrespective of size and vehicle capacity.

Additionally, they reported that poor clustering leads to inadequate solutions in the nearest neighbor heuristics and others. They concluded that interface design should avoid too many feedback options and focus on obtaining good clusters to foster better solutions. Studies by [18] deduced that three algorithms could be another method of discovering the solution to the minimal route. In this study, DA outperforms the other two algorithms in getting the optimal results. Author [19] worked on a system termed Gateway KLIA2 developed using Dijkstra to help users navigate from one location to another through a survey. The wheelchair users could find the minimum distance for an inside traverse from the source to the destination.

The study of literature and related works enlightens the choice of approach, technologies, and models used to advance this research problem. A brief outline of the different methods, input constraints, progression models, and changes in data structure [20]. There have been several factual studies on the efficiency of shortest-path algorithms [21–27]. [28] conceived and published the initial polynomial time, greedy-based techniques for an optimal solution in 1956 [29–31]. Other classic books, implementations, and practicable explanations of Dijkstra's algorithm are made available in [32–34].

2.2 Methodology

The conceptual framework of the study is presented in this section. Its design and accompanying elements, such as process chart, hierarchical processing framework, graph, and computational flowchart, are also presented. The conventional Dijkstra's and proposed modified Dijkstra's algorithms, the cost matrix, and how to generate its elements are discussed. The 40-node graph used for the study is also presented.

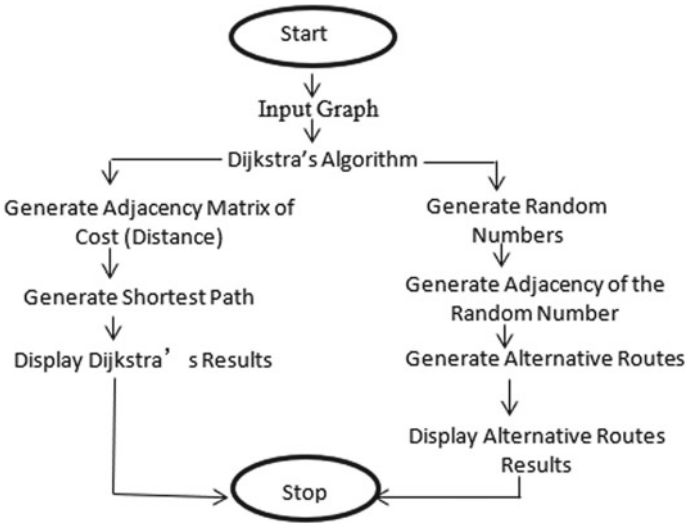

Fig. 1 Process chart of the conceptual framework

2.2.1 Conceptual Framework

Figure 1 represents the process flow of the conceptual framework. As stated in the diagram, this entails the component required for each section from the start to the end of the process. It describes the processes involved from the input graph, implementation of the algorithms for Dijkstra's, the modified Dijkstra's, and generation of random numbers resulting in all possible routes, including the shortest and alternative routes (path) justifying the result. Finally, the Dijkstra's and the modified routes will be obtained. Figure 1 consists of the various processes required for this research work to enhance the flow and design from the start to the stop process. This is further illustrated in Fig. 2, called the hierarchical representation of the framework, which categorically spelled out each section's requirements. This presents the input data to be processed and how to manipulate the data to give the required results at the final stage of implementation. It is classified into three sections: input, process, and output. The input section captures the necessary parameters and input for the graph. The formulated weighted-directed graph's data is processed using a cost matrix in the process section. This is accomplished using DA and MDA the desired results are captured in the output section.

2.2.2 Graph Formulation

A weighted-directed graph with forty nodes A to $M1$ (40-Nodes) illustrates cities (nodes) and distances (edges) in this study as the data set shown in Fig. 3. The graph is designed and transposed into a routing network of all vertexes stored

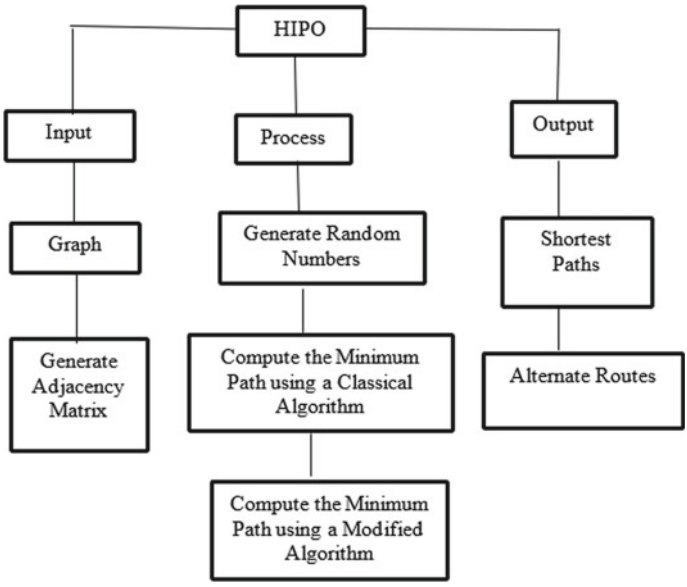

Fig. 2 Hierarchical representation of the framework

$V(v0, v1, v2, \ldots, vM1 \in V)$. The weights of each adjacent vertex are stored as $W(w0, w1, w2, \ldots, wM1 \in W)$. Calculating the components in graphs involves some steps as thus:

1. Initialize $S = \{s\}$, $V - S(v0, v1, v2, \ldots, vM1 \in V)$ Pick the initial node(s) 'v_j' and let $D(j) = \min$

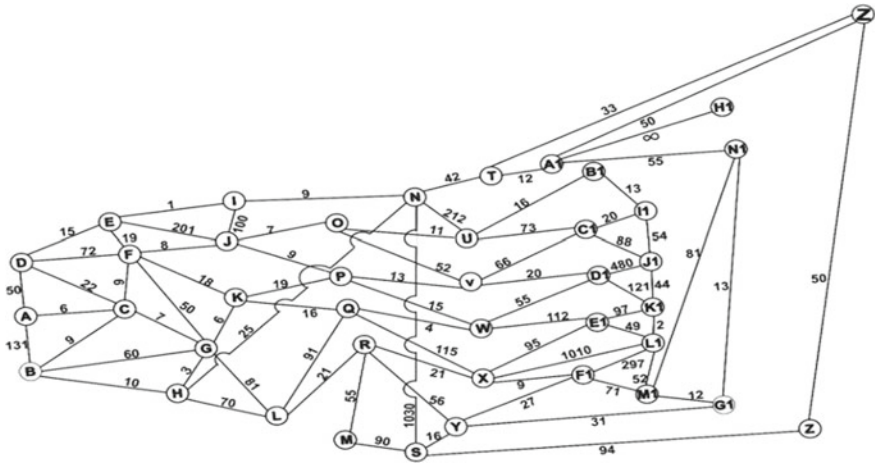

Fig. 3 Transposed 40-node weighted graph [35]

2. Change the initial node to 'A' to no 'v_j' $\in (V - S)$ and $D(j) = D(i) + L(i, j)$, if $D(j) > D(i) + L(i, j)$
3. Repeat (1) and (2) until the minimum path or route is obtained. The edges are represented in kilometers between nodes.

The proposed modified Dijkstra' algorithm was invoked and carried out on the designed network graph. A graph is said to be an abstract representation of a network consisting of edges, the road, and nodes representing intersections. The tremendous advantage of using a network as an abstract graph is that it can be used to represent any network. It could be the internet, where data are sent via as short a route as possible, road networks, etc. This makes graph algorithms applicable in a wide variety of contexts. The weighted-directed graph in Fig. 3 has 40 nodes (vertices) from A to MI; edge cost is the distance in kilometers from one node to another. From Fig. 3, the distance from node A to node B is 131 km (Figs. 4 and 5).

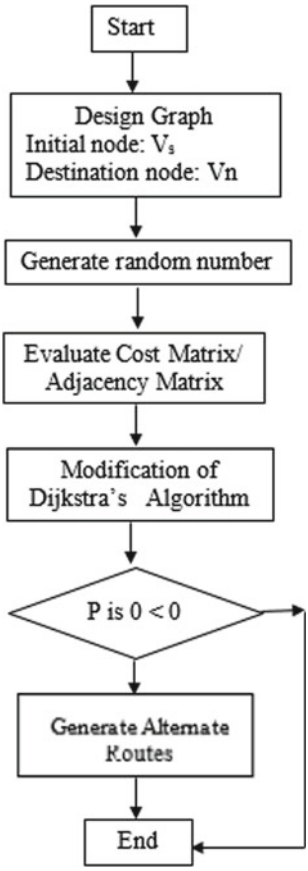

Fig. 4 Flowchart of Dijkstra's algorithm [36]

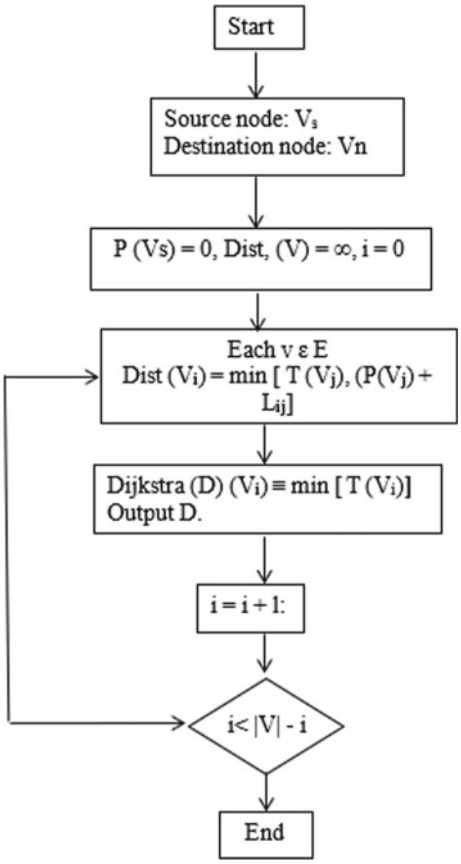

Fig. 5 Flowchart modified Dijkstra's algorithm [35]

2.3 Modification and Introduction of the Cost Matrix

This section presents a modified Dijkstra's algorithm by introducing a probability cost matrix assuming other routes would be available for use other than the shortest path as proposed by Dijkstra. In that case, the availability of routes is the main priority and not the minimum distance covered. The probabilities assigned were generated using a random number generator module of the computer program, and it was assumed that as the probability tends to one (1) that a particular route would always be available and as it tends to zero (0) such a route is not accessible or available for use as developed for this study. In some scenarios, the shortest routes might not be accessible due to some circumstances. In such a situation, the probability that other routes would be available should be considered since the shortness of routes is no longer interesting. Therefore, we present a modified Dijkstra's algorithm by introducing the probability that other routes may be available other than the path with the least distance covered. In Fig. 3, the vertices (nodes) of the graph can be

said to represent cities and the edge path or cost edge (weight) represents the driving distance from one city to the other. The application of DA will help find the route with the minimum distance between one city and all other connected cities. However, in situations where the shortest path is not accessible due to constraints such as traffic congestion, damaged roads, and accidents, there should be an alternative path to ply. Thus, the classical Dijkstra's algorithm was modified to overcome the constraints.

The New modified Dijkstra's **algorithm** introduced is as follows:

I: Procedure DIJKSTRA_ ALGORITHM (N, COST)

Capture: Weighted Graph $G = \{V, E\}$ and its vertex s (40-node graph)

Input the initial node, the specified/destination node.
/*V is nodes labeled (A to MI).
COST represents the cost matrix (distance)
/* Compute the distance from node A as the initial node, to every other node (destination as specified) on the weighted graph */
Place (Q, v, $d_{v)}$ // initialize vertex priority in the priority queue

II: T = (A); /* Initialize T to initial node*/

for i = 2 **to** MI **do**

III: DISTANCE [i] = COST [1, i],

end

IV: **for** i = 1 to V – 1 **do**

Pick a node u in N – T such that DISTANCE [u] is the least value:
Sum = u + T:

V: **for** each node d in N – T **do**

DISTANCE [d] = minimum (DISTANCE [w], DISTANCE [u] + COST [u, w]);
If (DISTANCE [u] + COST [u, w]) < DISTANCE [d]
then PREDECESSOR [w] = u **else** go to step iv
end
end

VI: **end** DIJKSTRA_ ALGORITHM

VII: Compute the least route from the initial node I to the given specified node j

VIII: Generate random numbers for all the edges using Linear Congruential Generator

$X_{n+1} = \alpha(X_n + C)$ modulo m
*/An initial seed to start is required */

IX: Arrange the results (probabilities) in ascending order

X: Start with routes having the highest probability (pick a route at random in case of a tie of probabilities)

XI: Record the run time of each route
XII The runtime is captured in order of efficiency
XIII: Stop

The methodology involved in this research work could be classified into two main sections:

i. Generate and update the cost matrix introduced by probabilities and
ii. Modify pseudocode for Dijkstra's algorithm as presented in this section.

3 Results and Discussion

Analysis of Results for Dijkstra's and the Alternative Routes. The modification in this study introduces a novel component to the CDA in the form of probabilities generated randomly. The MDA was implemented on a designed 40-node weighted graph in Python. The MDA was able to generate all possible routes and enabled the identification of the minimal path. Using the same graph G illustrated in Fig. 3, each graph's node direction was specified. The alternative routes are classified based on the probability ratio of the fact that the *probability cost*' on route (node–node) tends toward one (1) or can be approximated to one (1) or ($P \geq 0.45$), which implies that such a route is available for use and can be accessible but when it tends to 0 ($P < 0.45$) such a route is said to be non-available, and it cannot be accessed.

To evaluate the proposed modified Dijkstra's algorithm, the implementation was carried out on ten different source node–destination node pairs on graph G, each having their source node as **A**; other specified nodes selected include **P**, **Z**, **T, M1**, **H1**, **H**, **S**, **X**, **D1**, **G1**, covering most of the weighted designed graph. The results were presented in Table 1, with titles such as specified nodes direction, the total number of possible routes (**TPR**), the shortest route or path (**Dijkstra's**), distance covered by the shortest path (**D**) in Kilometers, number of alternative routes (**NAR**), available alternative routes (**AAR**), and the number of non-available alternative routes (**NAAR**). The shortest paths between the source destinations were obtained using Dijkstra's algorithm. The distance covered and all possible alternative routes were calculated for all obtained routes.

The execution time taken for each node was captured, and it was noted that the farther the destination node is from initial/source node A, the longer the execution time required, and the nearer it is, the lesser the execution time required.

Graph G was transposed into a routing system (road network) to map out the alternative routes, as depicted in Table 1. At this stage, only the available alternative routes were considered together with Dijkstra's, which is strategically represented in graphical or pictorial diagrams. The specified node A to P and node A to MI will be a showcase for this study, as shown in Figs. 6 and 7, respectively. The routes with the color ***GREEN*** on each diagram represent Dijkstra's shortest path. In contrast, the routes with the color ***RED*** represent the available alternative routes from initial node A to the specified destination node on the graph. Therefore, the research gap in finding alternative routes was established.

Table 1 Results obtained for Dijkstra's and modified Dijkstra's routes

S/N	Specified nodes	TPR	Dijkstra	D (km)	NAR	AAR	NAAR
1	A to P	33	a, c, f, j, p	32	32	8	24
2	A to Z	42	a, c, g, h, n, t, z	116	41	4	38
3	A to T	15	a, c, g, h, n, t,	83	14	2	12
4	A to MI	1209	a, c, g, h, n, s, y, g1, m1	110	1208	292	916
5	A to H1	99	a, c, g, h, n, t, a1, h1	103	98	22	76
6	A to H	12	a, c, g, h	16	11	1	10
7	A to S	27	a, c, g, h, n, s	51	26	3	23
8	A to X	77	a, c, g, h, m, r, x	122	76	13	63
9	A to D1	125	a, c, f, j, p, v, d1	65	124	36	88
10	A to G1	104	a, c, g, h, n, s, y, g1	98	103	26	77

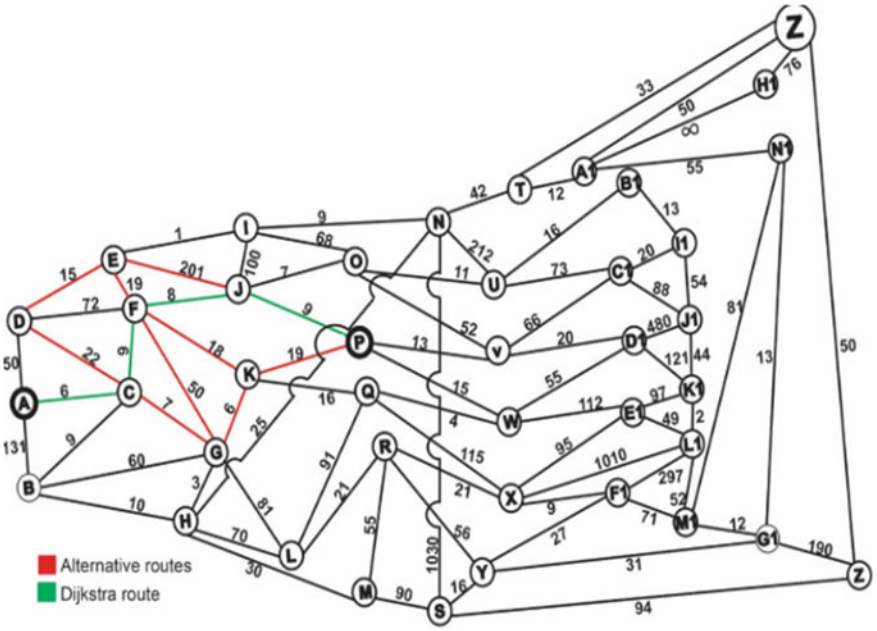

Fig. 6 Graphical representation for best alternative routes of initial node A to specified node P

3.1 Performance Evaluation and Discussion

The best four (4) routes (paths) with higher probabilities were selected and compared with that of Dijkstra's path (route) to measure the performance and effectiveness of the MDA as presented in Table 2. Figure 8 presented a bar chart of distance versus each of the selected best routes to that of Dijkstra's. It could be stated that

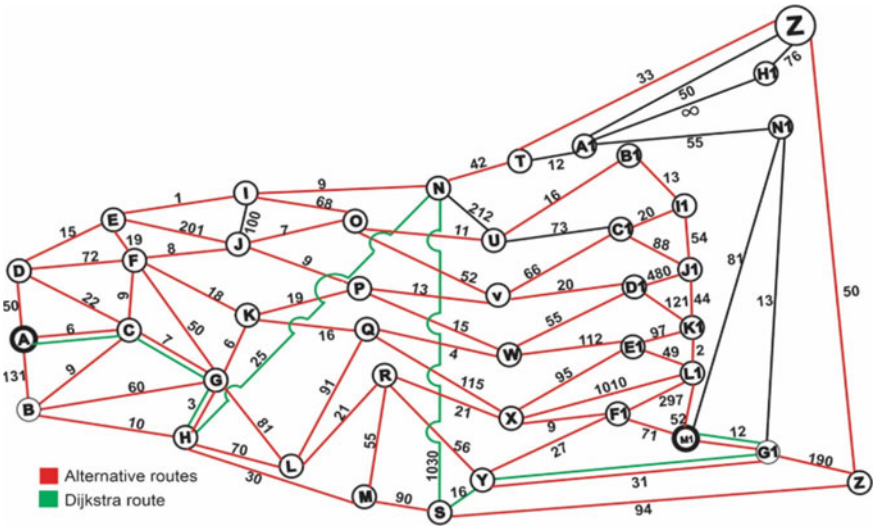

Fig. 7 Graphical representation for best alternative routes of initial node A to specified node M1

Dijkstra outperforms the alternative routes because it remains efficient in searching for the shortest path with minimum distance covered in all, although with fewer probability values. Figure 9 also represents a bar chart based on probability from Table 2; it is evident that the alternative routes outperform Dijkstra's in a broader range, showing the research work's significance. To further bolster this fact, Figs. 10 and 11 in pie chart were presented to show the percentage ratio of each best available alternative route compared to that of Dijkstra's for specified nodes A to P and A to M1, respectively. From Table 2, it is evident that the selected best alternative routes 1–4 from the new modified Dijkstra's have a higher probability ratio that can be approximated to one (1), indicating that the routes are more readily available for usage at a time than the Dijkstra's routes from the ten nodes considered. It should be noted that the proposed model termed ***'modified Dijkstra's algorithm'*** performs favorably well, achieving the aim of this research with slight variations in some instances, although at a higher computation time due to the weights and size of the graph.

3.2 Comparative Evaluation of Dijkstra's Best Alternative Routes Using the Pie Chart

Figure 10 implies that in the direction of node A to P, Dijkstra's path with 22%, which is the minimal distance covered, shows a higher performance ratio compared to the best available alternative routes with 19% and 20%, respectively. While in Fig. 10, the best available alternative routes outperformed Dijkstra's with variations

Table 2 Comparison of Dijkstra's route to selected best alternative routes based on probabilities

Nodes	Best routes selected	Distance (km)	Probability
A to P	Dijkstra's	32	0.5875
	A to P alternative route 1	42	0.512
	A to P alternative route 2	52	0.51
	A to P alternative route 3	79	0.5283
	A to P alternative route 4	253	0.536
A to Z	Dijkstra's	116	0.4067
	A to Z alternative route 1	241	0.454
	A to Z alternative route 2	167	0.4589
	A to Z alternative route 3	120	0.4729
	A to Z alternative route 4	128	0.4971
A to T	Dijkstra's	83	0.372
	A to T alternative route 1	208	0.4225
	A to T alternative route 2	134	0.4438
	A to T alternative route 3	87	0.455
	A to T alternative route 4	95	0.4833
A to G1	Dijkstra's	98	0.383
	A to G1 alternative route 1	291	0.5644
	A to G1 alternative route 2	253	0.5644
	A to G1 alternative route 3	202	0.565
	A to G1 alternative route 4	206	0.6086
A to M1	Dijkstra's	110	0.3937
	A to M1 alternative route 1	269	0.58
	A to M1 alternative route 2	1202	0.585

(continued)

Table 2 (continued)

Nodes	Best routes selected	Distance (km)	Probability
	A to M1 alternative route 3	218	0.5913
	A to M1 alternative route 4	273	0.6163
A to H1	Dijkstra's	103	0.3814
	A to H1 alternative route 1	299	0.5057
	A to H1 alternative route 2	178	0.5089
	A to H1 alternative route 3	204	0.5263
	A to H1 alternative route 4	186	0.5278
A to H	Dijkstra's	16	0.3233
	A to H alternative route 1	105	0.386
	A to H alternative route 2	141	0.4
	A to H alternative route 3	67	0.4433
	A to H alternative route 4	20	0.46
A to S	Dijkstra's	136	0.306
	A to S alternative route 1	1083	0.4283
	A to S alternative route 2	261	0.45
	A to S alternative route 3	187	0.4575
	A to S alternative route 4	140	0.4733
A to X	Dijkstra's	122	0.345
	A to X alternative route 1	225	0.5457
	A to X alternative route 2	187	0.5688
	A to X alternative route 3	136	0.572
	A to X alternative route 4	140	0.6217
A to D1	Dijkstra's	65	0.5567

(continued)

Table 2 (continued)

Nodes	Best routes selected	Distance (km)	Probability
	A to D1 alternative route 1	149	0.5275
	A to D1 alternative route 2	323	0.5329
	A to D1 alternative route 3	248	0.5486

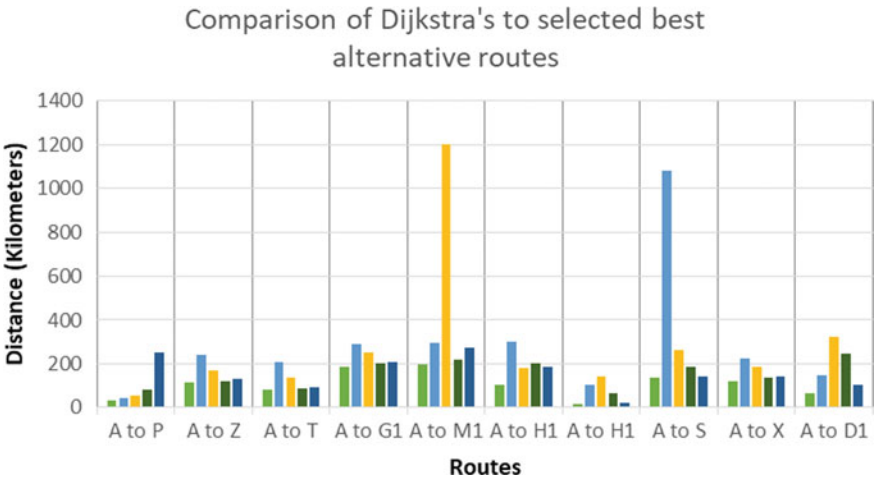

Fig. 8 Graph for Dijkstra's comparison with alternative routes based on distance

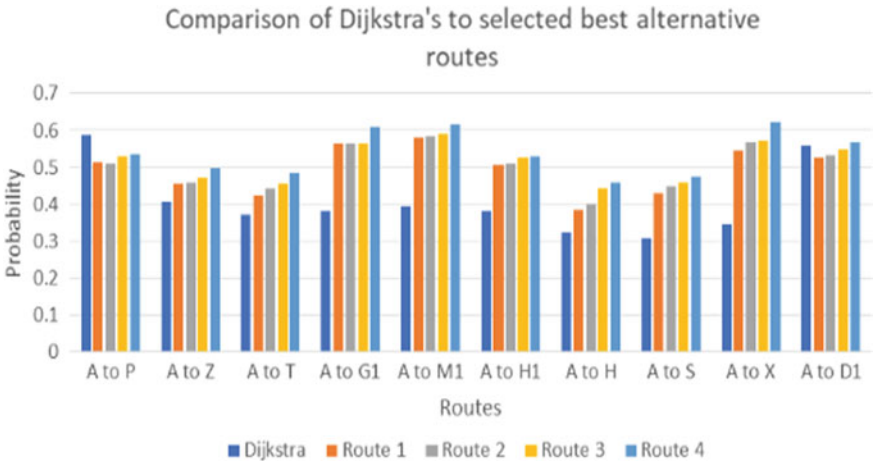

Fig. 9 Graph for Dijkstra's comparison with alternative routes based on probability

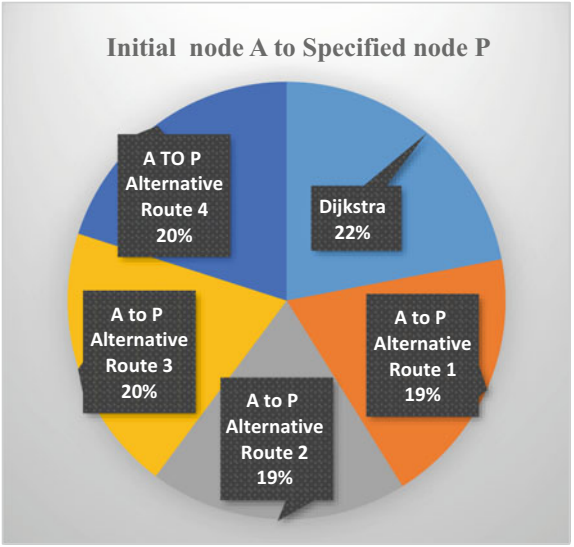

Fig. 10 Percentage ratio of Dijkstra's to best alternative routes from initial node A to specified node P

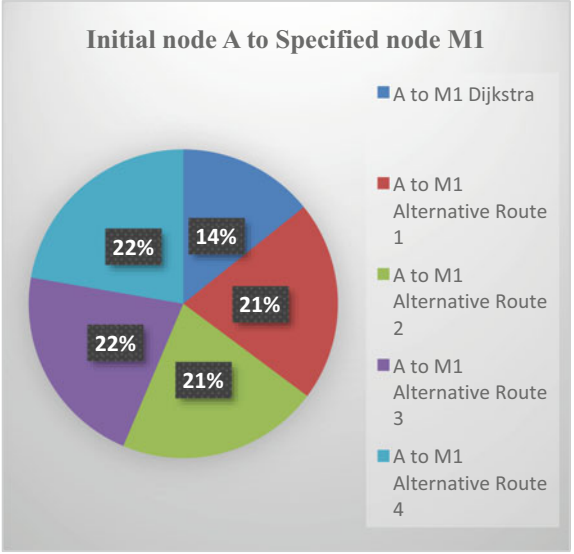

Fig. 11 Percentage ratio of Dijkstra's to best alternative routes from initial node A to specified node P

based on each direction specified in proportion to probabilities. This has proven its advantage in solving alternative path-finding problems for the safest and other routes aside from the conventional Dijkstra's path.

Table 3 Average results of both algorithms

	Distance covered (km)	Number of routes	Probability cost	Time complexity (average case)
Conventional Dijkstra's algorithm	88	1	0.41	O(E(log V))
Modified Dijkstra's algorithm	212	40	0.51	O(E(log V))

3.3 Average Results of Both Algorithms

The average distances covered for both the conventional and modified algorithms are exceptional distances of signs and can be used in public transport applications (Table 3). Even though modified Dijkstra's has a farther distance, its average distance covered is 212 km, while the conventional Dijkstra's algorithm maintained the shortest distance, having an average distance of 88 km. Moreover, it is observed that MDA is significantly better in terms of route generation as the best alternative route. Its average number of routes is 40% higher than the result of CDA. Additionally, MDA outperforms the CDA in average probability cost. Its average probability cost is 10% higher than conventional Dijkstra's algorithm's result. Although this algorithm is modified to provide alternative routes, this was deduced from the results. The average time complexity for both algorithms is similar in computation. The CDA provides the route with minimal distance. Also, the modified Dijkstra proposes alternative routes not catered for by the CDA, thereby establishing the research gap for this work.

4 Conclusion

This study is centered on the modification of the Dijkstra's algorithm (DA) for generating alternate routes in situations where the shortest path is under constraints and not accessible to time. MDA was implemented in a Python environment using a 40-node graph design. This study generated probabilities randomly used to modify the CDA and was able to generate all possible routes, allowing shortest-path identification. Therefore, the findings imply that the MDA functions as expected to enhance and provide efficient alternative routes for ease of transportation and the delivery of goods and services in a region. Thus, a path-finding route system is proposed by developing a modified Dijkstra's algorithm. The algorithm was designed, implemented, and evaluated, and analysis of the results revealed that MDA is significantly better than conventional Dijkstra's concerning the number of routes and probability cost. As proposed in this study, it can be stated as an ideal route planning for alternative routes, which logistic companies and transportation systems can use. For this research work to be more pragmatic, a real-life experiment should be conducted to compute

the probabilities. Further studies can extend the proposed model to other problem domains and the post-optimality study of the algorithms, that is, its sensitivity to changes in variables such as probabilities.

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A Security-Based E-government Adoption Framework: An Outcome of a Systematic Literature Review

Thembekile O. Mayayise

Abstract The pervasiveness of the Internet has propelled governments to provide online services through e-government platforms. Various countries are at different maturity levels regarding e-government adoption; where some developed countries such as Estonia are leading, whereas some developing countries are lagging. The uniqueness of every country calls for the need to understand the factors that promote e-government adoption. E-government adoption is a growing area of research where numerous studies have and continue to be conducted to test and validate new and emerging e-government adoption models. However, from a citizen's perspective, the lack of e-government awareness and the prevalence of privacy and information security threats are regarded as significant inhibitors to e-governance adoption. Thus, it is crucial to consider such factors when promoting e-government adoption. Through a systematic literature review, this study aimed to review the e-government empirical studies conducted from 2013 to 2022 from the IEEE, Science Direct and EBSCO Host databases to identify the dominant e-government adoption frameworks and determine if information security controls, privacy controls and e-government awareness were previously included. Out of the 51 articles synthesized, a security, privacy and awareness gap in the existing e-government adoption frameworks was identified; hence, a security-based e-government conceptual framework is proposed. The proposed conceptual framework extends the technology acceptance model (TAM). This study aims to contribute to the existing body of knowledge on e-government adoption and the respective theoretical frameworks. The proposed framework needs to be tested and validated in various contexts.

Keywords E-government · TAM · Adoption

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1 Introduction

E-government refers to the use of information and technology services by governments to offer services to citizens, governments, and businesses [72]. In the same way as electronic commerce (e-commerce) tends to have different market types such as business to consumer (B2C), business to business (B2B) and consumer to consumer (C2C). E-government can also be classified according to the following categories [41], namely government to citizen (G2C), government to business (G2B) and government to employee (G2E). G2C, which focuses on the provision of services by the government to citizens, will be the focus of this study.

As of 2014, close to fifty countries belonging to the United Nations had Web sites and portals where citizens can connect and download the information and content that is required 24 h a day, where the major requirement is an Internet connection [36]. Various countries such as Denmark, Estonia, USA and the United Kingdom have been running at the forefront of e-government adoption. The services commonly offered through e-government include the payment of rates and taxes, application of passports and car license renewals. The Internet is an enabler of e-government services. Despite the limited access to the Internet by some countries such as Cuba, North Korea and Egypt [47], those with unrestricted access can maximize their potential.

Numerous studies have been conducted on adopting e-government services in numerous countries situated in Asia, Europe, and Sub-Saharan Africa [72]. In South Africa, the e-filing system is an example of an electronic system used to capture and process tax information for individuals and businesses. It is noteworthy that the maturity level of e-government adoption varies from country to country, with certain countries, especially in developing economies, being left behind due to various reasons. Kurfalı et al. [36] posit that the success of e-government is dependent on the number of citizens that use it; hence awareness is key. E-government adoption continues to be an essential subject for research to continue identifying the determinants of e-governance adoption. Considering the volatility of the Cyberspace, there is continuous emergence of new threats and potential risks which can inhibit e-government adoption by the citizens if not managed. Cybersecurity is concerned with the protection of networks, technology and systems from cybersecurity attacks. One of the most common cybersecurity attacks which indulge in people's lack of awareness is social engineering. Social engineering attacks aim to use personal information or pieces thereof to lure victims into fraudulent activities where there is likely to be a financial or reputational loss, especially for organizations. Information security ensures information protection by ensuring that confidentiality, availability and integrity of information are maintained [31]. Data privacy is also a threat as it can potentially hinder e-government adoption due to the fear by citizens of having their privacy invaded in e-government platforms [1]. Awareness of e-government services is also important in encouraging adoption as the more people get to know about the service the more likely they will start using it, especially for people staying in remote areas [69]. Some of the benefits of e-government are an increase in quality of delivery and

efficiency [23, 36] and the promotion of communication between a government and its citizens.

Acknowledging that e-government has been studied and continues to be studied and as such various frameworks have been proposed and tested, there is a need to close the gap in the literature by focusing on an e-government adoption framework that will include the information security aspect, privacy and e-government awareness to bolster e-government adoption.

This study aims to investigate various empirical studies and the respective frameworks used in these studies from 2013 to 2022 and identify the extent to which they have been able to cater for privacy, information security and e-government awareness. Systematic literature reviews (SLR) are often conducted to review literature that has been published over a decade to obtain a holistic picture of the developments in specific research areas [58]. To propose a security-based e-government adoption conceptual framework which will encourage adoption by the citizens.

The study makes the following contributions:

- The theory on e-government adoption will be enriched through the inclusion of the proposed framework.
- Countries that seek to implement e-government can implement the proposed framework to encourage adoption in their countries.
- Future researchers on e-government can test this framework in different contexts and compare the results as required.

The remainder of this article has been arranged in this manner: A general literature review is detailed in Sect. 2, and the methodology of the SLR is covered in Sect. 3 along with the discussion of the findings. Section 4 covers the proposed conceptual framework. Section 5 concludes the study.

1.1 Problem Statement

The growing increase in cybersecurity attacks and privacy breaches [39] has brought the need to prioritize security when adopting e-government [20]. Estonia, which is one of the leading countries in e-government adoption, has prioritized cybersecurity in its e-government adoption plans [23]. It is thus important to ensure that the security of information coupled with privacy is not neglected when looking at e-government adoption. This warrants a fresh look at the factors which promote e-government adoption [41] that will accommodate built-in privacy and information security, amongst other measures. A decade of literature review has been regarded as sufficient to give a comprehensive view of the empirical research approaches to e-government adoption, specifically the theories and frameworks which have been used in such studies.

Numerous e-government adoption frameworks have been proposed and continue to evolve [40, 50, 51]. However, an examination of the adoption frameworks revealed

that e-government adoption frameworks that directly relate to the security of information, privacy and awareness of e-government are limited [39, 57, 61]. As a result, [72] recommended that e-government adoption models be refined under different contexts.

This study aims to achieve that objective by conducting a systematic literature review (SLR) to unearth empirical studies which have been done on e-government adoption and to identify the respective frameworks and the factors that promote e-government adoption. It further aims to investigate the extent to which information security, privacy controls and e-government awareness have been considered in the frameworks used in the previous decade. According to [30], very few studies have been conducted on e-government adoption focused on security and privacy. Hence it is based on the outcome of the SLR that a conceptual framework is proposed to address the gaps revealed in information security, privacy and awareness of e-government services.

Research questions that this study seeks to answer:

- Which empirical studies were conducted from 2013 to 2022 on e-government adoption?
- Which frameworks/theories have been dominant in e-government empirical studies conducted since 2013–2022?
- To what extent did the dominant e-government adoption frameworks cover security controls, privacy controls and e-government awareness constructs?
- How can an e-government adoption framework be designed to cater for information and privacy controls and e-government awareness.

1.2 Research Objectives

The objectives of this study are:

- To conduct an SLR to identify empirical studies on e-government adoption from 2013 to 2022.
- To identify dominant e-government adoption frameworks/theories from empirical studies from 2013 to 2022.
- To identify gaps in the existing G2C e-government adoption frameworks about information security, privacy and e-government awareness.
- To propose a security-based conceptual framework for e-government (G2C) adoption, which includes information security, privacy and awareness of e-government constructs.

2 Literature Review

This section discusses the general literature review on e-government implementations and cybersecurity and a high-level overview of some of the drivers of e-government adoption.

2.1 E-government Implementations and Cybersecurity

Estonia, a European country, is regarded as one of the most digitally advanced countries globally, with 99% of its basic public services online [23]. In its e-government implementations, it has factored compliance with relevant laws, cybersecurity risk identification strategies and monitoring. Estonia's e-services include I-Voting, E-Tax and E-Business registrations, among many others. Denmark and the United States of America are also among the leaders in e-government adoption, and they also need to mitigate cybersecurity and privacy risks. In 2019, the City of Johannesburg in South Africa became a victim of a cyber-attack where the attackers threatened to expose the customer records if the municipality failed to pay the ransom that was required within the specified period [49] whereas, in 2007, Estonia was hit by a major cybersecurity attack [23]. Therefore, bolstering information security controls when rolling out e-government services has become imperative as the risk exposure can be detrimental [70].

2.2 Drivers of E-government Adoption

Numerous studies have been conducted to unearth the factors which drive e-government adoption, and these include trust in the e-government service, perceived ease of use of the e-government Web site/portal and compatibility with other websites or resources [29, 39] and perceived usefulness [33]. Effort expectancy has also been identified as a factor that promotes e-government adoption, as users could find it attractive to use technology that requires less effort to operationalize and is more intuitive [7, 36]. Performance expectancy (PE) refers to the value that citizens can derive from the use of e-government platforms [27] and the greater the anticipated value, the more likely the adoption. The adoption of e-government can also be driven by social influence among the citizens [36] and the quality of service received from e-government platforms [32, 61]. Other e-government drivers of adoption include technological, strategic, operational, and performance motives [28], and inhibitors include cultural influences and lack of infrastructure [3]. Trust in the government and trust on the Internet by citizens can also promote e-government adoption [36, 37, 74].

2.3 Previous SLRs on E-government Adoption

An SLR was conducted by [2] to investigate the role of e-government in promoting sustainable procurement in developing countries in the public sector. The drivers of supply chain procurement in developing countries were also explored. Although the SLR was in the e-government domain, its scope focused primarily on supply chain procurement and not on the government to citizen e-government adoption, which is the focus of this SLR which is being undertaken.

3 Methodology

This section discusses the SLR methodology applied in this study.

3.1 Systematic Literature Review

To unearth the drivers of e-government adoption and answer the specific research questions as outlined in Sect. 1.1, an adapted version of the PRISMA flow chart is depicted in Fig. 1. Detailed discussions of these stages and activities are explained in the subsequent section.

The main objective of this SLR is to uncover the e-government adoption empirical studies conducted from 2013 to 2022 to address the specific questions as outlined in Sect. 1.1. The steps detailed in Fig. 1 were guided by the inclusion and exclusion criteria of the literature used in Table 1.

Following the outlining of the inclusion and exclusion criteria, the steps outlined in Fig. 1 were followed to address the research questions stated in Sect. 1.1. The section below explains the activities in the stages contained in Fig. 1.

Following the adapted PRISMA flow chart outlined in Fig. 1, the following steps were performed during the SLR.

Identification Phase

The following databases were identified for the SLR, namely: IEEE explore, Science Direct and EBSCO Host, as these sources were deemed comprehensive in terms of scope of coverage and relevance. The keywords/phrases chosen for this SLR are included in Table 2.

Terms that are synonymous with e-government, such as smart government or digital government, were considered during the analysis of the search results.

The initial search results yielded over 10,000 records, especially from the Science Direct database. However, a review of the initial search results per page of the returned search results revealed that many of these records were irrelevant. Only 332 articles were deemed relevant at a much high level from the three chosen literature sources,

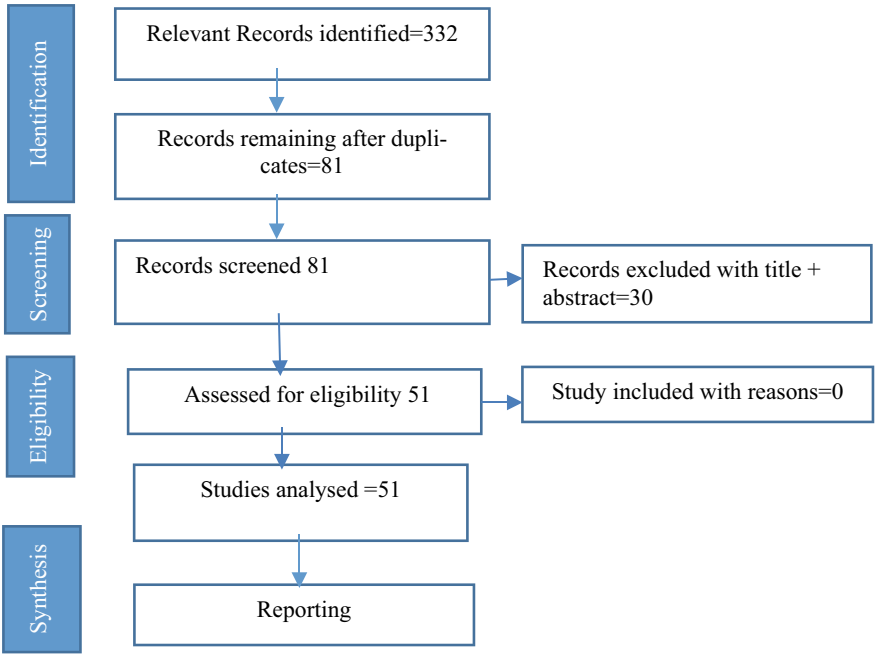

Fig. 1 Adapted PRISMA flow chart [9, 53, 64]

Table 1 Inclusion and exclusion criteria

Included	Excluded
E-government adoption studies	Non-e-government adoption-related articles
Period covered: 2013–2022	Period outside: 2013–2022
Conferences proceedings, peer-reviewed journal articles	Grey literature and book chapters
Empirical studies	Non-empirical studies
English written works	Non-english written articles
Open access articles	Articles that required payment to access
Available articles for viewing and downloading	Unavailable articles for viewing and downloading

Table 2 Keywords/phrases

Database	Search string
EBSCOhost and science direct	(“E-government” or “smart government”) and (“adoption”)
IEEE explore	(“E-government” or “smart government” or “digital government”) and (“adoption”)

where 6 came from IEEE, 198 came from Science Direct and 128 from EBSCO Host.

At the initial review and sorting of the articles, 251 articles were removed as some were duplicates and non-empirical studies. Consequently, 81 articles remained for further review.

Screening Phase

The 81 articles were reviewed based on the content of their abstracts and titles, and 51 articles remained for further consideration.

Eligibility

The remaining 51 articles were found suitable for further review, and there were no additional articles identified through backward tracing.

Synthesis

In total, only 51 articles were synthesized. An MS Excel spreadsheet was used to consolidate the results of the publications that remained. Mendeley referencing tool was used to group the sources and for orderly referencing.

Reporting

This section focused on the reporting and presentation of the SLR findings based on how they relate to the research questions introduced in Sect. 1.1.

Bias

To minimize location bias, the literature was sourced from three databases instead of one. The period of coverage of literature review covered a 10-year span. Selection bias was addressed through the inclusion of peer-reviewed conference proceedings papers and journal articles. Evidence bias was addressed by citing the sources for each specific area which directly refers to the output of research questions.

3.2 Findings and Discussions

Based on the literature reviewed, some of the empirical studies were conducted across multiple countries, as depicted in Table 3. The countries marked with an asterisk* are those where more than one study was conducted.

When interpreting the results of this SLR, it must be noted that in certain instances, a single study covered multiple countries, such as [51, 72].

Figure 2 depicts the outcome of the SLR in identifying the dominant frameworks and theories that were used in these e-government adoption studies. It is evident that for many of the studies, the frameworks were only used once and were not repeated in other studies, and all these were grouped under the “other” category. This includes studies that covered the following frameworks and theories: Convergence

Table 3 List of e-government studies per region and country since 2013–2022

Region	No. of studies	Countries where studies have been conducted	List of studies
Africa	3	Botswana, South Africa, Zimbabwe	[50, 51, 72]
Asia	19	*China, Hong Kong, India, Indonesia*, Japan, Korea, Lebanon, Malaysia, Pakistan, Philippines, Russia, Singapore, Taiwan, Vietnam, Thailand	[4, 8, 12, 19, 25–27, 32, 34, 38, 41, 44, 46, 48, 51, 54, 65, 75, 78]
Europe	18	Belgium, Bosnia and Herzegovina, Croatia, Denmark, Estonia, Finland, *France, Germany, Greece, Italy,*Latvia, Netherlands,*Norway, Spain,*Sweden, Switzerland*, Turkey*, UK*, Portugal	[5, 10, 11, 17, 24, 30, 36, 47, 51, 52, 57, 59, 63, 69, 71, 73, 74, 76]
North America	4	Canada*, USA*	[15, 22, 51, 55]
South America	2	Brazil, Chile and Peru	[18, 51]
Oceania	1	Australia, New Zealand	[51]
Western Asia	4	Dubai, Saudi Arabia*, Western Asia	[21, 60, 62, 77]

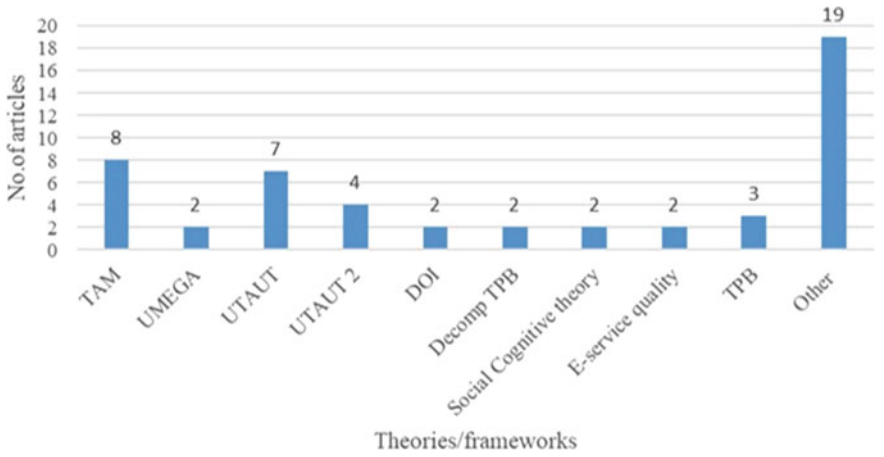

Fig. 2 Frameworks and theories used in e-government empirical studies 2013–2022

theory; Dual Factor and status quo bias theories; growth theory; e-service quality, interdisciplinary structuration theory and IS acceptance and resistance theories [32].

Figure 2 depicts a transparent picture with regard to the use of adoption frameworks and theories which have been tested in various technology adoption studies, such as UTAUT/2 and the theory of planned behaviour (TPB). Other theories have been used but to a limited extent, including the social cognitive theory [4, 5, 77] and the diffusion of innovation theories (DOI) and the decomposed theory of planned behaviour, [57, 68]. UTAUT [62, 74] and TAM [48, 61] emerged as the commonly used frameworks in the previous e-governments studies. The decision to select TAM in proposing this conceptual model was because TAM has fewer constructs than UTAUT, making it extendable and allowing additional constructs to be included for further testing; TAM has also emerged as the popular framework with 8 studies which have been conducted in the last decade as compared to UTAUT which has only 7 studies. According to [43], fewer studies have incorporated TAM and Privacy and security constructs, hence the inclusion of the proposed TAM extension in the proposed conceptual framework.

3.3 Information Security, Privacy and E-government Awareness as Artefacts of Previous Studies

In selecting TAM as the model underpinning the proposed framework, a review of studies where TAM was used was done to confirm if the proposed extensions were not previously added as additional constructs in the previous empirical e-government studies was done. Table 4 depicts the number of times TAM, and other models were used in e-government empirical studies. Out of the eight studies where TAM was

Table 4 Security, privacy and e-government awareness as artefacts of previous studies—TAM extensions

References	Theories used	IS	Privacy controls	E-government awareness
[13]	Extended TAM	×	×	×
[11]	TAM	×	×	×
[67]	TAM	×	×	×
[32]	TAM	Partially covered	×	×
[61]	TAM + TPB	×	×	×
[68]	TAM, DOI, UTAUT, TRA, TPB, decomposed theory of planned behaviour	×	×	×
[54]	TAM + theory of planned behaviour	×	×	×
[14]	Theory of planned behaviour (TPB); information system success model, TAM	×	×	×
Proposed framework	Extended TAM + information security, privacy controls, awareness of e-government platforms	√	√	√

used, eight studies did not have information security [48], privacy and e-government awareness. The proposed framework aims to include the additional constructs based on the need as revealed by the literature reviewed to build a comprehensive framework for e-government adoption.

4 Proposed Conceptual Framework

The results of the SLR as detailed in Sect. 3.1 have revealed that more e-government studies need to be done in other regions such as Africa and North America. The commonly used frameworks in e-government studies have been outlined in Fig. 2 which shows TAM as the leading framework in e-government adoption studies. Considering the importance of information security, e-government awareness and privacy, a conceptual framework is proposed in this section that seeks to address that gap as a start. This section details the proposed conceptual framework and the artefacts thereof.

4.1 The Proposed Conceptual Framework

TAM has been used in various adoption studies yet continues to be used in different contexts. However, it has been criticized for having few independent variables, which some researchers felt were inadequate for ascertaining the behavioural intention to adopt the technology in different contexts, as evidenced by the TAM extension [61]. On the flip side, this criticism is a strength as TAM allows for flexibility in adding other constructs which can be tested for validation. It is for that reason that TAM was chosen for our proposed conceptual framework as it has fewer variables, and it gave room for the inclusion of other variables [6, 45, 55].

4.2 Conceptual Framework Constructs

The proposed framework in Fig. 3 consists of the following independent artefacts, namely: perceived ease of use, perceived usefulness, e-government awareness, information security and privacy. These artefacts are explained in detail in the following sections.

Perceived ease of use can be defined as the degree to which a system can be used without experiencing complexity that can potentially inhibit further use or adoption [41]. When users find it easy to use the system, it is likely to increase their behavioural intention to use the technology [15]. It is based on this assertion that the following proposition is made:

Proposition 1 *Perceived ease of use positively influences the citizens' behavioural intention to adopt e-government.*

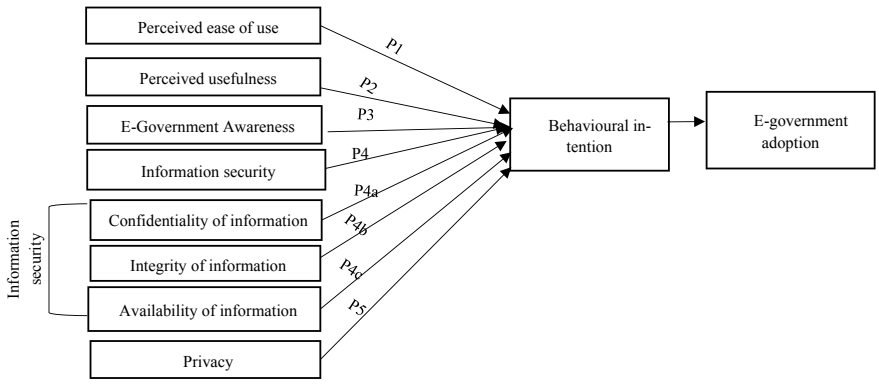

Fig. 3 Security-based e-government adoption conceptual framework

Perceived usefulness refers to the degree of usefulness that can be derived from using a particular system [15]. The more productive the system makes a user feel using it, the more likely the adoption [35]. It is from this premise that the following proposition is made:

Proposition 2 *Perceived usefulness positively influences citizens' behavioural intention to adopt e-government.*

Perceived e-government awareness refers to acquiring as much skill and knowledge that the users of technology perceive fit to allow them to maximize the use of the system to the point of knowing the advantages and disadvantages of the system. Awareness has been seen to promote adoption [37]. Hence, the following proposition is made:

Proposition 3 *Perceived e-government awareness positively influences the behavioural intention to adopt e-government.*

Information Security refers to the protection of information and information systems from unauthorized access, use, disclosure, disruption, modification or destruction. Information security ensures only authorized users can access accurate and complete information when required. Three main principles must be satisfied for information to be deemed secure [31]. These are **confidentiality**—A security principle that works to ensure that information is not disclosed to unauthorized subjects; **integrity**—It refers to the accuracy, completeness and validity of information and **availability**—refers to the information that is accessible when required by the citizens now and in the future. In online environments, the confidentiality, integrity and availability of information are also referred to as data security objectives [66].

In the study conducted by [70], it was found that in certain e-government Web sites, security vulnerabilities exist, which, if exploited, could result in successful cybersecurity attacks which could inhibit e-government adoption. On the other hand, secure e-government platforms promote e-government adoption. The perception that users have about the effectiveness of the security controls, the more likely they stand to adopt e-government. Hence, the following propositions about perceived information security on behavioural intention to adopt e-government are made.

Main Proposition 4 *Information security positively influences the behavioural intention to adopt e-government. This proposition has further been broken down into the following sub-propositions dealing with information security.*

Proposition 4a *Maintaining confidentiality of information on an e-government platform positively influences the behavioural intention to adopt e-government.*

Proposition 4b *Maintaining the integrity of information on an e-government platform positively influences the behavioural intention to adopt e-government.*

Proposition 4c *Maintaining the availability of information on an e-government platform positively influences the behavioural intention to adopt e-government.*

The increase in Internet penetration, also marked by the increased use of online services, has given rise to privacy concerns. The rise in privacy concerns leads to

reduced behavioural intention to use e-government services and negatively impacts the willingness to share personal information [28]. Their study [7] asserts that security and privacy have the greatest influence on trust in the Internet, yet they were not identified as independent constructs. Hence, the following proposition is made:

Proposition 5 *Perceived Privacy controls positively influence the behavioural intention to adopt e-government*.

5 Conclusion

Based on the literature reviewed, it is evident that there are different empirical studies conducted on e-government adoption from 2013 to 2022. The proposed conceptual framework highlights the need to include information security, privacy, and e-government awareness constructs in e-government adoption studies. The SLR uncovered studies and frameworks used in previous e-government adoption studies. As depicted in Fig. 2, TAM and UTUAT have been commonly used in e-government adoption, studies whereas other theories featured the least. However, it was evident that information security, privacy and awareness have not been covered to a greater extent, and the proposed framework aims to bridge that gap. The research questions outlined in Sect. 1.1 have been met through the outcome of the SLR as discussed in Sect. 3.2, where the empirical studies on e-government since 2013–2022 were outlined, the dominant frameworks/theories used in the studies were presented in Fig. 2, and the proposed framework is explained in Sects. 4.1 and 4.2. This study contributes to the growing area of e-government research from a theoretical perspective. Future studies could broaden the scope to include other sources and cover literature that contains articles from the industry as e-government is not confined to scholarly literature. The proposed conceptual framework still needs to be tested to validate the propositions; however, it lays a foundation for future researchers considering empirical studies on e-government research.

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Digital Technologies' Agency in Meaning-Making: A Theoretical Conceptualization

Karoline Schnaider and Stefano Schiavetto

Abstract Semiotic resources such as digital technologies have become the tools of the trade in various social practices and are promoting the digital globalization of educational contexts. Through constant renewals, technological impacts on education have elicited several challenges. This paper advocates a theoretical study on how digital technologies can challenge social settings, a conceptualization guiding upcoming empirical explorations on digital technologies in education. By synthesizing research data, new theoretical propositions can be initiated based on previous empirical analyses. An extended critical perception of technologies' social agency and how technologies regulate meaning-makers' social, political, and economic life can be obtained as an understanding of the democratization of the Internet space. The following research questions were used; During the last five years, what effects do digital technologies have on social practice, and how can the effects be theoretically conceptualized? Peer-reviewed research papers addressing digital technologies between 2017 and 2022 will be retrieved from scholarly databases. Through metasynthesis strategies, theoretical conceptualizations of the consequences different digital platforms for Internet navigation and social media have on social practices will be obtained. Findings indicate that the association between the concepts of calculation center, platform leadership, immaterial labor, and mindshare is interesting to strengthen critical perspectives on technical agencies for understanding the democratization of the Internet space. We conclude that there is a need for continuous critical expansion of theories to enrich educational research with tools for problematizing the digital globalization.

Keywords Digital technologies · Education · Calculation center · Platform leadership · Immaterial labor · Mindshare

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1 Introduction and Related Work

For over a decade, access to various semiotic resources, such as digital technologies [34], has had unprecedented effects on social practices such as schools [12]. By using the concept of semiotic resources as denotative for digital technologies, we aim to include both the hardware (the "equipment") and software (skills, knowledge, and experience organized into data, Li-Hua [18]), as well as the more fine-grained semiotic aspects of these technologies' designs [2, 36]. However, in this paper, we focus mainly on the software.

Teachers and students in schools currently experience an upscaled use of specific digital technologies [22]. Because digital hardware and software are renewed rapidly in teaching and learning practices, they constantly pose challenges by mediating meanings variously. For instance, different combinations of hardware and software technologies have distinct affordances and alter information exchange and social organizations [12, 21, 35]. Furthermore, in different configurations, the technologies' temporal and spatial framings create various symbiotic relations with their users [1, 2, 30, 31]. Teachers and students increasingly need to observe the changing demands of the digital globalization in these ways.

Digital technologies have interests, and when meaning-making is transacted via the technologies, a translation of interests between the actants (technologies and meaning-makers) into agency networks [28, 29] come to pose various consequences for sociocultural development [16]. For instance, education is regulated by the agency network when particular teaching strategies and learning trajectories are manifested.

This paper critically discusses the possible consequences of educational practices using digital technologies such as platforms for Internet navigation and social media. By building on existing theories and data on meaning-making via technologies, a critical elaboration of the concepts of calculation center [14], platform leadership [8], immaterial labor [16], and mindshare [33] aim to explain how technologies come to present, create, and preserve a specific insertion of meaning-makers in the contemporary world and how the democratization of the Internet can be understood and promoted.

2 Background

When examining digitalized education, an issue that stands out is the solidification of calculation centers [14]. Latour understands calculation centers as nodes (flows) in a network that are so dense that they make certain actants mandatory passage points and therefore compose the agency network [3, 10]. These actant holds a privileged position of power since their interests must be considered, for instance, by meaning-makers in their technology uses. Nowadays, digital technology corporations occupy calculation center positions since they offer hardware and software that become mandatory passage points for the user to pass when using the Internet and other digital

technologies. Therefore, conceptualizing how calculation centers become mandatory passage points is crucial. Moreover, enriched understandings can add to existing theoretical claims on technologies' impacts on social practices such as education.

In the early 2000s, when digital technologies could be found in schools all over the world, Hepburn [9] claimed that research and practice need to question whether educational projects were reduced to training students to use technological solutions from certain corporations and how they (as calculations centers) affect digital schooling. Such corporate companies' products are consumed even if their prices differ significantly from their competitors. In being rapidly developed and renewed, they increasingly mediate users' social lives. Certain corporations' digital technologies become legitimate by gaining power in the market and social life in these ways. Hepburn claimed that educational projects that do not critically reflect on how conventional technologies become calculation centers risk turning them into "natural tools" serving human interests. In these cases, technologies are naturalized, and corporate companies' strategies stay unreflected. This phenomenon, called mindshare [9, 33], can highlight how corporate companies' influence as calculation centers (not limited to technologies' characteristics) expands their agencies in creating and maintaining users' beliefs. One aspect of interest is the agency formed by the consumption and the product manufacturing processes, driving the so-called social cycle of immaterial labor forward [16].

The social cycle of immaterial labor [16] in which digital technologies descend from investments and various consumer interests (e.g., from opinion polls in the 1990s to polemic manipulation of user data in social networks during the 2020s) is created through communication. Communication exists in corporate marketing and advertising associated with technological products and is no longer only the "realization" of a product but an actual and proper social process [15]. Gawer and Cusumano [8] call the strategies of immaterial labor active in creating mainstream technical platforms "platform leadership" and is an essential indicator of the industrialization of electronics. The industrialization of platforms is marked by different companies appropriating various layers of electronic hardware and software, and this is done by establishing themselves as mandatory passage points for technical development, the industrialization of electronics, and consumer use [19, 22].

In summary, the immaterial labor investments and the mindshare effects strengthen platforms' leaderships and agencies and expand the platforms' positions as calculation centers, resulting in some electronic companies being promoted in industry and consumption. This hegemonization underlying digital globalization impacts several aspects of life and is relevant to incorporate in extended critical perceptions of how technologies regulate social, political, and economic practices to endorse the democratization of the Internet space. Furthermore, elaborating on these concepts can advance critical theories.

3 Methodology

This section outlines the methodological rationales. Examining the latest high-quality research on digital technologies in education through meta-synthesis strategies enables synthesizing of empirical data and making theoretical conceptualizations.

4 Data Retrieval

The databases used for the article retrieval will be selected based on several tryouts. These tryouts will be performed by testing different keywords related to the field of study and using different databases' thesaurus. It is a process that will undergo multiple iterations. In applying CHIP strategies (Context, How, Issues, Population, [32], keywords are first socially moderated and systematically used in different databases to select the aptest. Second, the 20 first search results are manually screened in full text and thus help determine the suitability of both databases and keywords for subsequent searches. Hence, this initial keyword refinement also facilitates the subsequent search string modeling. Databases ERIC, Scopus, and Web of Science are potential candidates for finding relevant research literature.

The inclusion criteria for literature to use in this study are research produced from 2017 to 2022, peer-reviewed full-text original research papers (empirical/theoretical/book chapters), and quantitative and qualitative studies. In addition, all school forms will be included as they will potentially yield exciting results for comparison. These inclusion settings will be applied in each database's advanced filter function. The combination of free-text search terms must be relevant for obtaining significant hits. A prospective search string—(digital AND technology AND resource AND education AND teacher AND student)—is applicable for several reasons. The first three search terms are pertinent to teaching and learning via various technologies (hardware, system, and application software). For instance, the search terms "digital" and "tools" (terms frequenting, e.g., curriculum, guidelines, and policies) might end up being too wide as they include a vast repertoire of different assets irrelevant to understand the use of digital technologies. The search terms "hardware" and "software," as well as naming particular hardware (laptops, smartphones, tablets) or software (Internet, applications), can also be unfeasible as these terms risk being too technical or narrowing the search hits. The search term "online" and "remote" related to distance education would probably also limit the search results by excluding the technologies used in face-to-face modes.

The word stem "technolog" (technology/technologies) is therefore selected as the most feasible search term together with the word "digital" (to exclude other—analog—technologies) and "resource," including a wide range of digital technologies (together with "education" as this is the focus of the study, and technology uses by the actors—"teachers" and "students"). These terms will probably entail streamlined

Table 1 Example of a concept charter

Categories	Empirical topics	Study components
Hardware	Devices	Desktop, laptop, smartphone, tablet
	Hardware components (processors)	Intel, OSX, iOS
	Accessories	Monitor, keyboard, headphones, earphones, mouse, scanner
Software	Information system for web browsing and publishing	World Wide Web
	Information system for web publishing	Fediverse
	Browsers	Edge, Firefox, Chrome, Safari, Tor
	Web conferencing systems	Microsoft Teams, Zoom, Google Hangouts
	Learning management systems	Moodle, Canvas
	Digital teaching materials	Publisher made digital material and books
	Microblogging and social media	Twitter, Mastodon
	Categorized software[1]	
	Linguistic applications (prompters of texts)	Word processing programs, Note-applications, e-mail applications, Wikis
	Auditory application	Spotify, podcasts, e-books
	Visual applications	YouTube, photo-applications, iMovie, Pinterest
	Multimodal applications	PowerPoint, repositories, social media, blogs

search hits and coverage of the contemporary and most frequently used twenty-first-century learning means in recent educational research. As a result, we anticipate approximately 1200 search hits in total. In the first process of efficiently delimiting the search results, we will apply Rayyan software (www.rayyan.ai) to rate the papers' abstracts based on combinations of the categories, topics, and components in Table 1. This step will delimit approximately half of the substratum to 600. The next step entails an equal division of the papers among the two authors to screen the full texts according to a qualitative rating procedure (yes–no) in a spreadsheet, including the papers with qualitative descriptions of technology use. This procedure will probably delimit the papers to approximately 90 to incorporate into the study.

[1] Software categorized from their semiotic capacities in mediating sign-systems facilitating certain uses.

5 Data Processing and Analysis

This section presents the methodological rationales applied in this study. They draw on Finfgeld-Connett's [5] guidelines for theory-generating meta-synthesis logic, including examples of primary research sources' characteristics and potential qualitative findings.

The intended meta-synthesis is grounded in solid topics that can facilitate the creation of narratives and understandings in constructing and refining new theoretical conceptualizations. Thus, applying a streamlined charter is essential [5]. The concept charter is exemplified in Table 1.

By meta-synthesis strategies of memoing and diagramming [5] and a simple thematic analysis method, the data processing is planned to be executed in several assessment phases. Initially, all the text data will be modeled in NVivo 12. A word frequency record assisting the code generation is the first part of the thematic analysis. After iterative readthroughs and discussions of the first 300-word frequency count retrieved in NVivo, concepts akin to the different groupings addressed in Table 1 will assist the first exploration of all the papers' data into themes. Finally, these themes will emerge into codes (nodes) organized in NVivo for further inquiries into the separate papers' contents.

Memoing is often the primary data analysis strategy when the research aims to build new theories on existing theoretical frameworks. Two types of narrative memos were used—within- and cross-study memos. First, findings and concepts linked explicitly to the different research concepts and categories defined will be addressed by comparing the within-study memos. Next, these will be used in developing cross-study memos by drawing on other studies' within-study memos into more comprehensive perspectives that can gradually be synthesized into valid concepts (for more details, see [5]).

Diagramming is a sturdy technique in data analysis and synthesis and a manual method of reliably and validly defining relations among concepts to develop theory (example in Table 2). Diagramming is accomplished through iterative processes of interpreting the data's meanings with aspirations to gain in-depth insights into its constituents [4, 5].

6 Expected Results

This section draws on hypothetical empirical data to demonstrate how actor-networks created by technologies and meaning-makers are sustaining the impacts of the digital globalization on the Internet space's democratization. Platforms for internet navigation and social media are exemplified to understand the concepts of calculation center, platform leadership, immaterial labor, and mindshare.

Table 2 Example of a within- and cross-study diagram

References	Relations to the categories/topics/components (Table 1)	Finding from primary source	Within-study memo	Cross-study memo	Development of concepts
La Cava et al. [13]	Masodon, Fediverse	"The extreme popularity gained by Facebook and the other worldwide available yet centralized OSN platforms (i.e., hosted and controlled by a single company) has soon led their owners to pursue a collateral social-marketing goal, which is mostly implemented through content personalization mechanisms and advertisement strategies. As it is well-known, side-effects such as the formation of information bubbles and concerns about the protection of data and user privacy normally characterize most existing centralized OSNs. The above aspects contributed to raise the opportunity for developing new paradigms of OSNs to become "user-centric" rather than "company-centric" platforms. As a major consequence, privacy control, as well as spontaneous and recommendation-free communications among the users, are favored and unbiased as much as possible from the invasiveness of advertisements" [13]	The first excerpt addresses political and economic actions by big companies that own digital social media and use its positions of power to primarily exploit commercial gains, which have resulted in fundamental problems for democratic life. The excerpt also addresses how decentralization is interesting for power-sharing by promoting the regulation of social media by users and communities, which helps to limit social exploitation and favors technical agencies that are interesting to explore in developing democratic life The second excerpt is close to the first arguments and emphasizes power relations and democratic culture. On open-source and moving society toward the realization of a full participatory culture, it refers to the gains in the decentralization of power when the open-source culture is adopted since the algorithms are exposed, and the possibility of social surveillance of technical and human agencies is raised. Furthermore, the adoption of open-source technologies by schools and education that teaches about social and political issues related to the technique, instead of an education that only prepares how to use certain technologies, favors a critical awareness of the social agents that determine ways of acting, thinking, and feeling	Both excerpts are representative of Mastodon and Fediverse as acting technical platforms in the political, economic, and cultural reorganization of contemporary society. Both evidence strategies of immaterial labor by companies interested in solidifying calculation center positions in the internet regulation, especially social media. Mastodon and Fediverse are both a result of and agents in un-black-boxing the non-neutrality of the technique. Subsequently, they can impact the reduction of the mindshare phenomenon since it makes technical development more transparent and accessible for those interested, reducing a social idea about only some companies or groups being capable of developing technicalities. This does not mean that Mastodon and Fediverse are exempt from criticism. Still, this paper focuses on these digital technologies' agencies in the decentralization of the internet regulation	An approximation between the concepts of calculation center, immaterial labor, and mindshare is vital to visualize the social and technical translations that establish power relations in contemporary society, capitalist strategies interested in manipulating user beliefs, and a democratization of the internet regulation. This triad of concepts is also valuable for illuminating educational projects in the thematization of the non-neutrality of technologies and their agencies in social life. Finally, educational projects that: (1) study the technical characteristics of the technologies they use, (2) explore the associations between technique and power relations, and (3) explore user beliefs, promote an un-black-boxing of digital technologies that favors critical awareness [6] of technopolitical phenomena that regulate teachers' and students' ways of acting, thinking and feeling

(continued)

Table 2 (continued)

References	Relations to the categories/topics/components (Table 1)	Finding from primary source	Within-study memo	Cross-study memo	Development of concepts
Zulli et al. [38]		"Instead of the corporate model where pre-existing technical structures determine social structures and platform capitalism often motivates network expansion, ASM [alternative social media, like Mastodon] users become social beings through processes of negotiation and interest-driven engagement. In many respects, negotiable, monitorial, and interest-based sociality on ASM aligns with the original idealizations and addresses the current critiques of participatory culture [7, 10]. Although the Web 2.0 and sites like YouTube were once celebrated for enabling the production and consumption of grassroots media (see [10]), scholars eventually realized that "full" participation should include not just interactivity through media, but the "equal power positions of all actors in a decision-making process" in media, which CSM [Corporate Social Media] does not and cannot provide ([11: 267; see also Pateman [24]). Scholars now argue that a "participatory internet can only be found in those areas that resist corporate domination… where users engage in building and reproducing non-commercial, non-profit internet projects" [7: 75]. Open-source projects like Mastodon are designed with these principles in mind and perhaps move us closer to realizing a full participatory culture vis-á-vis a reduction in abstraction" [38]			

* A developed within-and cross-study diagram [5]

7 Digital Platforms' Social Existence

Social media. With an interface similar to social media such as Twitter, Mastodon regulates a microblogging social network where users can publish images, videos, links, and messages. To use Mastodon, users must create or engage in user-created communities, called instances, which must be hosted on the instance's server. The creators of these instances are responsible for micro-regulations (e.g., the rules of conduct, community purposes, etc.). Each instance can "follow" and communicate with others. Unlike Twitter, Mastodon is not based on a company's private servers (electronic computers), thereby limiting it from having a centralized regulation of the technical and social rules that must be followed by whoever wants to use it. Instead, Mastodon offers a greater decentralization, which allows the user (or the non-owner or employee of the company) to regulate the technical space for communication and coexistence. This decentralization is not an expanded user choice in an "internet space," as a limited sociotechnical comprehension of the internet would lead to understand. It is based on the platforms' different internet infrastructures.

However, despite Mastodon's decentralized infrastructure in relation to Twitter, it does not exempt it from being a digital platform with a calculation center position. Mastodon itself is responsible for the macro-regulations through its centralization of power. For example, it strives to eliminate excessive advertising, racism, Nazism, sexism, discrimination against gender, and disinformation that undermine public health. This power space is not alternating as changes in these rules are made by Mastodon's founders and current administrators.

The occupation of a calculation center position and the exercise of macro-regulation in the Internet space is not, in essence, a democratization matter. However, limiting abuse of power is, and is common in societies where the division of labor involves the division of political power for representatives to regulate social life. Currently, corporations in the microelectronics industry offering technologies for Internet navigation and social media have received numerous complaints related to illegal and authoritarian manipulation of personal data used to influence and control behaviors in education [23] in consumption [25, 37], and elections [19]. These actions mark a deviation from the functions of immaterial labor laboratories. However, while there is a focus on creating valuable products for consumption based on the interests of consumers, an agency intended to manipulate the behavior of citizens in an illegal and unethical way is urged. Limiting the possibility of appropriating personal data illegally requires political and technical knowledge. For users and citizens to be aware of power abuse by calculation centers, the techno-politics of the Internet become imperative to understand in research building critical theories.

Microblogging and social media based on big microelectronic companies' products hold calculation center positions. This is not to say that companies are undemocratic. Instead, it means that users must know the technique of the technical objects they use. This knowledge favors an understanding of digital technologies' agencies in the organization of social life, which interpretations of the world the techniques carry, and how they will impact meaning-makers' understanding of the world.

Greater democratization of a virtual space must involve users' knowledge of how to reconfigure the Internet technique or choose a technical Internet infrastructure fit to their needs. Decentralization favors the democratization of the Internet space and is limiting mindshare. However, it still requires citizens to monitor the level of the regulation's power qualitatively. Limitations in users' understanding of the Internet favor mindshare, as it tends to naturalize the Internet as the only technical possibility.

Fediverse and World Wide Web. Mastodon is one of the dozens of microblogging social networks that use Fediverse as a technical platform—a set of international open-source servers organized together to publish and host content on the Internet. By creating technical conditions for free and open-source software to be used by anyone interested in setting up a server, the "federated universe" (Fediverse) decentralizes the regulation of the Internet [9]. The expression "federation" is influenced by political science and seeks to define the decentralization of decision-making while creating rules for how to coexist in a common place [20].

Decentralization, however, is not in a single horizontal layer. Rules for servers are created by making various infrastructural decisions. Therefore, Fediverse can be considered upper-macro-regulated. For instance, the translation of interests in Fediverse is politically and economically determined, turning this platform into an actant in the organization of social life. Its creation in 2010 ascended from a team of entrepreneurs and digital developers interested in harmonizing Fediverse as an open-source platform and an alternative to parts of the World Wide Web (www.), engendered from technical, political, and economic disputes. Evan Prodromou, the primary spokesperson for this group, stated in an article [23] that only content creation is decentralized on the www. The Prodromou team was interested in promoting greater decentralization of the Internet's regulation. These ideas arose from civil liberty and economic liberalism beliefs and the group wanted to extend the possibility for individuals, companies, and organizations to acquire and regulate parts of the Internet necessary to favor competition, price reduction, and technical innovations. These liberal privatization suggestions were generated by technological propositions and political-economic disagreements when corporate companies' servers became platforms in the super-macro-regulation of the Internet (i.e., platform leadership). Hence, Fediverse is grounded in liberal theories of the technique and acts against mindshare and the Internet's centralization (promoted by big private companies). Furthermore, by being transparent with the organization of immaterial labor, this platform politicizes the debate around the organization of the Internet and favors the empowerment of users to regulate the Internet space.

8 Conclusions

Tying concepts together can be essential for advancing fine-grained and comprehensive theoretical understandings of the impact of the digital globalization on social practices such as education as it can can strengthen the democratization of the Internet

space. Essential insights are gained in this paper by linking digital platforms' leadership to ways in which they become calculation centers by eventually promoting a specific form of mindshare through immaterial labor. Especially as these technologies demand anyone with Internet access to create content, publish, and communicate that situate them in intricate agency networks. In mapping the Internet's controversies [14] and by exemplifying digital platforms for Internet navigation and social media, the www. can be interpreted as an industrial dispute regulated by platform leadership [8] that occupy calculation center positions [14] and thereby promote particular social needs [16]. These technologies, from Fediverse to www, are actants with unneutral characters. Therefore, research theorizing agency networks created by humans associated with technologies is essential for enriching education with tools for the problematization of the ongoing digital globalization. In length, such conceptions can make citizens vigilant and proactive about the power of the sociotechnical structures in the Internet space and will favor the development of democracy in the digital world.

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A New Method and Case Study for Predicting Tutoring Performance in Students at the Universidad Politécnica Salesiana using Data Science and Support Vector Machines

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Abstract What has become evident over time in higher education is the low performance of students, especially in the first cycles, and higher education is of vital importance for our society today. That is why the GIETAES Group and ASU AyudantĀas Estudiantiles of the Universidad Politécnica Salesiana (UPS) offers tutoring to students. These tutorials are provided from students to students; however, the challenge is to detect the students most prone to fail the subject, in order to help them at an early stage. Therefore, in the present work, we propose an innovative analysis method of machine learning built in phases with the aim of predicting whether a student will lose or not the subject; firstly, we perform data preparation in which a preprocessing of variables, variable analysis, secondly, we perform a predictive analysis for this we have experimented with some techniques including support vector machines, Random Forest (RF) algorithm, KNN algorithm, and finally in the third phase performs the evaluation and interpretation of results. To demonstrate the effectiveness of our method, we have used a UPS own dataset and evaluated it with several quality metrics such as accuracy, precision, recall, and $F1$-Score. This research is a base point to experiment with various parameters based on the low performance of students not only in higher education but in any educational entity.

Keywords Data analysis · Machine learning · Support vector machines · Academic tutoring · Student orientation

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1 Introduction

What has been evidenced over time is a desertion or failure of students in their first years of university, since factors such as lack of economic resources or low schooling are key points for the student to choose to leave their studies. For not having the basics, it is more complex for the student to progress in his university career. Mainly, subjects that have mathematics or calculus have been detected, they have a high rate of repetition, this represents a problem since if a student does not have sufficient bases they cannot keep up with the classes, causing their learning to be truncated, and they can fail their matter. According to a study [1], in Ecuador, many university students receive classes only to fulfill a social or family commitment, so techniques are required to help or detect students who are in this type of situation in time to be able to guide better. the student either through peer tutoring, teaching materials, etc. Thus, in this section, we will present the fundamentals of the method proposed in this research; we will also present its main objective and review the points to be discussed in this report and then move on to the work related to it.
This section is divided into four subsections: (1) Fundamentals of the Academy (2) Fundamentals of machine learning (3) Fundamentals of support vector machines (4) Brief description of the method.

(1) **Fundamentals of the Academy**

Within the Universidad Politécnica Salesiana, peer tutorials are offered during the academic cycle, these are students of higher levels who studied with outstanding average, they help students who take subjects with high repetition rate, these tutorials can be consultation type, where a student receives a quick tutorial or process tutorials, the latter requires several sessions over a period of time. Therefore, in the Academy, it is necessary to automate all these processes, make predictions to analyze future trends and prevent problems; then, techniques are required to help predict and analyze the future with historical data; thus, the need for techniques such as machine learning arises.

(2) **Fundamentals of Machine Learning**

Machine learning or automatic learning is a field of artificial intelligence that consists of letting algorithms discover certain recurring patterns in a data set. There are four fundamental steps in developing a machine learning model. The first step is to select and prepare a training data set. The second step is to select an algorithm to run on the training dataset. The third step is to train the algorithm. The fourth and last step is the use and improvement of the model. Within the machine learning techniques, the most important currently are neural networks, support vector machines, etc. However, among all these techniques, a relevant one is that of support vector machines because they are intuitive, the predictions are fast, and they have a short learning time in relation to other techniques such as neural networks.

(3) **Fundamentals of Support Vector Machines**

According to [2], support vector machines are statistical and machine learning techniques with the main objective of prediction. They can be applied to continuous, binary, and categorical outcomes in a manner analogous to Gaussian, logistic, and multinomial regression.

(4) **Brief description of the method**

The main objective of this research is to identify students who are likely to fail subjects in order to establish a tutoring recommendation system, that is, the students who are selected will be given greater promotion about the tutoring program. For this, we use a dataset which we balance by duplicating the failed students and apply machine learning in order to obtain a prediction that is as accurate as possible. The **main contributions** of this work are the following: (1) A machine learning method that incorporates a novel step of predicting a student's academic performance (2) An architecture based on Data Science for the preparation, learning, optimization, and presentation of results. (3) A phased process for optimization of support vector machines to obtain the best prediction results (4) A set of experiments with a dataset belonging to the Universidad Politécnica Salesiana and the comparison of our method with other more relevant methods.
The structure of the article is presented below:

II. Related work: The most relevant works related to the problem posed and the techniques used in this work are presented.
III. Proposed method: The proposed method is explained in detail.
IV. Design of experiments: The characteristics of datasets, optimization parameters in the proposed method, and other state-of-the-art methods are exposed, as well as quality measures to evaluate and compare the methods.
V. Results and discussion: Tthe final parameters of each method and the most relevant results are presented, as well as an analysis of the results.
VI. Conclusions: At the end, we conclude with the main conclusions and future work based on this research.

2 Related Work

In this subsection, the different works related to learning and teaching in education together with machine learning will be announced: Supportive learning has played a crucial role in improving educational quality. Predicting the performance of the students is of great interest since it will be possible to announce whether or not they will pass the subject, in addition to highlighting their understanding of the topics. An improved support vector machine algorithm based on a conditional generative adversarial network is proposed to predict the performance of students under the support of family or school tutoring [3]. Tutorials have long been known to enhance

student engagement in learning and have often been used by learning institutions to enhance the student learning experience. However, in the recent past, there has been a gradual decline in the use of group tutorial discussions due to the large classes a teacher is expected to teach [4]. The article [5] emphasizes the importance of support vector machines and how they have been used in remote sensing, especially among researchers who work and study hyperspectral data sets. Then, a classification result of a HyMap dataset is raised using two of the proposed improvements: import vector machines and relevance vector machines, and compared with the support vector machine. In the article [6], a method of grouping and reclassification for the recommendation of movies through an improved algorithm is proposed of K-means to perform grouping based on the scores of similar users. As a result of optimization, the improved algorithm has significantly improved the accuracy of recommendation results. In the article [7], an insurance product recommendation method is proposed using the RF algorithm and comparing it with other methods such as the KNN, the ID3 algorithm, the C4.5 algorithm, and the Nave-Bayes algorithm. As a result, it was possible to obtain that the RF prediction error is less than 2.02 % compared to the other methods, so it can be said that it is highly feasible to recommend insurance products with RF. In the article [8], an improved classifier for support vector machines is proposed, but with fuzzy multicategory (IFMSVM). It is based on the knowledge of the ambiguity associated with the belonging of the data samples to a certain class and the location relative to the origin, in order to improve the classification performance with a high generalization capacity. As a result, it was found that the algorithm is effective and efficient specifically for small data sets; however, it has the disadvantage of time complexity. In the article [9], it is stated that the changes in the context of higher education are forcing institutions to rethink the type of related offer that educational institutions offer regarding student support and academic orientation.

In article [10], the use of agile practices in the teaching process is proposed, emphasizing a much more active role by teachers and students. In addition, the results obtained are also presented based on three inquiry processes: student survey, teacher interview, and planning analysis in order to know the perspective of both the teacher and the students in relation to the application of agile practices in the process. In the article [11], a descriptive study of the different aspects related to the strategies implemented for the dictation of different subjects is proposed in order to elucidate which pedagogical models emerge from the development of distance learning processes. As a result of what was observed, the strategies developed by the teachers were identified, some vulnerable and strong points were also recognized and, based on this, it is proposed to propose some future lines of work. In the article [12], the effectiveness of tutorials seen from the student's perspective is raised so that teaching work can be improved. The results obtained show that face-to-face tutoring is even more valued, that is, the virtual modality is increasingly valued and useful. In the study [13], it is proposed to improve the provision of help between tutors and its implementation in a classroom. As a result, it was obtained that the assistant improved the conceptual content of the help and the use of the interface characteristics, consequently, it was found that the fellow tutors responded better to the assistance that made them feel responsible for the help they provided. In the study

[14], a machine learning feature selection method (MLFS) combined with the support vector machine method is proposed with the aim of extracting and verifying patterns and/or key features that influence the academic performance of students. As a result, it was found that the quality and effectiveness of the model are better than other conditions. In the article [15], a model that is capable of offering remedial tutoring is proposed. To demonstrate the effectiveness of this intelligent model, INTUITION, an existing business simulation game, has been developed. Evaluation of INTUITION shows that the recovery operations model is a useful method for providing efficient recovery tutoring. In the study [16], an exhaustive survey on the recent advances in the automatic learning of the Lie group is proposed oriented to what would be image processing. This survey will allow researchers to comprehensively understand the state of the field and identify the most appropriate tools for particular applications. In the study [17], it is stated that machine learning has its limitations, which is why a solution is proposed which is the additional integration of previous knowledge that leads to the notion of informed machine learning. A taxonomy is presented that serves as a classification framework for informed approaches to machine learning. In the article [18], it is proposed to carry out a longitudinal study designed to show the perception of the students on the Institutionality. To carry out the study, a diagnosis had to be made to identify the advantages and disadvantages of applying academic tutoring. In the article [19], a method is proposed that applies machine learning algorithms (K-means and SVM) to automatically classify students as attentive or inattentive. The results of this research can be used to improve teaching strategies for instructors. In the study [20], a method based on a random forest algorithm is proposed to evaluate the effectiveness of anti-bird devices, which makes full use of the collected historical anti-bird device usage data. As a result, it was obtained that the proposed method can provide analysis conclusions on the level of influence of each factor on the effectiveness of the anti-bird device as a percentage.

In the article [21], the importance of having a support vector machine algorithm is pointed out in order to help in the underwriting methods of Chinese life insurance companies, at the end it points out the directions to improve this algorithm. In the article [22], they propose the use of artificial neural networks (ANN) with the aim of predicting some phenomenon with good results in order to detect concentrations of heavy metals from magnetic parameters. The result of the study was that there are several sides, especially roads with high concentrations of heavy metals. In the article [23], they talk about mining educational data in order to analyze student performance and from this improve the quality of teaching. This is in order to have a personalized tutorial and with the data obtained have a better idea of how to explain to the student. In the article [24], he tells us about SVM and how it is used to classify remote sensing images, and it is proposed to make use of the decomposition scheme of the decision function of such that the time is greatly reduced. In the article [25], they mention that hyperspectral images have recently been introduced in learning based on vector support machines, and all this allows improving the sort rate and makes better ranking maps without noise. In the article [26], he tells us that artificial intelligence is one of the most recurrent topics today and within this is machine learning (ML) and this is in great demand, but in addition to this its teaching has

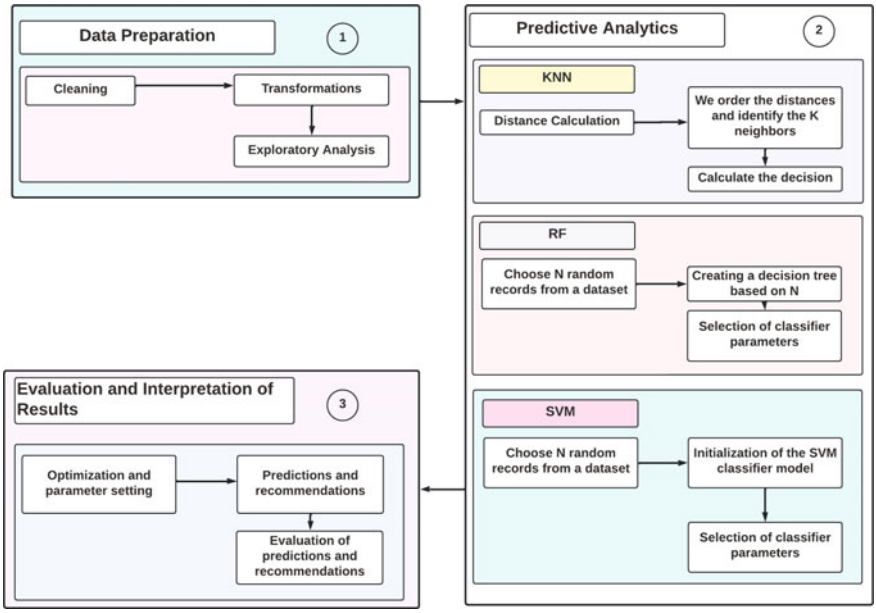

Fig. 1 Process of the proposed analysis method

been made difficult especially with high school students. In the article [27], reference is made to distance courses and how innovative they are, the objective of the research is to present a qualification scheme with a high predictive performance in reviews of Massive Open Online Courses (MOOCs). This has been ventured into the methods of joint learning and deep learning.

3 Proposed Method

In this section, the proposed analysis method is presented, emphasizing its architecture, parameters, methods, etc. It should be noted that the proposed analysis method is based on the CRISP-DM methodology [28].

As can be seen in Fig. 1, we have several phases which will be detailed below.

3.1 Data Preparation

1. Cleaning
   In this part, then, what is done is with the set of data to solve anomalies in it in order to improve the quality of the data to later go on to transform them.

2. Transformations
   In this part, what is done is that we classify the data into numerical or categorical variables as appropriate.
3. Exploratory Analysis
   In this part, we see how the data is related to others through correlations and any anomaly that the already transformed data set may present.

3.2 Predictive Analytics

This phase allows predicting whether or not a student will fail a subject, for which several predictive methods have been used, which are KNN, RF, and SVM.

3.3 Evaluation and Interpretation of Results

Finally, in the third and last phase, an evaluation and interpretation of the results is carried out, and for the three cases it is the same process: The optimization and adjustment of parameters explained in the table of parameters below, predictions and recommendations, and finally, we evaluate said predictions and recommendations. The design of experiments carried out during this investigation is presented below.

4 Design of Experiments

This section is divided into two subsections: (1) characteristics and optimization parameters of the methods and (2) quality measures.

(1) **Dataset characteristics and method optimization parameters**

There is a dataset with student records based on which it is intended to predict whether new students will be able to pass the cycle, taking into account various factors. In the Table 1 refers to the own dataset of the Universidad PolitÃ©cnica Salesiana.

Next, the different parameters/variables of the dataset are presented in Table 2.

Next, the different optimization parameters for the different methods applied are presented in Table 3.

Table 1 Properties of the dataset used in the experiments

Dataset	Number of instances	Number of variables
TUPS [29][a]	7565	13

[a] Own dataset of the Universidad Politécnica Salesiana

Table 2 Description of dataset variables

Name	Description
Grupo	Group to which the student belongs
Carrera	Student career
Materia	Student subject
Nivel	Student grade level
Edad	Student age
Colegio en el que se graduo	College where student graduated
Promedio de graduacion	Student graduation average
Ciudad de origen	City of origin of the teacher
Quintil	Student quintile
Numero de tutorias	Number of tutorials of the student
Numero de horas	Number of hours of tutorials of the student
Numero de tutores	Number of tutors the student has had
Calificacion	Final student classification

Table 3 Method optimization parameters

Method	Parameters
SVM	Gamma = [0.1, 0.5, 1, 1.5] Kernel = [poly, linear, rbf, sigmoid] C = [0.001, 1, 20, 50, 70]
KNN	n_neighbors = [20, 2, 50, 300, 20, 2, 50, 5, 2, 87] Weights = [uniform, distance]
RF	n_estimators = [20, 40, 60, 100, 150, 200] max_depth = [none, 5, 15, 30, 35, 40]

(2) **Quality Measures**

This subsection presents the quality measures to evaluate each of the predictive methods, in which k-fold cross-validation was used in which $K = 20$ and the quality measures precision, recall, $f1$-score were used and accuracy which are presented below:

1. Precision

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}} \tag{1}$$

It is the spread of a set of values, in this case the smaller the spread then the higher the precision, this involves both positive and negative predictions.

2. Recall

$$\text{Recall} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \tag{2}$$

It is the precision that the algorithm had when giving real positive values, that is, values that marked positive and that were effectively positive.

3. $F1$ Score

$$F1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3}$$

Accurately summarizes precision and recall into one, this helps especially when class distribution is uneven.

4. Accuracy

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{4}$$

This is the total number of correct predictions divided by the total number of predictions; this helps us see how close we are to the true value.

In the next section, the results obtained during the entire analysis method will be presented, starting from the descriptive analysis, variables more correlated with the output variables, results of the predictive analysis and evaluations and interpretations of the results.

5 Results

This section follows the proposed method of analysis and presents the results.

5.1 Data Preparation

In this section, we made a thorough analysis of our data set, and we used heat maps to note the correlation between the different variables with the output variable. Figure 1 presents the correlations, and it can be seen that the most relevant variables with respect to the output variable are the average graduation with age, also the most correlated variables are the number of tutorials with the number of hours.

In Fig. 2, we can see how the grade is positively correlated with the age of the student, the average graduation rate, the number of tutorials and the number of tutors, which indicates that when these parameters increase so does the grade.

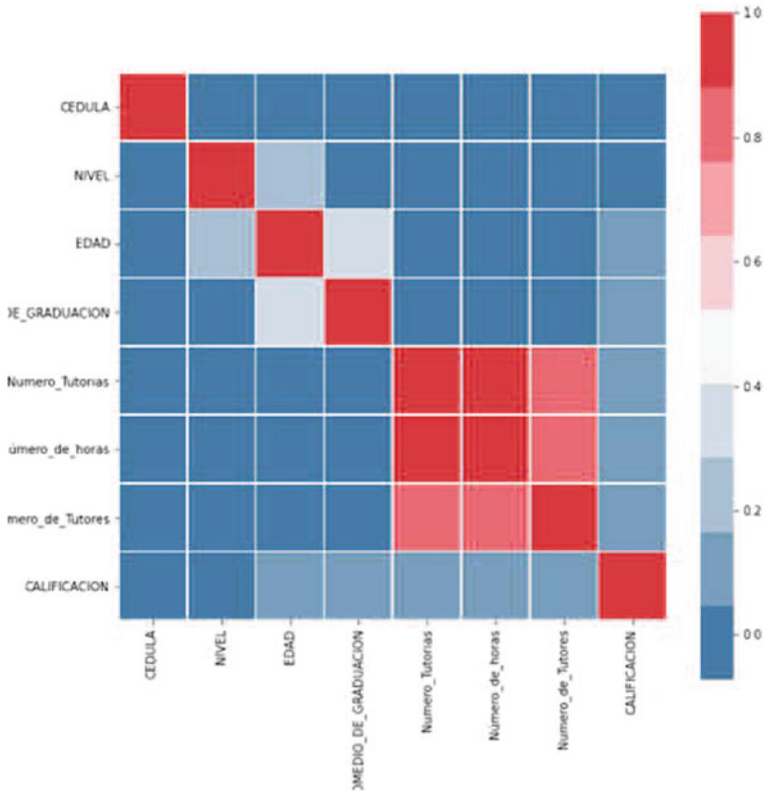

Fig. 2 Variable correlation matrix

5.2 Predictive Analytics

In this section, we present phase 2 of the modeling in which we experimented with several methods in which we adjusted the different parameters of each one in order to obtain better results. Table 4 shows the final optimization values.

5.3 Evaluation and Interpretation of Results

In this section, phase 3 of the modeling is presented, and some classification measures were experimented with for the evaluation of the modeling; among them are precision, recall, $F1$-Score, and accuracy. The results are presented in Table 5.

Based on the method of analysis, it was concluded that the best method is the support vector machine method, since it has an accuracy of 0.90. However, it is

Table 4 Final values of each method

Method	Parameters
SVM	Gamma = 1 Kernel = rbf C = 70
KNN	n_neighbors = 2 Weights = distance
RF	n_estimators = 200 max_depth = none

Table 5 Comparison of methods

Method	Precision	Recall	$F1$-score	Accuracy
KNN	0.96	0.78	0.86	0.87
SVM	**0.94**	**0.85**	**0.89**	**0.90**
RF	0.95	0.82	0.88	0.89

Based on the method of analysis bold indicates the best method that is support vector machine method which has an accuracy of 0.90

important to emphasize that in the case of the KNN method, although it also gives us a good accuracy, this method tends to work better with a not so large amount of data.

6 Conclusions

In this research, an innovative analysis method was provided that includes machine learning, fulfilling the objective of predicting whether or not a student will fail the subject. In phase 1, it was obtained as an observation that the most relevant variables are the average graduation rate and age in relation to the exit variable. In phase 2 of the predictive method, the best technique was SVM because it has the best accuracy of 90%. The process of each method has its particularity, some are faster, but less efficient and others take longer to give a result, but are more precise. The proposed method will improve the performance of students in any educational institution that has tutoring. In the future work, it is proposed to experiment with new automatic learning techniques such as neural networks or to implement the boosting technique, in addition, the proposed model does not take into account the temporary variables, however, if required, they could be used to measure the performance of the students. through recurrent neural networks for time series. Finally, with the present work, the creation of new support services for higher education institutions is encouraged, and to achieve greater precision, it is recommended to experiment with a greater amount of data.

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A Study on the Pressure Sensor for Estimating the Load Point in a Prosthetic Socket

Na-Yeon Park, Su-Hong Eom, Jung-Hwun Ryu, and Eung-Hyuk Lee

Abstract A transfemoral prosthesis is a device that performs locomotion in place of the amputated lower leg. It is necessary to change the locomotion style suitable for each environment in order to cope with the locomotion environment that changes discontinuously. To implement this, studies on the transfemoral prosthesis have been conducted in the direction of detecting the user intention to change locomotion through the biomechanical characteristics inside the socket in direct contact with the amputated section. Among the biomechanical features, the pressure change inside the socket enables the identification of a load point according to the intentional movement of the lower leg. Therefore, studies have been conducted to detect the user intention in locomotion by measuring the pressure change. However, previous studies have left the need for a sensor system suitable for the body flexion of the amputated section and the internal environment of the socket. Therefore, in this study, a pressure sensor that is not vulnerable to noise caused by body impedance, has a flexible film type, and can respond to the curved surface of the socket was fabricated. In this study, a pressure sensor was fabricated by applying Velostat film that satisfies the requirements of the sensor inside the socket, and a cutting method was considered to remove a unfastened problem due to uneven surfaces. The sensor proposed in this study will be able to be used to estimate the load point inside the socket by improving the problems of the existing pressure sensor system. In addition, it will be possible to apply it to a system that detects the user intention to change the prosthetic leg control through future studies.

Keywords Prosthetic leg · Sockets · Velostat · Pressure sensor

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1 Introduction

The transfemoral prosthesis is an auxiliary device that replaces the function of the upper lower leg of the knee joint lost due to accidents and diseases [1, 2]. The transfemoral prosthesis began with a passive prosthetic leg in the past and developed into an active prosthetic leg that generates and provides the necessary trajectory of locomotion using actuators. The active prosthetic leg supports various functions of locomotion on flat ground, stair locomotion, sitting, and standing [3]. However, each functional motion provided by the prosthetic leg has no similarity in the locomotion sequence. Therefore, the prosthetic leg should be changed to a suitable control method for each locomotion environment [4]. In the past, passive methods have been used to determine when prosthetic leg users need to change and change them directly [5, 6]. However, prosthetic leg users feel unnatural in the passive change process and require different prosthetic legs where more natural changes are made [6, 7].

In response to such a request, studies are being conducted to determine the user intention of changing the control inside the prosthetic leg and to change the locomotion method. The preceding studies were conducted to detect the users intention in locomotion by measuring the pressure inside the socket in direct contact with the section of the femoral amputation. The pressure change inside the socket is a biomechanical feature that changes the position of the load point as the weight of the dispersed prosthetic leg is concentrated at a specific point due to the movement of the lower leg. The position and pattern of the load point detected by measuring the pressure change in the socket indicate the intentional hip joint movement of the user. Therefore, the previous studies have attempted to determine the location of the load point inside the socket by measuring the pressure change in the socket with a capacitive pressure sensor or a resistance change pressure sensor [8, 9]. However, the capacitive pressure sensor is vulnerable to noise caused by skin impedance that changes as the temperature inside the socket rises and sweat occurs. In addition, in the case of commercial sensors, the reproducibility of sensor data is reduced due to the shape and attachment method that does not take into account the unevenness of the body, and there is a problem that causes wounds to the skin inside the socket [8, 10].

In contrast, the film-type resistance change pressure sensor is relatively strong against noise caused by skin impedance that changes with the increase in temperature inside the socket and the occurrence of sweat. In addition, because it is a flexible type, it does not cause a wound in the socket worn area, which is advantageous for application inside the socket. However, commercial sensors have the same problem that the unevenness of the body and the socket is not considered due to the structured shape. Sensors that do not take into account the unevenness have poor reproducibility of sensor data due to the unfastened sensor or crumpling sensor when attached to the inside of the socket [11]. In conclusion, sensors for measuring pressure in the socket should not be vulnerable to noise caused by body impedance, should be a flexible film type, and should be able to respond to body curves.

Accordingly, this study aims to fabricate a pressure sensor that is not vulnerable to noise caused by body impedance, has a flexible film type, and can respond to uneven surfaces. This is to establish a sensor system that detects the locomotion intention of the transfemoral prosthesis user through identifying the position of the load point inside the socket according to the intentional hip joint movement. The requirements for the pressure sensor inside the socket can be satisfied using Velostat film. The Velostat film is a resistance change type that is not vulnerable to noise caused by body impedance, and is a flexible film type. In addition, since it is easy to fabricate various sizes and shapes, it is possible to fabricate a form that does not cause a unfastened problem by considering the unevenness of the body and socket. Therefore, this study intends to consider a sensor fabrication method that is suitable for the internal environment of the socket using the Velostat film and does not cause excitation due to the unevenness.

Chapter 2 confirms the principle of the pressure measurement of the Velostat film and describes the method of fabricating a pressure sensor using the Velostat film. In addition, it is intended to understand the fabrication method necessary for solving the unfastened problem inside the socket. Chapter 3 attempts to verify the possibility of improving the unfastened problem by cutting the sensor in various forms and conducting pressure measurement experiments on the cutting sensor. The sensor proposed in this study will be able to be applied to the system for estimating the load point inside the socket by improving the problems of the existing pressure sensor system.

2 Research Method

This study aims to fabricate a pressure sensor that is not vulnerable to noise caused by body impedance, has a flexible film type, and can respond to body unevenness. The requirements for the pressure sensor inside the socket can be satisfied using the Velostat film. Therefore, in this chapter, the principle of pressure measurement of the Velostat film is verified, and the method of fabricating the pressure sensor using the Velostat film is described. In addition, a cutting method necessary for solving the excitation inside the socket is to be verified.

2.1 Requirements for the Internal Pressure Measurement System of the Socket

For determining the intention of the active transfemoral prosthesis user to change the control method in the pressure measurement system inside the socket, it is necessary to satisfy the following conditions:

Condition 1. The sensor shall not be affected by the internal environment of the socket and the body resistance components.

Condition 2. The sensor shall not cause injury to the sensor contact area.

Condition 3. The sensor shall be attached without excitation, considering the socket structure and unevenness of the amputated lower leg.

These three requirements can be satisfied using the Velostat film based on a resistance variable type similar to an FSR sensor. Therefore, a pressure sensor using the Velostat film based on a resistance variable type that satisfies these three requirements is to be fabricated. Also, the cutting method, size, and shape required to solve the internal excitation of the socket are to be investigated.

2.2 Method of Fabricating a Velostat Film-Based Pressure Sensor.

As shown in Fig. 1, the Velostat film can verify the applied pressure level by measuring the electrical resistance that changes when pressure is applied [12]. The pressure sensor is fabricated in a sandwich type with electrodes attached to both sides of the Velostat film, as shown on the left side of Fig. 2. The circuit of the sensor consists of a Wheatstone bridge as shown in Fig. 2. The Velostat electrodes are attached to an upper section close to the applied power source to form a circuit. This configuration is to measure the level of pressure in the form of an upward voltage when pressure is applied. The internal reference resistance of the circuit is specified to produce an initial output of 500 mV with no pressure applied. The applied pressure level may be measured through an increasing output voltage value. The availability of the Velostat-based sensor has been confirmed through the study conducted by our research team in the past [13].

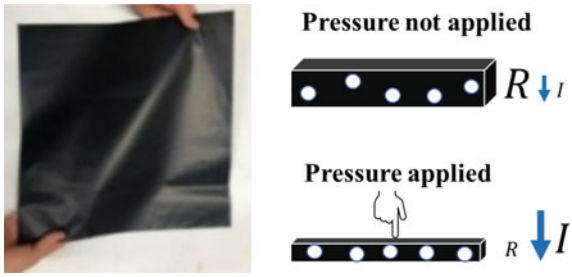

Fig. 1 Velostat film and pressure sensing principles

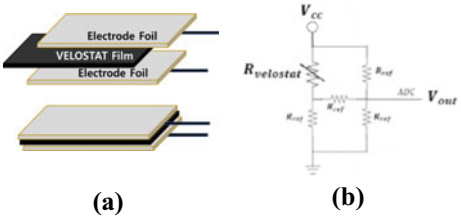

Fig. 2 **a** Fabricated pressure sensor: electrode foil and the sandwich structure of the Velostat film, **b** wheatstone bridge circuit for measuring the applied pressure

2.3 Method for Improving the Unfastened Problem Inside the Socket

Since the transfemoral prosthetic socket of the prosthetic leg has a structure for enclosing the amputated lower leg, there exists uneven surfaces. For this reason, a sensor attached to the inside of the socket does not come into close contact with the socket surface, causing a unfastened problem. The unfastened problem of such a sensor causes deformation in the structure of the sensor such as crumpling, thereby reducing reproducibility of sensor data. This problem can be solved by cutting the outskirts of the sensor in a triangular shape as shown in Fig. 3b. The cutting of the outskirts can easily solve the unfastened problem in a wider form. However, the large cutting area causes excessive loss of the sensor as shown in Fig. 3c. Therefore, in this section, it is necessary to verify the fabrication method of the sensor that does not cause any unfastened problem in the uneven surfaces inside the socket with the minimum cutting area.

3 Implementation and Experiments

In this chapter, the sensor is cut into various sizes and shapes to understand the fabrication method necessary for solving the unfastened problem inside the socket. In addition, a pressure measurement experiment is performed on the fabricated sensor to confirm the possibility of improving the unfastened problem. The larger the cutting

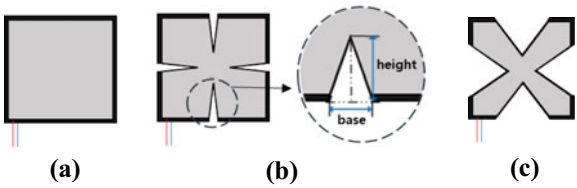

Fig. 3 **a** Sensor before cutting the outskirts: for fabricating it in a large size, there is a unfastened problem inside the socket, **b** sensor after cutting the outskirts: insert an incision line at the unfastened section to increase the adhesion of the sensor, **c** sensor with excessive cutting: as the base of the cutting triangle is lengthened, the sensor loss area is widened, resulting in excessive gaps

area is, the more likely it is to be solved. However, the large cutting area shows a blank area of measurement due to the loss of the sensor area. Therefore, in this chapter, it is necessary to identify the method of minimizing the cutting area without any unfastened problem inside the socket.

3.1 Measurement Characteristics of the Cutting Sensor Fabrication and Cutting Rate

This section attempts to verify the fabrication method necessary for solving the unfastened problem inside the socket by cutting the sensor in various forms. The sensor cutting is performed in a triangular form as shown in Fig. 3b. The cutting amount of the sensor can be adjusted by varying the ratio of the height to the base of the cutting triangle. The sensor cutting fabricated for this experiment can be found in Table 1.

The unfastened problem of each sensor may be verified through the initial output value of the sensor. The initial output value with no pressure applied is 500 mV set through the internal reference resistance. The initial output value exceeding 500 mV is the result of lowering the resistance component of the sensor in accordance with the Velostat film pressure measurement principle described in Figs. 1 and 2. Therefore, if the initial output value exceeds 500 mV, it can be determined that the sensor is bent or wrinkled due to the unfastened problem.

Figure 4 shows the area where the sensor is attached to verify the initial output voltage of the sensor applied inside the prosthetic leg socket. Figure 4 shows the area where the sensor is attached to verify the initial output voltage of the sensor applied inside the prosthetic leg socket. Figure 4 shows the area where the sensor is attached to verify the initial output voltage of the sensor applied inside the prosthetic

Table 1 Sensors cut to different sizes

	1	2	3	4	5
Pictures					
Image					
Cutting amount	**Base** – (0%) **Height** – (0%)	**Base** – (0%) **Height** 18 mm (30%)	**Base** 3 mm (5%) **Height** 12 mm (20%)	**Base** 3 mm (5%) **Height** 18 mm (30%)	**Base** 3 mm (5%) **Height** 24 mm (40%)
Cutting rate (loss rate) (%)	0	0	2	3	4

Fig. 4 Sensor attachment point to determine the degree of excitation of the sensor

leg socket. The attachment position was designated as the lower part where a large curve exists inside the socket to check the degree of sensor excitation according to the cutting amount.

Figure 5 is a graph showing the initial output values of the five sensors shown in Table 1. The degree of sensor excitation according to the cutting amount can be determined by comparing the output values before and after attaching the sensor inside the socket shown in Fig. 5. Sensor 1, which is not cut, is measured with the highest initial output value after being applied to the socket compared to the other four sensors. In comparison, the initial output values of the remaining four sensors tend to decrease according to increases in the cutting amount. Among them, Sensor 5, which has the largest cutting amount, is measured with an output value close to 500 mV, and is considered an ideal sensor that improves the unfastened problem. Through these experiments, it was confirmed that the unfastened problem of the sensors can be improved by adjusting the cutting amount.

Sensor 2 is cut in a simple straight line without the base of the triangle. Sensor 2 shows a high initial output value even though it is cut to a high level of 30% in

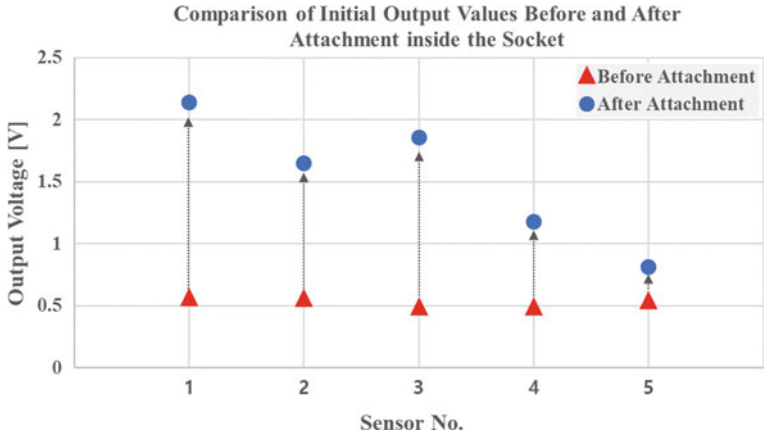

Fig. 5 Comparison of outputs before and after attaching the sensor inside the socket—no excitation: initial output voltage approaches 500 mV, excitation: initial output voltage exceeds 500 mV

length. Based on this, it can be seen that the length of the base of the cut triangle is essential to remove the unfastened problem. However, excessive cutting of the base increases the amount of sensor loss as shown in Fig. 3c. Therefore, in this study, the base of the cutting was fixed to 3 mm, which is a 5% ratio of 60 mm on one side of the sensor, and only the cutting height was changed to adjust the cutting size.

3.2 Measurement Characteristics of the Pressure Change According to the Cutting Rate

In this section, the pressure measurement characteristics of the sensors cut to various sizes are to be checked. What is to be confirmed through experiments is the tendency of pressure change according to the presence or absence of the cutting and the cutting amount. The experiment was conducted by attaching Sensors 1, 3, 4, and 5 shown in Table 1 to the lower part of the socket before applying pressure. The results of the pressure application experiments are shown in Fig. 6.

Sensor No. 1, which has not been cut, shows the highest initial output value compared to the three sensors that have been cut. For this reason, Sensor 1 has a narrow pressure measurement range, making it difficult to accurately measure pressure. The three sensors that have been cut tend to decrease the unfastened problem and widen the range of pressure measurement according to increases in the cutting amount. Based on this, it can be confirmed that the cutting outskirts of the sensor can solve the unfastened problem. Sensors 2 and 3 in Fig. 6 represent a high initial output value and a narrow measurement range compared to Sensor 4, but there is an

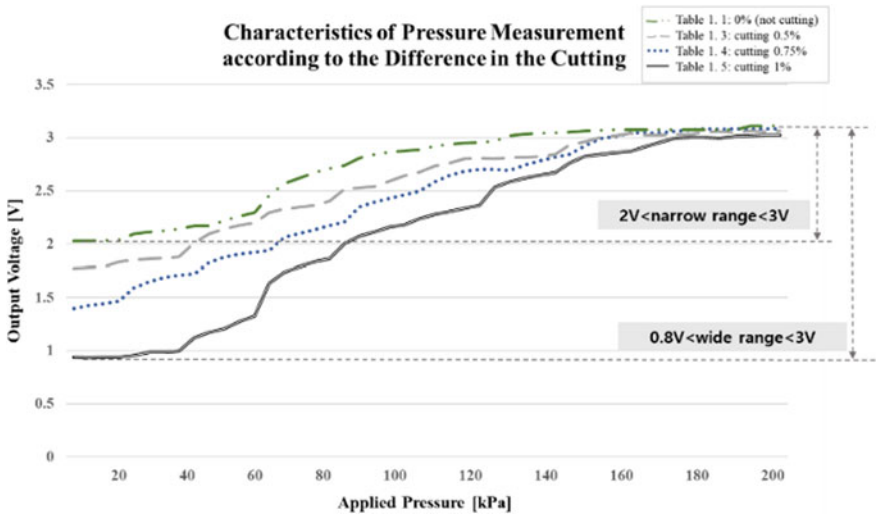

Fig. 6 Characteristics of pressure measurement according to the difference in the cutting amount

advantage that the sensor loss area due to the cutting is small. Therefore, it is verified that it is possible to nicely use in the areas with less curvature. The sensor cutting can be applied selectively as necessary in consideration of the unevenness pattern of the socket and the sensor loss area.

Cutting sensors were attached as shown in Fig. 7a to confirm the possibility of use inside the socket of the sensor that removed the unfastened problem when attaching the curvature. The attached sensor is No. 4 of Table 1 and is a sensor in which the minimum cutting amount that does not cause a unfastened problem in the curvature inside the socket is considered. The experiment is repeatedly performed after the standing posture as shown in Fig. 7b, taking a posture of lifting the lower leg so that the foot and the ground are separated. The results of the experiment are shown in Fig. 7c. In a standing position where the foot and the ground contact each other, initial pressure due to the body's load is generated. It is confirmed that the pressure inside the socket decreases as the body load is removed in the posture of separating the foot from the ground. The experiments conducted confirmed the possibility of detecting the pressure change inside the socket caused by the intentional posture and the possibility of quantifying the pressure change.

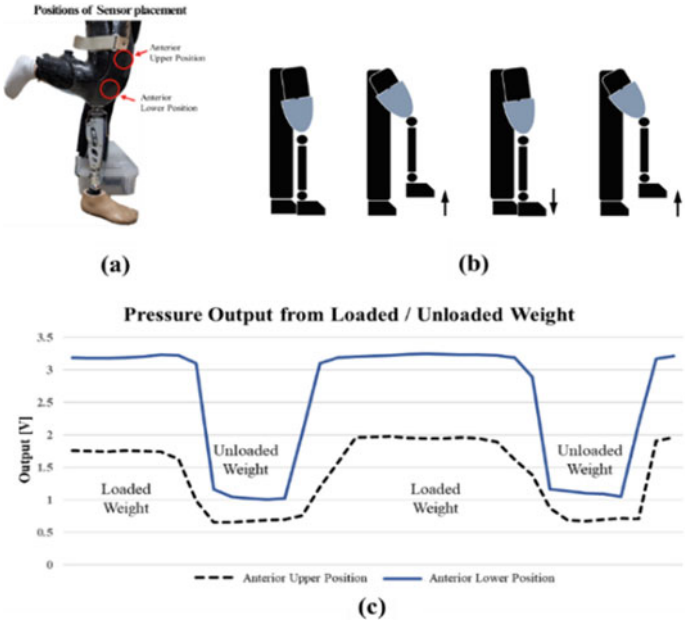

Fig. 7 An experiment for evaluating the usability of sensors: checking the pressure changes during loaded weight and unloaded weight

4 Conclusions and Future Study Directions

In this study, the locomotion intention of the transfemoral prosthesis user was detected by grasping the position of the load point inside the socket according to the intentional hip joint movement. Through this, a pressure sensor that is not vulnerable to noise caused by body impedance, has a flexible film type, and can respond to the curved surface of the body was fabricated. In this study, a sensor fabrication method using the Velostat film satisfying the requirements of the socket internal pressure sensor was considered to improve the problem of the existing socket internal pressure sensor. Chapter 2 showed the principle of measuring the pressure of the Velostat film and the fabrication method of the pressure sensor, and identified the cutting method necessary for solving the unfastened problem inside the socket. In Chap. 3, sensors were cut in various shapes, and pressure measurement experiments were conducted on the cut sensor to confirm the possibility of improving the unfastened problem. These processes demonstrated the usability of the proposed system to solve the problems of the existing system. However, since the sensor system presented in this paper has not been verified in terms of durability, further research will be needed. The sensor considered in this study could be applied to a system for estimating the load point inside the socket by improving the problem of the existing pressure sensor system. In addition, it will be applied inside the socket and possible to use it as a system to detect the user intention to change the prosthetic leg control through future studies.

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An Evolutionary Computation-Based Platform for Optimizing Infrastructure-as-Code Deployment Configurations

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Abstract PIACERE is an H2020 European project which objective is to implement a solution involving the development, deployment, and operation of Infrastructure-as-Code of applications running on cloud continuum. This technical paper is focused on describing a specific module of the whole PIACERE ecosystem: the *IaC Optimizer Platform*. The main objective of this component is to provide the user with optimized Infrastructure-as-Code configurations deployed on the most appropriate infrastructural elements that best meet the predefined requirements. For properly dealing with this problem, the *IaC Optimizer Platform* is based on Evolutionary Computation metaheuristics. More specifically, it resorts to NSGA-II and NSGA-III algorithms, depending on user needs. Additionally, we not only describe the *IaC Optimizer Platform* component in this paper, but we also show how it helps the user to find the most adequate Infrastructure-as-Code configurations.

Keywords Infrastructure-as-Code · Non-dominated sorting genetic algorithm II · Cloud computing · Optimization

1 Introduction

Evolutionary Computation (EC) has risen as one of the most intensively studied fields within artificial intelligence [1]. The abundant research carried out around EC demonstrates the interest that sparks in the related community, mainly attracted due to the capability and adaptability of EC techniques for efficiently solving a myriad of problems. The renowned flexibility of EC solvers for dealing with both real-world and academic-oriented problems is the most appreciated strength of EC-based metaheuristics [1]. For this reason, up to now, EC algorithms have been successfully adapted to a wide range of areas, such as medicine [2], energy [3], transportation [4], industry [5, 6], or software engineering [7]. More concretely, the platform presented in this technical paper is framed at the last of these categories: software engineering.

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The solution detailed in this manuscript has been developed as part of an EU research project, under the program Horizon 2020. The principal objective of the project, coined as PIACERE,[1] is to implement a solution involving the development, deployment and operation of Infrastructure-as-Code (IaC, [8]) of applications running on cloud continuum. As part of the whole system, PIACERE has a specific module named as *IaC Optimizer Platform* (IOP, [9]). This paper is focused on describing this concrete module and demonstrating its main advantages and how it contributes to reach the objectives of the whole PIACERE Ecosystem.

In a nutshell, the goal of the IOP is to provide the user with optimized deployment configurations of the IaC on the most suitable infrastructural elements that best meet the predefined restrictions and requirements. For doing this, the module counts on with a component coined as Infrastructural Elements Catalogue (IEC), where the attributes of all available elements are detailed.

The motivation of this work is to introduce and demonstrate the applicability of the IOP, which is based on EC metaheuristics for facing the above-described task. For reaching this goal, we describe the main optimization problem to solve, deepening on its particularities and demonstrating its adaptability to the user needs. Also, we detail the developed flexible solving platform, the IOP, which resorts on the Non-dominated Sorted Genetic Algorithm II (NSGA-II, [10]) and Non-dominated Sorted Genetic Algorithm III (NSGA-III, [11]), depending on user requirements.

The structure of this work is as follows. Section 2 is devoted to describing the optimization problem related with PIACERE and dealt by IOP. Next, we introduce the developed IOP in Sect. 3. Then, in Sect. 4, we present some examples for showcasing the relevance of the implemented platform. We finish this paper with conclusions and further work (Sect. 5).

2 Optimization of IaC Deployment Configurations: Problem Description

In few words, the IOP platform successes if it provides the best IaC deployment configurations, optimizing the user introduced objectives and considering all the predefined requirements and constraints. Once the optimization is done, the IOP should provide several ranked solutions, clearly showing their main characteristics, so that the user can choose the most appropriate one. Having said that, along this section we describe the main steps for properly defining the optimization problem in PIACERE.

[1] https://www.piacere-project.eu/.

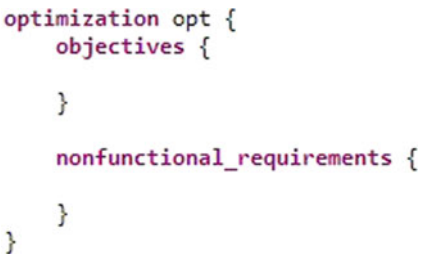

Fig. 1 Generic form of the optimization section in DOML

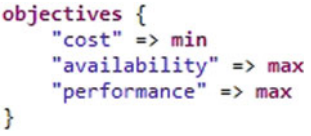

Fig. 2 `Objectives` section considering three objectives

2.1 Introducing the Optimization Objectives and Requirements

An interesting point to highlight here is that the optimization problem dealt in PIACERE is fully defined by the user. First, for performing an optimization, the IOP should receive an input file from the PIACERE Ecosystem written in an ad-hoc developed modeling language, the PIACERE DevSecOps Modeling Language (DOML[2]). This input file should include an optimization dedicated section, which is the one that defines the optimization problem to solve by the IOP. More specifically, the optimization related section should have the generic form depicted in Fig. 1.

The first part of this section should be devoted to establishing the objectives to optimize. At this moment, three different objectives can be contemplated in the IOP: minimize the cost and maximize the availability and the performance. Thus, any combination of these objectives can be considered, meaning that the IOP can deem a two-objective and three-objective multi-objective problem to solve and even single-objective problems. The example depicted in Fig. 2 shows how the information should be introduced for considering a three-objective multi-objective problem.

In addition to the optimization objectives, the IOP has been adapted also for considering a set of nonfunctional requirements. Up to now, and based on the interests expressed by use case owners, five different requirements are contemplated for the IOP:

- Assign a *maximum cost* for the overall configuration.
- Assign a *minimum availability* for the overall configuration.
- Assign a *minimum performance* for the overall configuration.
- *Restrict the region* of the selected elements.
- *Restrict the providers* of the elements.

[2] https://www.piacere-doml.deib.polimi.it/.

```
nonfunctional_requirements {
    req1 "Cost <= 200.0" max 200.0 => "cost";
    req2 "Availability >= 98.0%" min 98.0 => "availability";
    req3 "Performance >= 10.0%" min 98.0 => "performance";
    req4 "Region" values "00EU" => "region";
    req5 "Provider" values "AMAZ" => "provider";
}
```

Fig. 3 `nonfunctional_requirement` part considering five different requirements

With all this, we show in Fig. 3 an example of the five requirements, and how they should be introduced in the `nonfunctional_ requirement` part previously explained:

As can be seen, cost, availability, and performance are introduced as double values, while region and provider features should be defined using string-based keys. As in the case of the objectives, the user is able to choose as many requirements as needed (among the five above defined) to define the use case.

Finally, and regarding the optimization process, the definition of this kind of constraints determines the search space of the optimization algorithm. Once this solution space is defined, the algorithm is run guaranteeing that all solutions provided as output compulsorily meet each and every one of the requirements defined. In other words, solutions that do not meet all constraints will be categorized as unfeasible.

2.2 Introducing the Optimization Variables

Another important feature to consider when designing the problem is related with the optimization variables that will compose it. At this moment, three different elements are available in the IEC: Virtual Machines (VM), Storages, and Data Bases. This means that the IaC deployment configurations will be composed by any combination of these elements. In order for the user to be able to fix the kind and amount of elements needed for the use case, an additional requirement can be contemplated in the `nonfunctional_requirement`, which can be depicted as follows:

```
req1 "elements" => "";}
```

Using this structure, the user is able to feed the combination of elements that is searching for. For example, if the user needs to deploy a service composed of three different VMs and one database, the `elements` part should be

```
req1 "elements" => "VM, VM, VM, Database";
```

That is, the elements requirement should be introduced as a list of strings. It is important to spotlight here that this combination of elements defines how complex the problem is, and also the solutions size. In other words, it defines the size that individuals of NSGA-II and NSGA-III will have.

3 IaC Optimizer Platform

Once the input DOML is received by the IOP, it (i) gathers the information from this DOML, (ii) retrieves all the data from the IEC, (iii) builds the optimization problem, and (iv) computes the best elements combination which optimizes the defined objectives, meeting the nonfunctional requirements. Furthermore, the IOP resorts to the above-mentioned algorithms for performing this task:

- *Non-dominated Sorting Genetic Algorithm II* (NSGA-II): Arguably, this algorithm is the most used one for multi-objective optimization purposes. The NSGA-II consists of a generational genetic algorithm which resorts to a Pareto ranking scheme to enhance the convergence. Furthermore, it employs the crowding distance density estimator in order to ensure the diversity on the Pareto front. For the IOP, this well-known algorithm is employed for solving both single-objective and two-objective multi-objective problems.
- *Non-dominated Sorting Genetic Algorithm III* (NSGA-III): It is an evolution of the above-mentioned algorithm, which follows a similar structure. The NSGA-III, which is used in the IOP for dealing with the three-objective multi-objective problems, substituted the crowding distance operator with a clustering mechanism guided by a group of reference points.

We introduce now a simplified example with the main objective of properly describing how EC metaheuristics are adapted to solve the problem detailed in Sect. 2. This way, let us assume an IEC composed of `Storage`, `Database`, and `VM` type elements. Furthermore, for each of these elements, let us assume five different options, forming the following simplified IEC:

- `Storage`: [St_Europe, St_Spain, AZ_2, G_2, St_Spain, St_USA]
- `Database`: [mysq.GB, db.dyn, postgreSQL.GR, r4.larg, m3.med]
- `VM`: [C1France, C2Europe, m5.large, t2.nano, DS13v2]

Additionally, each of these elements has a set of attributes assigned regarding its cost, provider, expected availability or region. Furthermore, let us assume that a user has introduced as input the real-world-based DOML depicted in Fig. 4.

Meaning that the IOP should find the best combination contemplating one storage, one database and three VM, while optimizing the cost, the availability, and the performance. Moreover, the solutions offered by the IOP must not exceed a total cost of 100 Euros, region of the selected elements must be `00EU` (which represent the European Union), and the expected availability must be higher that a 98%.

Based on this example, the NSGA-III, in this case, could define a tentative solution using the following codification: `[0, 2, 3, 1, 0]: [195.5, 99.5, 10]`. It should be pointed here that a solution is codified as a list of indexes of the elements in the IEC. Thus, considering that the combination to find is `[Storage, Database, VM, VM, VM]`, the solution `[0, 2, 3, 1, 0]`

```
optimization opt {
    objectives {
        "cost" => min
        "availability" => max
        "performance" => max
    }
    nonfunctional_requirements {
        req1 "Cost <= 100.0" max 100.0 => "cost";
        req2 "Availability >= 98.0%" min 98.0 => "availability";
        req3 "Region" values "00EU" => "region";
        req4 "elements" => "Storage, DB, VM, VM, VM";
    }
}
```

Fig. 4 Example of an input DOML, based on a real case

represents [St_Europe, postgreSQL.GR, t2.nano, C2Europe, C1France]. Furthermore, the associated objective values of this solutions would be [195.5, 99.5, 10], depicting a cost equal to 195.5 Euros, an availability of 99.5% and a performance metric of 10.

4 Applicability Demonstration

It is interesting to mention that the IOP has been implemented in JAVA programming language, and that NSGA-II and NSGA-III have been implemented using jMetal framework [12]. It is worth mentioning that the choosing of NSGA-II and NSGA-III has been conducted as a result of an experimentation using additional similar methods such as the SPEA2 [13], MOCell [14] or MOMBI [15], among many others. This experimentation has demonstrated that, for the planned uses cases, NSGA-II and NSGA-III are excellent choices for minimizing the computation effort and maximizing the results quality. Furthermore, we depict in Table 1 the parameterization used for these techniques, which is the same for both of them. These settings have been selected after carrying out an extensive empirical analysis.

Having said that, we present in this section a real-world example addressed by the IOP. For this test, an IEC composed of 49 elements has been used: 10 `Databases`, 7 `Storages`, and 32 `Virtual Machines`. In this example, a three-objective problem was faced. The input DOML was the same as represented in Fig. 4.

Once this input DOML was received by the IOP, it conducted the optimization through the application of NSGA-III. After the completion of the optimization process, the IOP returns the solutions found using also the DOML modeling language. To do that, the IOP enriches the input DOML extending it with all the information referred to the optimization. In this specific example, the IOP found three solutions, which were returned as depicted in Fig. 5.

Table 1 Parameter values for NSGA-II and NSGA-III

NSGA-II & NSGA-III	
Parameter	Value
Crossover probability	90%
Crossover distribution index	20
Crossover function	Integer simulated binary crossover [16]
Mutation probability	10%
Mutation distribution index	20
Mutation function	Integer polynomial mutation [17]
Maximum of evaluations	10K
Population size	100

```
optimization opt {
    objectives {
        "cost" => min
        "availability" => max
        "performance" => max
    }
    nonfunctional_requirements {
        req1 "Cost <= 100.0" max 100.0 => "cost";
        req2 "Availability >= 98.0%" min 98.0 => "availability";
        req3 "Region" values "00EU" => "region";
        req4 "elements" => "Storage, DB, VM, VM, VM";
    }
    solution sol2 {
        objectives {
            cost 75.53 euro
            availability 98.82000000000001 %
            performance 26.0 metric
        }
        decisions ["[Storage1_Spain, db.dynamo.3, m1.tiny, t2.nano, m1.small]"]
    }
    solution sol3 {
        objectives {
            cost 84.53 euro
            availability 98.88 %
            performance 24.0 metric
        }
        decisions ["[Storage4_Europe, db.dynamo.3, m1.tiny, t2.nano, m1.small]"]
    }
    solution sol4 {
        objectives {
            cost 95.53 euro
            availability 98.92 %
            performance 25.0 metric
        }
        decisions ["[Storage1_Spain, db.dynamo.3, m1.tiny, t2.nano, m1.medium]"]
    }
}
```

Fig. 5 Results for the two-objective use case

For each of these solutions, the value of each objective is depicted in the section `objectives` of each solution, while the elements chosen for the deployment are listed in the `decisions` part. Lastly, the IOP introduces the features of each found solution in the `concretizations` part of the DOML. For the sake of space limitations, we represent in Fig. 6 just an except of a specific solutions (*sol3* in Fig. 5).

Furthermore, the IOP ranks the different deployment configurations found using one of the optimization objectives as reference. In this sense, and in order to do it flexible enough, the IOP adapts itself to the needs of the user, who can define which is the objective considered as reference. For doing that, the input DOML is used. More concretely, the `objectives` part of the `optimization opt` section of the DOML is used, deeming the first value as reference objective. In the example above depicted, we have defined the `Cost` as reference objective, as can be seen in Fig. 5. For this reason, returned solutions are ordered using this criterion (starting from the cheapest solutions and finishing with most expensive one).

5 Conclusions

PIACERE is an H2020 European project whose objective is to implement a solution involving the development, deployment and operation of Infrastructure-as-Code of applications running on cloud continuum. In this context, this technical paper has been focused on describing a specific module of the whole PIACERE ecosystem, coined as IOP, which main goal is to provide the user with the optimized deployment configurations of the IaC on the most suitable infrastructural elements that best meet the predefined restrictions and requirements.

The IOP is based on EC metaheuristics. More concretely, the IOP resorts to the well-known NSGA-II and NSGA-III algorithms, depending on the user needs. Furthermore, in this paper, we have not only described the IOP component, but we have also shown how it works and how it helps the user to find optimized IaC configurations.

Finally, the evolution of the *IaC Optimizer Platform* has been detected as short-term future work. More specifically, we have planned the adaptation of the IOP to further real-world oriented use cases, by introducing additional objectives and requirements. As long-term work, more sophisticated versions of both the NSGA-II and NSGA-III will be developed and added to the IOP.

Acknowledgements This research was funded by the European project PIACERE (Horizon 2020 Program, under grant agreement no 101000162).

```
concrete_infrastructure con_infra3{
    provider openstack {
        storage Storage4_Europe {
            properties {
                st_flavor = "Storage4_Europe";
                st_name = "Storage4_Europe";
                st_Availability = 99.8;
                st_Cost_Currency = 15;
                st_Request_Response_time_Storage_Performance = 3;
                st_Region = "00EU";
                st_Storage_Subtype = "BLOK";
                st_Storage_Capacity = 100;
                st_Storage_Type = "GENE";
                st_provider_OU = "ARSY";
                st_Storage_Data_Redundancy = "ZONS";
            }
        }
        dbms db_dynamo_3 {
            properties {
                db_flavor = "db_dynamo_3";
                db_name = "db_dynamo_3";
                db_Availability = 99.6;
                db_Database_Technology = "AMNR";
                db_Data_Transfer_OUT = 35;
                db_Zone = "DEEU";
                db_Virtual_CPU_Cores = 2;
                db_Data_Transfer_IN = 35;
                db_Database_Storage_Capacity = 100;
                db_provider_OU = "AMAZ";
                db_Database_Type = "00NR";
                db_Transaction_Unit_DTU_Database_Performance = 3;
                db_Cost_Currency = 35;
                db_Region = "00EU";
            }
        }
        vm m1_tiny{
            properties {
                vm_flavor = "m1_tiny";
                vm_name = "m1_tiny";
                vm_Availability = 98;
                vm_Response_time_Virtual_Machine_Performance = 10;
                vm_Zone = "SPEU";
                vm_Memory = 512;
                vm_Frequency_per_Core = 1500;
                vm_Virtual_CPU_Cores = 1;
                vm_provider_OU = "OPEN";
                vm_public_IP_type = "IPV4";
                vm_Cost_Currency = 10;
                vm_Region = "00EU";
                vm_Instance_Storage = 1;
            }
        }
```

Fig. 6 Excerpt of how the IOP concretizes the results in the output DOML

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Disparity of Abstract Color Representations in Convolutional Networks

Mikkel Pedersen and Henrik Bulskov

Abstract A common occurrence in the deep learning community is to theorize on what abstract representation data takes inside a network. The aim of this paper is to demonstrate that the expected representation from a simple well-defined problem takes on other forms than what human thought processes would expect it to do. The experiment uses CIFAR-10 and a FRUITS dataset as its base and compares models trained on RGB variants to models trained on separated red, green, and blue color channels. A simplified FRUITS dataset variant represents a much simpler problem of classifying tomatoes and capsicum based on their significant red and green color. Generally, the RGB model variant outperformed the separated variants; but for the simplified FRUITS experiment, we observed the blue color channel outperforming the red and green model variants with its performance on par with the RGB variant. This suggests that the model has chosen a blue filter to represent the classification features. We also confirm that the blue color variant is most prominent feature contributor through cross-testing the RGB model variant. For a simple classification problem, the models choose to represent the classes in a less intuitive form than what was expected from the simplicity of the data representation. We aim for further discussion about the disconnect of internal data representation of deep learning to the human counterpart.

Keywords Deep learning · Neural network · Convolutional network · Color representation · Image data analysis · Data preprocessing · Data representation · CIFAR · MNIST

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1 Introduction

A general course of action within the deep learning community is to let models construct their own internal representation of an image and rely on the mechanisms of deep neural networks to solve the transformations and significant feature representations on its own. Thus, there only exists focus on preprocessing of image data such that it conforms to the structural limitations of neural networks and the biases held within structures such as convolutional layers or image representations in matrices.

When image data is processed for ingestion into convolutional networks a number of presumptions are generally accepted: (1) The model is able to represent data in a feature specific meaningful way in relation to the characteristic of the truth labeling of the problem without human intervention. (2) The model is able to identify and importantly remove insignificant features of the image data in relation to the truth labeling of the problem. (3) The model is able to perform data transformations for representational features that are significant for the truth labeling without affecting the significance of the said features. (4) The model, if performing subjectively well, will always have found an efficient way to transform and represent features regardless of how the data is represented at ingest (only preprocessing to conformity for convolutional networks are needed). (5) The model is able to perform the same abstract functions that biological being can perform without specific representation to data before ingest.

These assumptions rely heavily on the model to perform the representational workload that is handled manually within other genres of data science. Through exploratory data analysis processes, data science explores the significant parts of the data before ingestion in order to represent the problem through representation and truth labeling in a meaningful way to the given problem. Hence, the model is focused on representing the problem rather than adding transformations by simply allowing the data scientist to understand the problem while minimizing the representational biases added from processing. Although within traditional data science, it is possible to test the representation of the data within the model through various methods and explanability; we currently do not have this possibility within deep learning as these are black box models and their explainability is severely reliant on presumptions and regions of interest rather than actual explanations. These presumptions of explainability are discussed in detail by Rudin [1] which simply advocates for models that are explainable by design if explanations are needed, while Lundberg et al. [2] exemplifies the approach to design a system for surgery that priorities explanations into actionable explanations.

Also, the presumption is that the model will be able to process and verify representations and data in the same way biological processes does it. A child can easily be taught to recognize fruits based on simple colors, while being able to still classify fruits that are more and less ripen than others. This could simply be expressed by a simple shape detection combined with a threshold for a given amount of color within the object. Deep learning models might not be able to represent the problem in the same way (i.e, red pixels in sphere is a tomato, green pixel in an cylinder is

a cucumber), and we currently have no way of verifying the results in an objective manner.

With this paper, we aim to show that there is a reliance on colors for truth labeling in datasets that is significant to the performance of the models and their internal representation of the problem. We aim to demonstrate that the exploratory data analysis is a vital component of deep learning with image data in order to gain the expected function representation that humans abstractly expect when defining the data and model parameters. Finally, this paper is a continuation of exploring our previous findings regarding exploratory data analysis on renal cancer CT images in the context of deep learning, Pedersen et al. [3], as we want to stress that a relation between colors and truth labeling stretches beyond standardized datasets into the real world domain.

1.1 Related Works

Currently, a number of methods and frameworks for interpreting the results given by a model in more abstract terms exist. These include SHAP (shapley values) by Lundberg et al. [4] and GRAD-CAM by Selvaraju et al. [5]. Each framework clearly shows regions of interest in within the network while some apply negative or positive values for that region toward a given class, but without explaining the abstract thought behind the decision of network. Although they all operate without a single important step. They do not explain the significance of colors to a given class, only the total impact of either a monochannel aggregate as with grayscale or the full RGB spectrum. This abstraction could cause problems for some truth labeling where colors are indicative of the classification of classes, e.g., when classifying flags. Hence, regions of interests will be shown, but cannot be distinguished from other colors in the same region.

The same phenomenon is seen in other high ranking paper as such by He et al. [6], and while the use of residual networks was groundbreaking for the deep learning community, there was no testing of separate color channels or even an exploratory data analysis before application of the network to the dataset. Only a reliance of the algorithm to perform transformation internally without forethought to the structure of the data, the truth labeling, of how the data is represented internally in the perspective of the features rather than the algorithmic representation.

Others like Lai et al. [7] have used exploratory techniques while color testing their network to detect polyps. The study found that no single color channel performed better than the white-light endoscopy images but when combining the red and green channel their performance increased. Lai et al. go on to discuss the implication of the blue color channel and argue that the blue color channel may contribute negatively to the classification based on a feature mask in the color channel.

Likewise, Gupta et al. [8] use color channel separation to extract color specific features before merging them into a classifier. They found that performance was higher for both cases of color splitting without merging features and color splitting

with merging of features than compared to the RGB network variant. Further more, Gupta et al. performed exploratory data analysis and found that the red and blue color channels contributed more toward the classification than the green color channel.

Supporting both Lai et al. [7] and Gupta et al. [8] is our own previous work on diagnosing renal tumors from CT images using deep learning. Pedersen et al. [3] used exploratory data analysis in order to preprocess images in order to move the representation closer to the intended contextual representation. Hence, colors were removed from the image and cropping was incorporated into the network ingest process. This allowed for the network to be considerably smaller while gaining higher classification performance on internal test and validation datasets, although the performance on the external validation dataset remained the same. Pedersen et al's performance after the removal of colors supports the findings of Gupta et al. and Lai et al..

2 Experimental Setup

The experimental setup is focused on providing a consistent workflow for processing image data in a given dataset in order to provide comparable performance results. Hence, the RGB representation is separated into its component color channels and trained separately to compare performance to color and grayscale-trained models. If any performance gain is significant, it could indicate that either less noise is present when removing complexity of colors, or that a specific color is more relevant to the given representation and truth labels of the given use-case the model solves. The latter case could warrant the use of exploratory data analysis in order to represent and engineer the data and truth labels to the purpose of the inference, instead of relying on implicit processes within the models to represent the problem in a relevant way (Fig. 1).

In order to test the performance, rather than the abstract concepts, of the implicit truth processes within the models we also compartmentalize the performance results within the extracted color channels (EDA processes) and the aggregate representations (implicit processes, color, and grayscale). Comparing the compartmentalization only after the model has completed training it becomes possible to rationalize the effects of the needed complexity, the efficiency of network architecture, and the resulting performance to the internal representation of the problem within the implicit processes of problem representation. Although we do recognize that these are black box models which further raises the difficulty in obtaining explanations that are abstractions of the mechanics within the network.

The datasets used are

- CIFAR-10 [9]—Well known within the community as a benchmark dataset. This version consist of ten classes of different object that are distinct from one another with a wide array of color spaces.

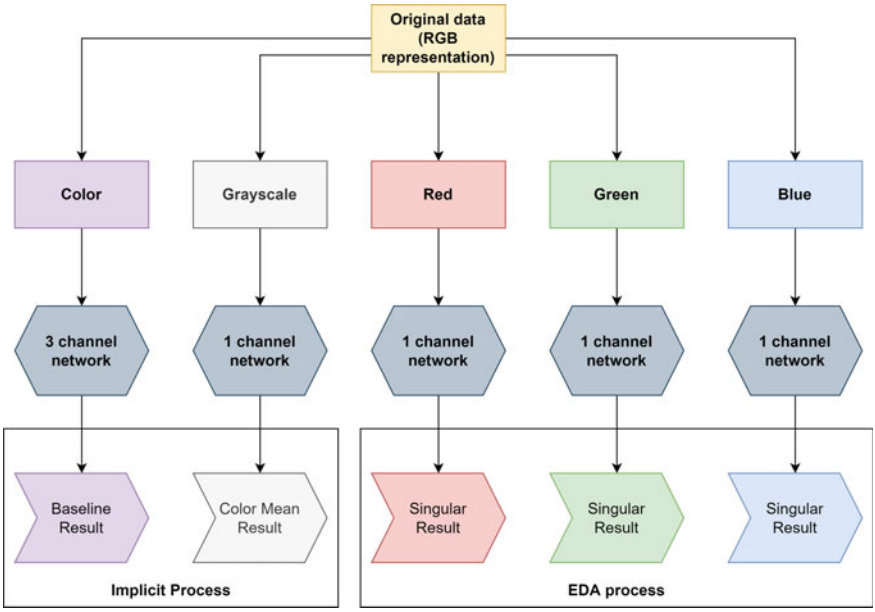

Fig. 1 Experimental processing workflow separating color channels for comparative results. The processing workflow is consistent across datasets and models

- Fresh and Stale Images of Fruits and Vegetables—A dataset consisting of 12 classes of fruits in both their ripe and stale state made by Potdar [10] published on Kaggle. The dataset will be referenced as FRUITS throughout the article.
- FRUITS-SIMPLIFIED—A subset of the FRUITS that only consists of tomatoes and cucumbers, thus gaining a separate distinctive two class truth labels where the green and red color channels separate the two classes.

To ensure consistency across the entire dataset, we use K-fold validation for all training runs. All datasets will use a twofold setup because of the individual sizes of the classes, while running 20 full training runs. A mean of the accuracy scores across the folds will be used for the comparison.

With this in mind, we expect to see a clear difference between color and separated color channels for the CIFAR-10 dataset as there is more color variability in the data while specific colors might not be sensitive to the problem classification. While with the FRUITS and FRUITS-SIMPLIFIED datasets, we expect to see an increasingly difference in the color separated models than with the color models as the color of fruits are partly indicated of their classification. Hence, full RGB color models would have to transform the data before processing on its own.

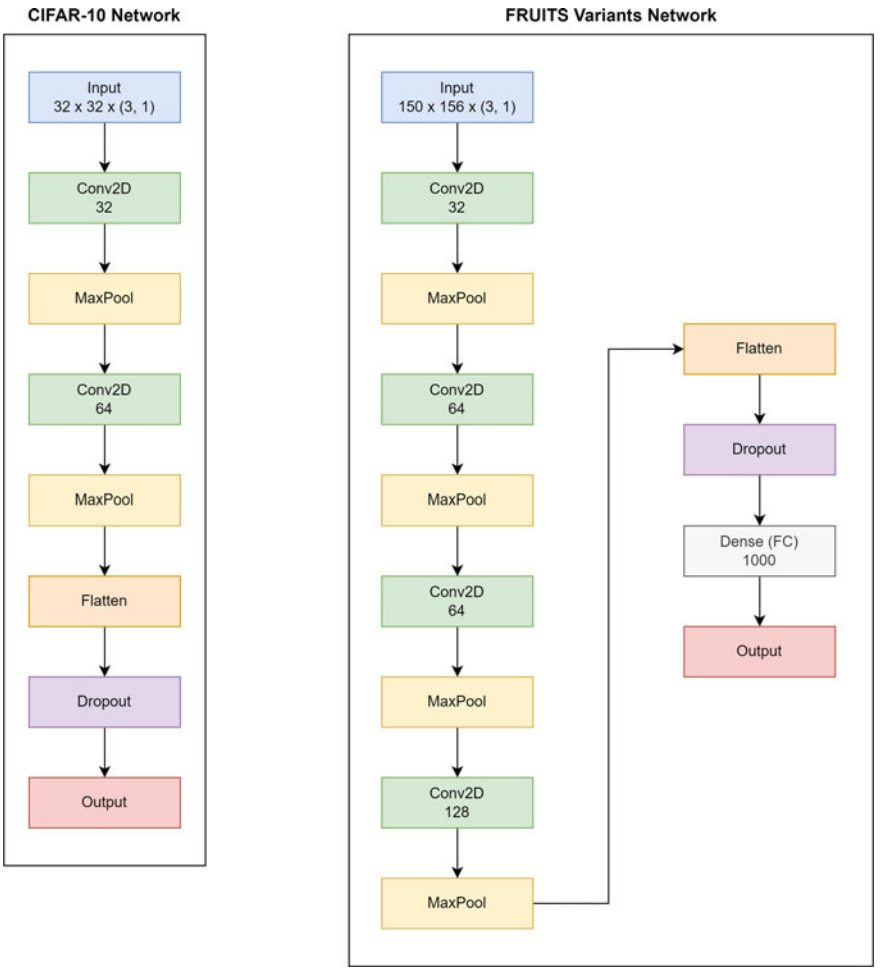

Fig. 2 Network variants for both CIFAR-10 and FRUITS dataset variants

2.1 Convolutional Network

The convolutional network used is fairly simple and is frozen during testing with each data set as shown in Fig. 2. Obviously, there are the parameter difference when using multiple channels for colors as opposed to monochannels, but we argue that the results are still comparable because of the focus on abstract feature representation and their impact on performance. For the CIFAR-10 variant, we have chosen a simple network that performs convolutions and directly flattens to the classification layer. We argue that a larger network would be prone to over-fitting because of the small image size of the CIFAR-10 dataset.

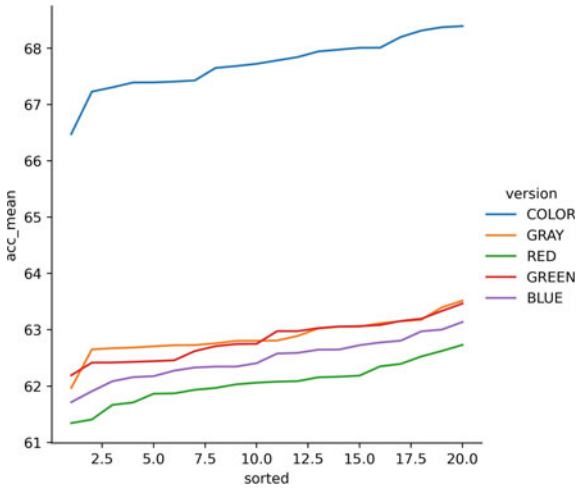

Fig. 3 CIFAR-10 accuracy mean results for K-folds. The *X*-axis is sorted by the accuracy mean to order training runs from lowest to highest accuracy mean for 20 training runs

For the FRUITS variants, we have chosen to extend the convolutional block and to insert a dense layer before classification, because of the increased image size and features that might be underlying in the subtle variance of the feature population.

3 Results

As expected it is clear from Fig. 3 that the RGB color model performs significantly better than its monocolor variants. We theorize that this is based on the models ability to extract the small significance a color has (for example fruits will greatly benefit from colors, where vehicles will not) together with the abstract features of shapes, perceived textures, and might even size. But it was unexpected that the grayscale variant performs on par with single color channel models. The grayscale model will partly contain parts of the color variants features as the gray monochannel is a mean of the color version. Whether this is lost to noise is unknown.

Another unexpected result is the performance of the green color channel as this performs as well as the grayscale version with both having a clear advantage over red and blue color models. Thus, the green color channel seems to provide more distinctive data of features to the model than other channels for the CIFAR-10 classification problem. It should also be noted that the monocolor models show less variability in their performance across iterations. This could be the result of the preprocessing work involving explicitly defining features in color channels instead of relying on implicit processes within the model that we can neither confirm or deny has happened during training, as well as the problem of expecting this variability in deployment environments.

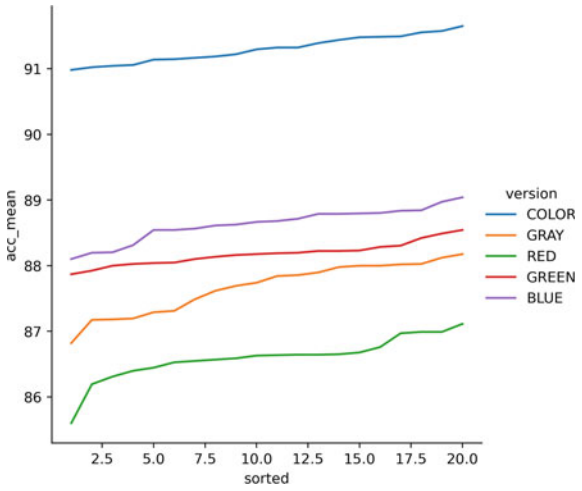

Fig. 4 Mean accuracy achieved for the different color on the fruits dataset. The accuracy is measured over fivefold (K-fold) for the fruits dataset and the mean is taken. The *X*-axis is sorted by the accuracy mean to order training runs from lowest to highest accuracy mean for 20 training runs

In Fig. 4, we expected to see a smaller performance gap from the RGB color space to the monocolor channels. But there still exists a significant gap of performance between the two. We expect this to be caused by the significant color differences of the fruits involved as well as the difference combined with the shapes of the fruit categories. But again we have no way of ensuring that the process of transforming the color space to label fruit classification to a given threshold of colors is present within the color variant.

However, we see a clear difference between the grayscale variant and the color variants. Both the blue and green color channels perform significantly better, and with better stability than the grayscale version, leading us to believe that the color mapping thresholds to the fruits categories has been used to a certain extent. Also when comparing with the red color channel variant, it is clear that there is a separation of the significance of the colors to the truth labeling of the dataset.

Lastly, we expected the red or green color model variant to perform significantly better than all other variants due to the colors red and green being distinctive for the two classes involved in the truth labeling of the simplified dataset. As shown in Fig. 5, this is clearly not the case. The green- and grayscale performs significantly worse. This is highly unexpected as one fruit is all green and a simple threshold of pixels would be enough for a classification. For contrast, the red color model performs exceedingly great leading to a disparity in understanding color selection for givens tasks.

The performance of the blue color channel performing 100% throughout its iterations with comparable performance to the full color channels is most unexpected. When applying abstract logic to the problem at hand, it would be obvious that the model should either be able to separate classes based on colors, or that it would need the full color spectrum to separate features of the classes. But using the blue color channel as gaining the same performance as the full color variant suggests that the

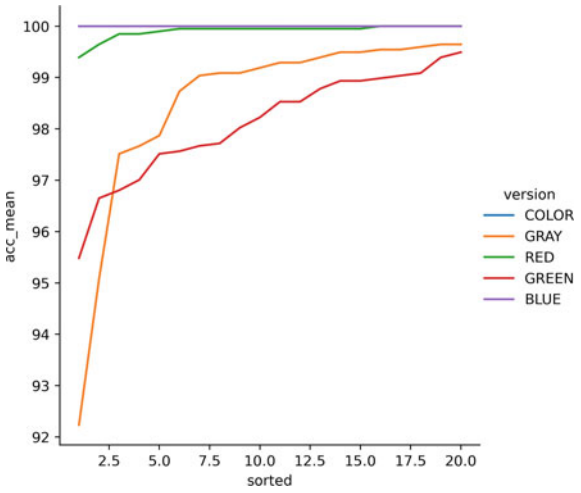

Fig. 5 Mean accuracy achieved for the different color on the fruits simplified dataset. The accuracy is measured over twofold (K-fold), instead of 5 as seen in the fruits dataset, and the mean is taken. The *X*-axis is sorted by the accuracy mean to order training runs from lowest to highest accuracy mean for 20 training runs. Notice the immediate jump to 100% for the blue channel

Table 1 Cross-testing of separated color data inference on a full RGB trained model for the fruits simplified dataset

Color mode	Accuracy	Loss
RGB	1.0	1.430992853e-07
Red	0.49771690368652344	8.013839721679
Green	0.5022830963134766	10.95164871216
Blue	0.5022830963134766	4.147336006165

model is consistently choosing features that are encoded in the blue color spectrum. This could also suggest that the color variant has mechanisms to filter out red and green color features internally to represent the data with the blue color representation, especially with regard to their comparable performance.

Cross-testing the separated color data with a model trained on the full color spectrum partially confirms this theory. We have trained a model on the RGB version of the fruits simplified dataset, and afterward, we use the same dataset but with colors separated to compare color channel attribution to the classification effort. Table 1 demonstrates the cross-color evaluation performance of the complete fruits simplified dataset for RGB, red, green, and blue color modes with the RGB mode as the baseline trained model. Although the accuracy is quite comparable across the separated channels, the loss is significantly lower for the blue color mode which suggests a more significant number of features are encoded in the blue mode for the problem representation chosen by the model. But a fair amount of loss is still apparent for the blue color mode which might be explained by the transformation of the black pixels (0 value in the 2 channels for red and green in the blue color mode) present in the blue mode that is not transformed.

Or the blue mode might be the most significant feature contributor to the inference, while red and green channels still supply smaller less significant features to the inference. This is still highly unexpected with regard to the common conception of data and problem representation in deep convolutional networks being compared to abstract human processes.

4 Conclusion

Based on our results, we conclude that the color significance to a given truth labeling has an effect on the model performance. One can take advantage of such explicit definitions in the processing of image data and can be handled before ingestion of the data to the model to enhance the chance of the model using an equivalent function of a given abstract thought process, e.g., red equals apple, and green equals cucumber. We also conclude that we cannot ensure that the model will capture the color relationship on its own while capturing this expected process behind the truth labeling of the data set. Unexpectedly, we must also conclude that the abstract processes humans use to classify objects signified by colors are difficult capture by deep learning models, while also being significantly difficult to expect the performance of based on a separated color channel. Our findings are also supporting of not only our own work in Pedersen et al. [3], but also of findings by other authors analyzing the use of colors on deep learning performance such as Gupta et al. [8] and Lai et al. [7]. Hence, our study suggests that any future work using image data should explore the representations and features through the colors of the image data, as both noise and contributing features might be intertwined in the RGB color representation. Therefore, future works could explore the separated color representations or the combination of specific colors to improve both performance and representation as has been shown in this study.

Finally, we can conclude twofold. (1) More exploratory data analysis processes are needed for deep neural network working with image data, to ensure a capture that aligns with the presumptions made while preprocessing and truth labeling the given dataset. Even the process of comparing the performance of separated color channels to the RGB color variant can be defined as an exploratory data analysis process before the training of the final deployable model. (2) More research is needed to understand the color impact on the performance of models with respect to the variability in training and deployment as well as the impact on the expected processes taking place inside the models. This might be inherently tied to the truth labeling of the datasets used completely separated from the problem of data quality.

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Cross-link Interference Handling of 5G with Subband Non-overlapping Full Duplex

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Abstract Subband non-overlapping full duplex (SBFD) simultaneously receives uplink (UL) and transmits downlink (DL) signals on the same time division duplex (TDD) carrier but on different frequency resources, which improves UL coverage and throughput. However, these benefits are damaged greatly due to the severe inter-SB cell-to-cell cross-link interference (CLI). Besides, inter-SB cell-to-cell CLI might cause UL communication blocking with a high probability. To cope with this challenge, the performance of coordinated beamforming (CBF) and minimum mean square error (MMSE)-interference rejection combining (IRC) on inter-SB CLI suppression is studied. Firstly, the characteristics and model of inter-SB CLI are analyzed in SBFD scenario. Then, MMSE-IRC and detailed CBF schemes are proposed to reduce inter-SB CLI. To evaluate the proposed schemes, system-level simulation is provided. In the simulation, CBF could suppress inter-SB CLI by 20 dB and avoid UL blocking issue. Moreover, MMSE-IRC receiver improves the UL coverage by 4.85 dB when compared with legacy TDD.

Keywords Subband non-overlapping full duplex · Coordinated beamforming · Interference rejection combining · Cross-link interference

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1 Introduction

To support wider bandwidths, frequency bands used for fifth generation (5G) are much higher than that of 4G long-term evolution. Then, a larger path loss is inevitable in 5G, which results in limited coverage. Furthermore, in legacy time division duplex (TDD) system in 5G, only a small portion of time resources for UL transmission. As a result, the UL coverage is quite limited. To deal with this challenge, a promising and innovative duplex scheme called subband non-overlapping full duplex (SBFD) is explored in third-generation partnership project (3GPP) [1].

The concept of SBFD is depicted in Fig. 1. It can be seen that SBFD can provide uplink (UL) resources in downlink (DL) slots of legacy TDD, i.e., slots 1, 2, 3, and 4. As a result, user equipment (UE) in SBFD has more UL resources to be scheduled, and UL performance of UE can be improved, which means that UL capacity and UL coverage can be enhanced [2]. Besides, UL latency is reduced since more UL resources can be used. The UL and DL resource configuration of SBFD in time and frequency is named as SBFD configuration. The legacy TDD can be divided to two SBs in frequency domain, which is shown in Fig. 1. The slot that contains both DL and UL SB can be named as SBFD slot.

Considering that cell receives on SB#1 and transmits on SB#2 simultaneously in SBFD slot, there exists inter-SB cross-link interference (CLI) and self-interference (SI) in the network. There are two types of inter-SB CLIs, i.e., cell-to-cell CLI and UE-to-UE CLI. With inter-SB CLI and SI, the benefits of more UL resources in SBFD network are affected. The UL capacity and UL coverage can be greatly enhanced if the SI and inter-SB CLI are carefully handled. In [3], the link budget was analyzed and concluded that inter-SB CLI is comparable with the UL desired signal in power. To cope with CLI, diverse elimination methods, such as coordinated beamforming (CBF), minimum mean square error (MMSE)-interference rejection combining (IRC) receiver and self-interference cancelation receiver, were studied [4, 5]. However, MMSE-IRC is evaluated when CLI and desired signal are on the same frequency. Besides, details of CBF scheme are not presented in previous studies. Thus, more practical and detail studies are required to be conducted to investigate the applicability of SBFD network with inter-SB CLI further.

CBF and MMSE-IRC receiver-based CLI handling schemes are studied in the SBFD network in this article. Specifically, the contribution of this work mainly consists of three parts. First, inter-SB CLI of Macro network with SBFD is analyzed

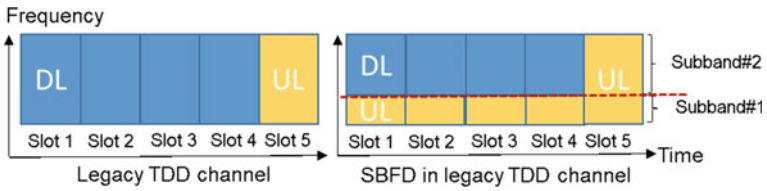

Fig. 1 Concept of SBFD in legacy TDD channel

and modeled. Then, MMSE-IRC receiver and proposed CBF-based inter-SB CLI handling schemes are described in detail. The blocking issue is also brought out. Finally, system-level simulation based on the realistic 5G wireless network is provided. It can be observed that the blocking issue always exists in the Macro network with SBFD and can be solved with the proposed CBF scheme. Besides, 4.85 dB UL coverage enhancement is obtained when MMSE-IRC receiver is used. The simulation results can be used as guideline for the Macro deployment scenario with SBFD.

The remainder of this article is organized as follows: In Sect. 2, a tutorial on the concept and CLI handling schemes of SBFD are described. In Sect. 3, system-level simulation results are provided for CLI handling schemes, i.e., CBF and MMSE-IRC, in SBFD network. In Sect. 4, the conclusion of this study and future work are presented.

2 System Model

3 Scenario and Interference

Considering that the distance between Macro cell and UE is large and only a small portion of time resources can be allocated to UL if legacy TDD is used, UL coverage is critical for Macro cell. Thus, Macro cell deployment scenario with SBFD is considered in this article. It is assumed that all Macro cells have same SBFD configuration, which is one essential deployment case discussed in the 3GPP. The SBFD configuration is shown in Fig. 1.

In this scenario, the interferences considered at slot 1/2/3/4 (i.e., SBFD slot) are shown in Fig. 2 and summarized in Table 1. In Fig. 2, dotted line represents interference signal, and solid line means desired signal. UE#1 and UE#3 receive desired DL signals from Macro cell#1 and Macro#2, respectively. The desired DL signals are on SB#2. Macro cell#1 and Macro cell#2 receive desired UL signals from UE#2 and UE#4, respectively. The desired UL signals are on SB#1. The interferences considered are as follows.

① UL-to-UL interference means that interference signal and desired signal are both UL signal on the same frequency. For example, as illustrated in Fig. 2, the UL signal from UE#2 can be seen as UL-to-UL interference to the UL signal from UE#4.

② DL-to-DL interference indicates that interference signal and desired signal are both DL signal on the same frequency. For example, as illustrated in Fig. 2, the DL signal to UE#1 can be seen as DL-to-DL interference to the DL signal to UE#3.

③ Inter-SB cell-to-cell CLI means that interference signal from cell#1 is DL on SB#2, and desired signal to cell#2 is UL on SB#1. Assuming that one base station (BS) consists of three Macro cells, inter-SB cell-to-cell CLI can be named

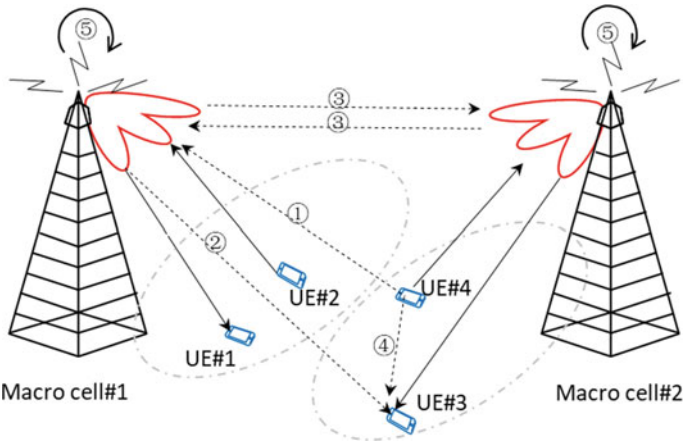

Fig. 2 Interference considered in the Macro deployment scenario

Table 1 Summary of interference types

Interference type	Details
① UL-to-UL interference	Interference signal and desired signal are both UL signal on the same frequency
② DL-to-DL interference	Interference signal and desired signal are both DL signal on the same frequency
③ Inter-SB cell-to-cell CLI	DL interference from one cell to another cell, where the DL interference and UL desired signal are on different SBs
④ Inter-SB UE-to-UE CLI	UL interference from one UE to another UE, where the UL interference and desired DL signal are on different SBs
⑤ Inter-SB SI	DL transmission leaks to UL reception in the same cell, where the DL signal and UL signal are on different SBs

as intra-BS inter-SB cell-to-cell CLI when cell#1 and cell#2 belong to the same BS and be named as inter-BS inter-SB cell-to-cell CLI when cell#1 and cell#2 belong to the different BS.

④ Inter-SB UE-to-UE CLI means that interference signal is UL on SB#1, and desired signal is DL on SB#2. For example, as illustrated in Fig. 2, the UL signal from UE#4 can be seen as inter-SB UE-to-UE CLI to the DL signal to UE#3.

⑤ When Macro cell transmits and receives simultaneously, inter-SB SI occurs at the cell. Inter-SB SI means that interference signal from cell#1 is DL on SB#2, and desired signal is UL to cell#1 on SB#1.

It can be assumed that intra-BS inter-SB cell-to-cell CLI and inter-SB SI can be effectively handled, and the residual interference can be ignored. For convenience, inter-SB cell-to-cell CLI and inter-SB UE-to-UE CLI are written as cell-to-cell CLI

and UE-to-UE CLI, respectively, in the rest of this article. Besides, there is only UL-to-UL interference at slot 5 (i.e., UL slot).

4 Channel Modeling and Blocking Issue

In the specification of 5G, the channel models for link between Macro cell and UE and link between Micro cell and UE have been modeled. The channel model for link between Macro cell and UE can be reused for link between Macro cell and Macro cell (i.e., cell-to-cell link) with some modification. For example, the line of sight (LOS) probability between the cells should be higher than the link from Macro cell to UE. Similarly, the channel model for link between Micro cell and UE can be used for link between UE and UE (i.e., UE-to-UE link) with some modification [3, 6].

The channel models mentioned above are used for the situation that interference and desired signal are on the same frequency. However, interference and desired signal are on different SBs for inter-SB cell-to-cell CLI and inter-SB UE-to-UE CLI. Thus, inter-SB leakage based on the frequency isolation between DL SB and UL SB should also be considered for the strength of inter-SB CLI. For example, with a given transmit power of DL signal on SB#2 (UL signal on SB#1), apply the channel model for cell-to-cell link (UE-to-UE link) to obtain the received power P_0 (P_1) of cell-to-cell CLI (UE-to-UE CLI) on SB#2 (SB#1), and multiply an inter-SB attenuation value -45 dB (-30 dB) to obtain the received power of inter-SB cell-to-cell CLI (inter-SB UE-to-UE CLI) on SB#1 (SB#2) leaked from SB#2 (SB#1) [3].

In addition, potential blocking issue should be considered as well in the Macro cell deployment. The blocking issue is caused by the fact that the current Macro cell is using a wide band analog filter before its low-noise amplifier (LNA). The DL cell-to-cell CLI and UL desired signal both pass the wide band filter and are amplified by the LNA. If the received DL cell-to-cell CLI is too strong, the LNA will be saturated/blocked and the UL desired signals cannot be restored. Usually, the blocking issue would occur when the power of interference is larger than -30dBm.

5 CLI Handling

The cell-to-cell CLI can be handled at the receiver and transmitter of the Macro cell. The Macro cell that suffers cell-to-cell CLI can be named as victim cell, and the Macro cell that causes cell-to-cell CLI can be called as aggressive cell.

It is assumed that there are M Macro cells and K_m UEs in mth Macro cell. There are K_m^{UL} UEs that transmit UL signals and K_m^{DL} UEs that receive DL signals. The receiving signal of m^{th} Macro cell can be formulated as Eq. (1).

$$\boldsymbol{Y} = \boldsymbol{H}_{k,m}\boldsymbol{S}_{k,m} + \sum_{\substack{n=1 \\ n \neq k}}^{K_m^{\mathrm{UL}}} \boldsymbol{H}_{n,m}\boldsymbol{S}_{n,m} + \sum_{\substack{i=1 \\ i \neq m}}^{M} \sum_{g=1}^{K_i^{\mathrm{UL}}} \boldsymbol{H}_{g,m}^{i}\boldsymbol{S}_{g,i} + \sum_{\substack{i=1 \\ i \neq m}}^{M} \boldsymbol{H}_{i,m}^{\mathrm{CLI}} \sum_{j=1}^{K_i^{\mathrm{DL}}} \boldsymbol{W}_{j,i}\boldsymbol{S}_{j,i} + \boldsymbol{N}, \quad (1)$$

where

- $\boldsymbol{H}_{k,m}$ is the channel between mth Macro cell's kth UL UE and mth Macro cell,
- $\boldsymbol{H}_{n,m}$ is the channel between mth Macro cell's nth UL UE and mth Macro cell,
- $\boldsymbol{H}_{g,m}^{i}$ is the channel between ith Macro cell's gth UL UE and mth Macro cell,
- $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$ is the channel between ith Macro cell (i.e., aggressive cell) and mth Macro cell (i.e., victim cell),
- $\boldsymbol{S}_{k,m}$, $\boldsymbol{S}_{n,m}$, $\boldsymbol{S}_{g,i}$, and $\boldsymbol{S}_{j,i}$ are kth UL UE's UL signal, nth UL UE's UL signal, UL signal from gth UL UE to ith Macro cell, and DL signal from ith Macro cell to jth DL UE,
- $\boldsymbol{W}_{j,i}$ is the precoding of the DL signal from ith Macro cell to jth DL UE, and
- $\boldsymbol{N}$ is noise, which consists of thermal noise and noise figure.

It is assumed that $\boldsymbol{S}_{k,m}$, $\boldsymbol{S}_{n,m}$, $\boldsymbol{S}_{g,i}$, and $\boldsymbol{S}_{j,i}$ are uncorrelated. The precoding and power of UL signals are included in $\boldsymbol{H}_{k,m}$, $\boldsymbol{H}_{n,m}$, and $\boldsymbol{H}_{g,m}^{i}$. As MMSE-IRC receiver is quite common in the state-of-the-art BS implementation, MMSE-IRC receiver is considered at BS. With MMSE-IRC receiver, the equalization at receiver for k^{th} UL UE can be expressed as Eq. (2).

$$\hat{\boldsymbol{s}}_{\boldsymbol{k}} = \boldsymbol{H}_{k,m}^{H} \left(\boldsymbol{H}_{k,m}\boldsymbol{H}_{k,m}^{H} + \sum_{\substack{n=1 \\ n \neq k}}^{K_m^{\mathrm{UL}}} \boldsymbol{H}_{n,m}\boldsymbol{H}_{n,m}^{H} + \sum_{\substack{i=1 \\ i \neq m}}^{M} \sum_{g=1}^{K_i^{\mathrm{UL}}} \boldsymbol{H}_{g,m}^{i}\boldsymbol{H}_{g,m}^{i,H} + \sum_{\substack{i=1 \\ i \neq m}}^{M} \boldsymbol{H}_{i,m}^{\mathrm{CLI}}\boldsymbol{H}_{i,m}^{\mathrm{CLI},H} + \sigma^2\boldsymbol{I} \right)^{-1} \boldsymbol{Y}, \quad (2)$$

where

- $\hat{\boldsymbol{s}}_{\boldsymbol{k}}$ is the estimated signal,
- $\boldsymbol{H}_{k,m}^{H}$ is the conjugate transpose of channel $\boldsymbol{H}_{k,m}$,

- $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{UL,intra-cell}} = \sum_{\substack{n=1 \\ n \neq k}}^{K_m \mathrm{UL}} \boldsymbol{H}_{n,m} \boldsymbol{H}_{n,m}^{H}$ is the covariance of the interference introduced by other UL UEs' UL signal,
- $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{UL,inter-cell}} = \sum_{\substack{i=1 \\ i \neq m}}^{M} \sum_{g=1}^{K_i \mathrm{UL}} \boldsymbol{H}_{\boldsymbol{g,m}}^{i} \boldsymbol{H}_{\boldsymbol{g,m}}^{i,H}$ is the covariance of the interference introduced by other cells UEs' UL signal,
- $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{DL,CLI}} = \sum_{\substack{i=1 \\ i \neq m}}^{M} \boldsymbol{H}_{i,m}^{\mathrm{CLI}} \boldsymbol{H}_{i,m}^{\mathrm{CLI},H}$ is the covariance of the interference introduced by DL cell-to-cell CLI,
- $\boldsymbol{\sigma}^2 \boldsymbol{I}$ is the covariance of noise, $\boldsymbol{\sigma}^2$ is the variance of noise, and $\boldsymbol{I}$ is unit matrix, and
- $\boldsymbol{R} = \left(\boldsymbol{H}_{k,m} \boldsymbol{H}_{k,m}^{H} + \boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{UL,intra-cell}} + \boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{UL,inter-cell}} + \boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{DL,CLI}} + \boldsymbol{\sigma}^2 \boldsymbol{I}\right)$ is the covariance matrix including the interference.

Considering that inter-SB cell-to-cell CLI is interference leaked from DL SB to UL SB, $\boldsymbol{W}_{\boldsymbol{j,i}}$ can be ignored when calculating $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{DL,CLI}}$[7]. The power of DL signals and inter-SB attenuation are included in $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$. It can be observed that the demodulation performance is highly related to the accuracy of the desired UL signal channel estimation $\boldsymbol{H}_{k,m}^{H}$ and the interference estimation, wherein the interference includes both the UL interference from UEs and cell-to-cell CLI. Muting resources method can be used to obtain the accurate value of $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{DL,\ CLI}}$ [3], and MMSE-IRC receiver can suppress cell-to-cell CLI with obtained $\boldsymbol{R}_{\boldsymbol{uu}}^{\mathrm{DL,\ CLI}}$. Conventional MMSE-IRC algorithm is used to suppress CLI in this article, and the realization of conventional MMSE-IRC algorithm can be found in [8].

Cell-to-cell CLI can also be handled at transmitter of Macro cell by CBF. In our proposed CBF, *i*th Macro cell (aggressive cell) could use transmit beamforming considering $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$ to suppress the cell-to-cell CLI from *i*th Macro cell to *m*th Macro cell (victim cell) by the following steps:

Step 1: Obtain singular value decomposition (SVD) of channel from *i*th Macro cell to *i*th Macro cell's *j*th DL UE $\boldsymbol{H}_{\boldsymbol{j,i}}$ and channel from *i*th Macro cell to *m*th Macro cell $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$.

$$\left[U_{j,i}, E_{j,i}, V_{j,i}\right] = \mathrm{SVD}\left(\boldsymbol{H}_{\boldsymbol{j,i}}\right), \tag{3}$$

$$\left[U_{i,m}^{\mathrm{CLI}}, E_{i,m}^{\mathrm{CLI}}, V_{i,m}^{\mathrm{CLI}}\right] = \mathrm{SVD}\left(\boldsymbol{H}_{i,m}^{\mathrm{CLI}}\right), \tag{4}$$

$$U_{i,m}^{\mathrm{CLI}} = \left[U_{i,m}^{\mathrm{CLI},y_0}, U_{i,m}^{\mathrm{CLI},y_1}\right], \tag{5}$$

$$V_{i,m}^{\mathrm{CLI}} = \left[V_{i,m}^{\mathrm{CLI},y_0}, V_{i,m}^{\mathrm{CLI},y_1} \right], \tag{6}$$

where

- $U_{j,i}$ and $V_{j,i}$ are unitary matrices from the SVD of $\boldsymbol{H}_{j,i}$, which means that $U_{j,i}^{H} U_{j,i} = I$, I is identity matrix,$U_{j,i}^{H}$ is the conjugate transpose of $U_{j,i}$,
- $E_{j,i}$ is diagonal matrix from the SVD of $\boldsymbol{H}_{j,i}$,
- $U_{i,m}^{\mathrm{CLI}}$ and $V_{i,m}^{\mathrm{CLI}}$ are unitary matrices from the SVD of $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$, and
- $E_{i,m}^{\mathrm{CLI}}$ is diagonal matrix from the SVD of $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$.

It is assumed that y_0 strongest singular values in the SVD of $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$ will be considered in the transmit beamforming of ith Macro cell. $U_{i,m}^{\mathrm{CLI},y_0}$ and $U_{i,m}^{\mathrm{CLI},y_1}$ are the first to y_0^{th} vectors of $U_{i,m}^{\mathrm{CLI}}$ and remaining vectors of $U_{i,m}^{\mathrm{CLI}}$, respectively. $V_{i,m}^{\mathrm{CLI},y_0}$ and $V_{i,m}^{\mathrm{CLI},y_1}$ are the first to y_0^{th} vectors of $V_{i,m}^{\mathrm{CLI}}$ and remaining vectors of $V_{i,m}^{\mathrm{CLI}}$, respectively.

Step 2: Obtain the updated V matrix with $V_{j,i}$ and $V_{i,m}^{\mathrm{CLI},y_0}$, which is shown in Eq. (7).

$$V = \left[V_{0,i}, \ldots, V_{K_i^{\mathrm{DL}},i}, V_{i,m}^{\mathrm{CLI},y_0} \right], \tag{7}$$

where

- $V_{\mathrm{target}} = \left[V_{0,i}, \ldots, V_{K_i^{\mathrm{DL}},i} \right]$ is the V matrix for UEs that receives DL signals in ith Macro cell and
- $V_{i,m}^{\mathrm{CLI},y_0}$ is the V matrix for mth Macro cell.

Step 3: Obtain the updated precoding matrix with updated V matrix by zero forcing, which is shown in Eq. (8).

$$W = \left[W_{0,i}, \ldots, W_{K_i^{DL},i}, W_{i,m}^{\mathrm{CLI},y_0} \right] = V \left(\left(V^H V \right)^{-1} \right)^H, \tag{8}$$

where

- $W_{\mathrm{target}} = \left[W_{0,i}, \ldots, W_{K_i^{\mathrm{DL}},i} \right]$ is the precoding vectors for the DL UEs in ith Macro cell and
- $W_{i,m}^{\mathrm{CLI},y_0}$ is the precoding vector for mth Macro cell.

Step 4: The mth Macro cell uses $U_{i,m}^{\mathrm{CLI},y_0}$ for equalization to suppress CLI interference, which is shown in Eqs. (9) and (10).

$$\mathrm{DL}_{\mathrm{signal}} = W_{\mathrm{target}} S_{\mathrm{target}}, \tag{9}$$

$$I_{\mathrm{CLI}} = U_{i,m}^{\mathrm{CLI},y_0,H} \boldsymbol{H}_{i,m}^{\mathrm{CLI}} W_{\mathrm{target}}, \tag{10}$$

where

- $\mathrm{DL}_{\mathrm{signal}}$ is the DL signals of ith Macro cell,
- I_{CLI} is the CLI interference at mth Macro cell after equalization, and $U_{i,m}^{\mathrm{CLI},y_0,H}$ is the conjugate transpose of $U_{i,m}^{\mathrm{CLI},y_0}$.

It is assumed that matrix $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}\boldsymbol{H}_{i,m}^{\mathrm{CLI},H}$ consists of Y eigenvalues. It can be known that the singular values in the SVD of $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$ are the square root of the eigenvalues. When y_0 strongest singular values are considered in the transmit beamforming of ith Macro cell, the power of the cell-to-cell CLI received by mth Macro cell can be reduced by about $\sum_{y=1}^{y_0}\lambda_y/\sum_{y=1}^{Y}\lambda_y$, where λ_y is the y^{th} eigenvalue of matrix $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}\boldsymbol{H}_{i,m}^{\mathrm{CLI},H}$. As a result, CLI is suppressed by CBF. However, the DL performance of ith Macro cell will be degraded with CBF since W_{target} is suboptimal. Thus, value y_0 should be carefully chosen to satisfy cell-to-cell CLI suppression requirement and DL performance degradation requirement. The proposed CBF is summarized in Algorithm 1.

Algorithm 1 Details for proposed CBF

Input: Channel $\boldsymbol{H}_{j,i}$ and $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$, CLI suppression requirement r_0

Output: Precoding vectors for the DL UEs W_{target}

1: Obtain eigenvalues of $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}\boldsymbol{H}_{i,m}^{\mathrm{CLI},H}$ and minimum value

of y_0 satisfies that $\sum_{y=1}^{y_0}\lambda_y/\sum_{y=1}^{Y}\lambda_y \geq r_0$

2: Apply steps 1–3 to obtain precoding vectors for the DL UEs W_{target}

3: **return** W_{target}

5.1 Complexity Analysis

The complexity of MMSE-IRC receiver can be expressed by the required number of multiplications, which is given by $\mathrm{Q} = 2N^2+KN^2+\left(N^3+\frac{7}{2}N^2+\frac{5}{2}N-4\right)+KN$, where K and N are the antenna number of the transmitter and receiver, respectively [9]. Thus, the complexity of MMSE-IRC receiver is $\mathrm{O}\left(KN^2+N^3\right)$. The complexity of CBF is related to realization of SVD, which can be expressed as $\mathrm{O}\left(N^3\right)$.

6 Simulation Results

7 Simulation Platform

In order to demonstrate the performance of CBF and MMSE-IRC receiver in the Macro cell deployment, following simulation results are provided. The simulation results are obtained by system-level platform based on the realistic 5G wireless network.

8 Simulation Parameters

In the simulation, Macro deployment scenario with 21 Macro cells is considered, which is shown in Fig. 3. Each cell is configured with same SBFD configuration, i.e., XXXXU (five slots per period). X means the slot contains DL SB and UL SB, and U means UL slot, which is illustrated in Fig. 1. It is assumed that MMSE-IRC receiver is applied by the Macro cell. Other simulation parameters are shown in Table 2. The LOS probability of cell-to-cell link is still under discussion in the 3GPP, and one candidate value is 0.8 in previous discussion [1].

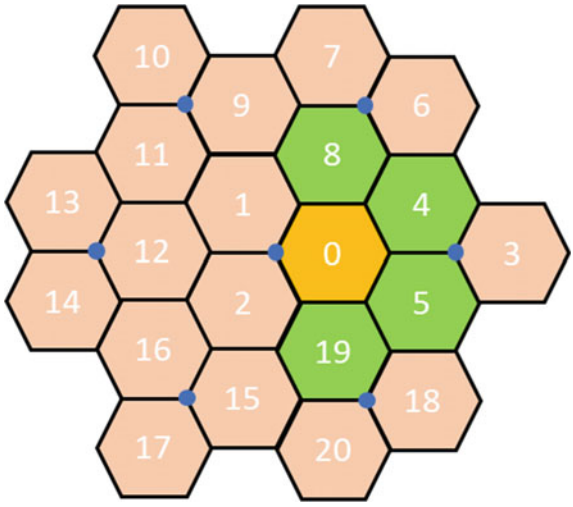

Fig. 3 Deployment layout of 21 Macro cells

Table 2 Simulation parameters

Parameters	Values
Carrier frequency	4 GHz
BS/UE height	25 m/1.5 m
BS/UE antenna	64T64R/2T2R
UE number	10UE/cell
Inter-site distance	300 m
UE distribution	80% indoor and 20% outdoor
UE speed	3 km/h
Subcarrier spacing	30 kHz
Channel bandwidth	100 MHz
SBFD configuration	XXXXU, X: 20 MHz for UL SB and 80 MHz for DL SB
Cell-to-cell CLI channel model	Channel for link between Macro cell and UE with some modification
UE-to-UE CLI channel model	Channel for link between Micro cell and UE with some modification
Channel estimation	Ideal channel estimation
Multiple-input multiple-output (MIMO)	Multi-user (MU)-MIMO
Maximum paired DL/UL layer number	Single user: 2, MU: 12
Maximum paired DL/UL UE number	12
DL/UL transmit power	53dBm/23dBm
Modulation and coding scheme	Up to 256QAM
Traffic type	Full buffer

9 Simulation Results

CBF performance. One example is illustrated in Fig. 3. Cell#0 is the aggressive cell, and cells#1–20 are victim cells. Except for victim cells#4, 5, 8, and 19, cell-to-cell CLIs to other victim cells are weak since they are located far away from cell#0 or at the back of cell#0. CBF can be used to suppress strong cell-to-cell CLI from aggressive cell to victim cells, i.e., CLI from cell#0 to cells#4, 5, 8, and 19. In the simulation, $\boldsymbol{H}_{i,m}^{\mathbf{CLI}}$ is generated in the system-level platform. Two cases can be considered when using CBF.

Case 1: Determine the value of y_0 when cell#0 should suppress the cell-to-cell CLI to one victim cell by about 20 dB, i.e., $1 - \frac{\sum_{y=1}^{y_0} \lambda_y}{\sum_{y=1}^{Y} \lambda_y} \leq \frac{1}{100}$.

The simulation results are shown in Fig. 4 for resource block (RB)#0. For other RBs, the simulation results are similar. It is shown that the value of y_0 is 3 for victim cells#4, 5, and 8. The value of y_0 is 1 for victim cell#19.

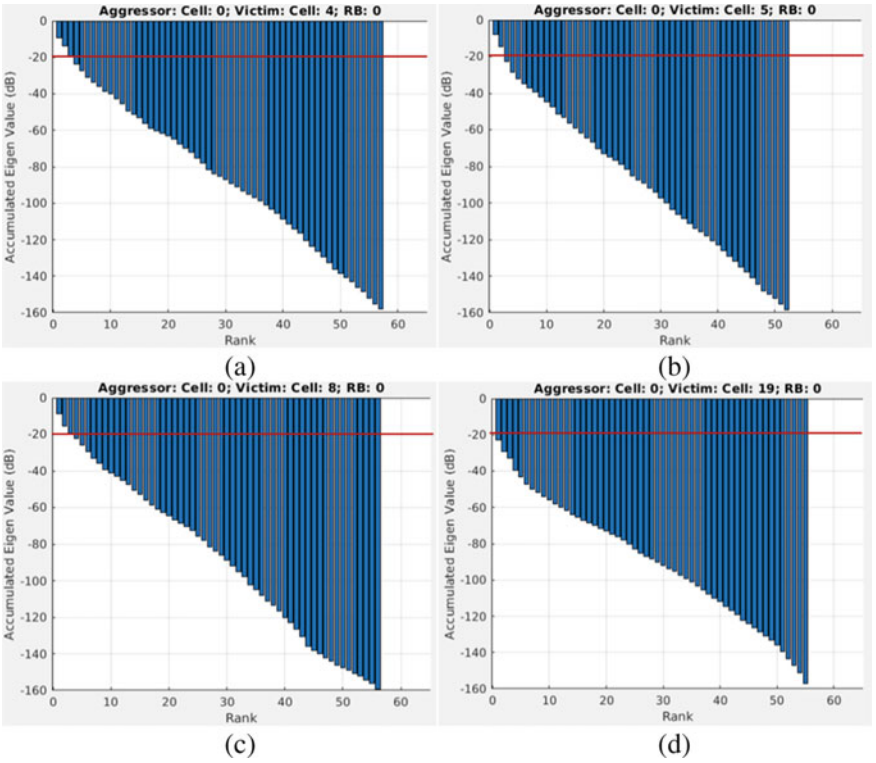

Fig. 4 Value of y_0 when cell 0 should suppress the cell-to-cell CLI to one victim cell by about 20 dB

Case 2: Determine the value of y_0 when cell 0 should suppress the cell-to-cell CLI to 4 victim cells (cells#4, 5, 8, and 19) with strong CLI by about 20 dB in total. In this case, $\boldsymbol{H}_{\mathbf{CLI}} = \begin{bmatrix} \boldsymbol{H}_{0,4}^{\mathrm{CLI}} \\ \boldsymbol{H}_{0,5}^{\mathrm{CLI}} \\ \boldsymbol{H}_{0,8}^{\mathrm{CLI}} \\ \boldsymbol{H}_{0,19}^{\mathrm{CLI}} \end{bmatrix}$, where $\boldsymbol{H}_{0,4}^{\mathrm{CLI}}$, $\boldsymbol{H}_{0,5}^{\mathrm{CLI}}$, $\boldsymbol{H}_{0,8}^{\mathrm{CLI}}$, and $\boldsymbol{H}_{0,19}^{\mathrm{CLI}}$ are the channels of cell-to-cell CLI from aggressive cell#0 to victim cells#4, 5, 8, and 19, respectively. When using CBF, replace $\boldsymbol{H}_{i,m}^{\mathrm{CLI}}$ with $\boldsymbol{H}_{\mathbf{CLI}}$.

It is shown in Fig. 5 that y_0 is about 7 to suppress 20 dB cell-to-cell CLI of 4 victim cells.

Blocking Issue. 2000 slots are considered for the system-level simulation. Each cell schedules the serving UEs per slot and records the strength of interference and amount of data transmitted.

The blocking issue is simulated in three cases. Case1: cell-to-cell link is LOS or non-LOS (NLOS), and the probability of LOS is 0.8; case 2: all cell-to-cell links are LOS; and case 3: all cell-to-cell links are NLOS. The power of cell-to-cell CLI

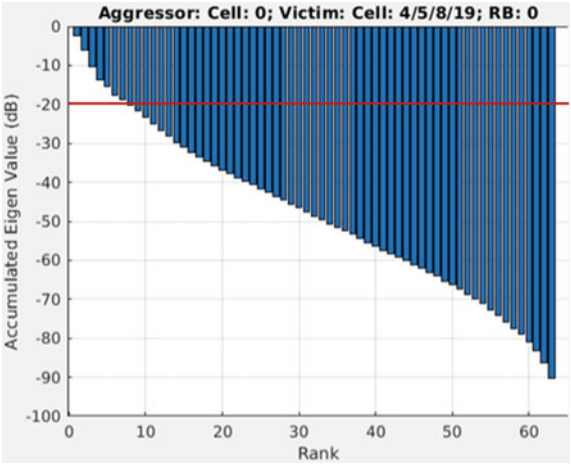

Fig. 5 Value of y_0 when cell 0 should suppress the cell-to-cell CLI to 4 victim cells by about 20 dB

received by LNA is shown in Fig. 6, and it can be seen that blocking issue (power of cell-to-cell CLI is over -30dBm) occurs 100% in case 1 and case 2. As case 1 is close to practical scenario, it can be observed that blocking issue is quite severe in Macro deployment scenario. To address the blocking issue, the CBF method could be used to reduce the power of cell-to-cell CLI received by the victim cell by about 20 dB. Besides, LNA could be redesigned to have large saturation/blocked power, e.g., −20dBm.

Performance of MMSE-IRC receiver. The performance of the MMSE-IRC receiver is shown in Table 3. TDD DDDDU is the baseline and contains one UL slot and four DL slots in five slots. SBFD w/o CLI means that cell-to-cell CLI is ignored in the simulation. SBFD w/CLI means that the cell-to-cell CLI is considered in the

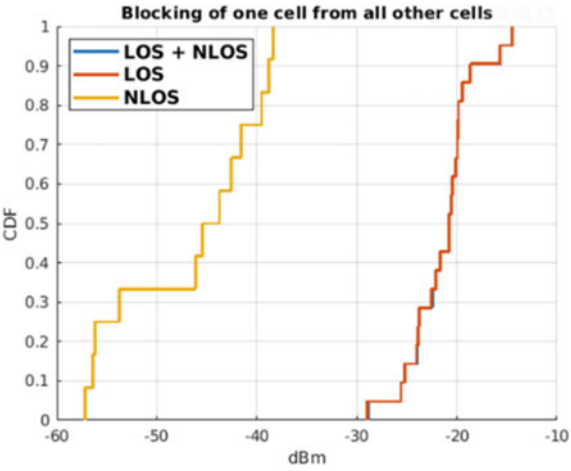

Fig. 6 Power of cell-to-cell CLI received by LNA

Table 3 Performance of MMSE-IRC receiver

	TDD: DDDDU	SBFD: XXXXU (w/o CLI)	SBFD: XXXXU (w/ CLI)
UL average throughput (Mbps)	466.12	840.96	783.37
UL edge throughput (Mbps)	1.73	6.94	5.29

simulation. When compared with DDDDU, the UL edge throughput of SBFD w/ CLI increases by about 3.0578 times, i.e., 4.85 dB coverage enhancement. Considering the UL average throughput, there exists 15% headroom for SBFD w/ CLI when compared with SBFD w/o CLI.

10 Conclusions and Future Work

In this work, we have studied the performance of wireless network based on SBFD and found that blocking issue always occurs if CBF is not applied and LNA is not enhanced. To avoid the blocking issue and improve UL performance, novel algorithms, i.e., CBF and MMSE-IRC, have been proposed. The performance improvement of proposed algorithm has been evaluated by a system-level simulation based on the realistic 5G wireless network. The simulation result indicates that the three strongest singular values should be considered in the CBF to suppress 20 dB cell-to-cell CLI for one victim cell. With MMSE-IRC receiver, the coverage performance is enhanced by about 4.85 dB when compared with legacy TDD system. The simulation results can be used as guideline for the Macro deployment scenario with SBFD. In the future, CBF and MMSE-IRC would be considered jointly in the simulation, and the results can be used to choose proper CLI handling schemes in the deployment. Besides, the performance of real channel estimation would also be studied, and the results will be more realistic and persuasive.

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Toward a Framework to Improve Employees' Compliance with Cybersecurity Policy in Organizations

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Abstract Digital transformation has influenced organizations' operations significantly. However, non-compliance with cybersecurity policy (CSP) is a growing concern for organizations. Technology alone cannot protect organizational cyber assets such as computer systems, networks, and data. Human aspects should be considered when designing and implementing a CSP. The lack of effective CSP training and awareness programs (CSPTAP) is attributable to employees' non-compliance with the CSP. This paper aims to develop a framework to enhance employees' compliance with the CSP by implementing effective CSPTAP. Drawing from the present literature and reflecting on the existing behavior change wheel (BCW) framework, and capability, opportunity, motivation, and behavior (COM-B) model, the cybersecurity policy compliance (CSPC) framework is developed. The CSPC framework comprises the following key concepts: learning existing policies, conducting employees' gap analysis, reviewing existing policies/developing new policies, provision of relevant content and delivery mode, and periodic auditing. These key concepts are essential elements in cybersecurity policy compliance. The model indicates that the implementation of the essential elements will substantially influence employees' compliance with CSP. Moreover, when organizations consider these key elements, cybersecurity policy training and awareness, can positively enhance employees' CSP compliance. The proposed development of CSPTAP provides a firm base for future empirical work including action research.

Keywords Cybersecurity awareness · Cybersecurity policy · Cybersecurity training · Employee cybersecurity policy compliance

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1 Introduction

Digital transformation has brought about various cybersecurity challenges to organizations. Cybersecurity incidents are increasing at an alarming rate despite cyber protection mechanisms being installed on computers, mobile devices, and network infrastructure. Cyber mechanisms do not fully mitigate cyber breaches manifesting from human errors [1]. According to the Varonis Systems Software Company survey report, human error counts for 95% of cybersecurity breaches [2]. As a result, organizations suffer reputational risk and financial damage [3]. The cybersecurity threats that organizations experience include phishing and social engineering which occur as a result of the lack of effective cybersecurity policy training and awareness programs (CSPTAP) [4, 5].

The concerns emanate from organizations not conducting the employees' CSP knowledge gap analysis prior to providing the CSPTAP. Gap analysis informs the knowledge that employees have regarding the organizational CSP or identifies a need for updating or developing a CSP, and the content and delivery mode relevant to providing CSPTAP [6, 7]. Organizations should monitor their employees' performance post the provision of CSPTAP and evaluate the characteristics that influence the employees' compliance with CSP [6, 7]. According to Ertan, Rikke, and Jensen [6], compliance is the act of conforming to a set of rules and policies that govern activities and processes in organizations. The rules and policies are designed in a way suitable to the kind of business that the organization is operating on, as well as how employees are expected to behave daily [6]. Cybersecurity policy compliance depends on the employees' behavior.

Proudfoot and Arcy [8] evaluated the challenges that might contribute to employees' non-compliance with the CSP and they proposed penalizing employees that click on phishing links and rewarding employees for communicating attempted social engineering [8]. Cram, Proudfoot, and Arcy [8] also enforced that participation in CSPTAP is compulsory although solutions were found to be ineffective. The aim of the paper is to develop a cybersecurity policy compliance framework to enhance CSP compliance through the implementation of an effective CSPTAP. The objective of the framework is to provide a tool that can be used by organizations to notice employees' behavior change (compliance with CSP) acquired from the provision of effective CSPTAPs.

This paper is structured as follows: Sect. 1 introduces the paper, Sect. 2 provides the theoretical background, and Sect. 3 discusses the developed cybersecurity policy compliance framework. Section 4 concludes the paper.

2 Theoretical Background

Although technology has improved the ways of conducting business processes efficiently and effectively, it causes the rise of employee-related cyber breaches, which negatively impact organizations [9]. Organizations are facing cybersecurity risks that are emerging and increasing at an alarming rate due to employees that do not comply with the CSP [7]. Employees according to [1], do not comply with CSP as a result of ineffective CSPTAP that does not engage relevant stakeholders and include human aspects [10]. The human aspects assist in the development of an informed CSP while also assisting in the provision of an effective CSPTAP [10]. The reason is that human aspects address the knowledge gap among employees, that when acquired, can influence employees' compliance with the CSP [10].

The lack of compliance is attributed to employees' lack of access to effective training and awareness programs on CSP requirements [5]. Employees need to understand the CSP to avoid human errors. Human errors occur as a result of different factors such as intentional and unintentional [1]. Intentional error is when an employee is aware of the existence of the organizational cybersecurity policy but deliberately does not observe it [1]. An unintentional error occurs if an employee is ignorant of the handling of the job which exposes the organization to cyber threats [1].

Employees do not comply with the CSP due to a lack of knowledge because of an ineffective CSPTAP, which does not adequately address employees' changing cybersecurity behavior such as intergroup dynamics, compliance, email behavior, and password behavior [7]. Addressing human-caused flaws can be challenging since it requires changing employees' attitudes and behavior habits [11]. Therefore, for cybersecurity to be effective, organizations must be able to instill the right cybersecurity culture in their workforces [10, 12]. Organizations must provide their employees with effective training and awareness programs that capacitate them to be on continuous alert for security breaches [13].

In this paper, the authors propose the development of a framework by combining attributes and concepts of BCW framework and COM-B model that incorporate employees' behavior change in the CSPTAP [7].

2.1 Lack of Knowledge

More often, the leadership of the organizations develops policies but fails to effectively communicate them to the employees by developing an effective CSPTAP [7]. Employees that do not know of the CSP are victims of cybersecurity threats [5]. These cybersecurity threats do not only happen because of intruders, but also because of employees [5]. The common cybersecurity threats that organizations experience include: phishing, social engineering, and distributed denial of service (DDOS) [4]. According to the Varonis Systems Software Company 2021 survey report, 48% of

malicious email attachments appeared as office files [2]. Due to lack of knowledge, the uninformed employees perform some mistakes that expose their organizations to cyber threats such as sharing of organizational information with strangers, clicking of links without verifying their legitimacy, and accidental leakage of confidential information as a result of smartphone or memory stick misplacement [4].

2.2 *Ineffective Cybersecurity Policy Training, and Awareness Programs*

CSP training and awareness is teaching and equipping employees with the required CSP skills and knowledge needed to avoid and protect against cyber threats [7]. After cybersecurity policy training, organizations test employees' knowledge through continuous cybersecurity policy awareness programs intended to draw employees' attention as a way of ensuring that employees know and understand that the CSP exists [1, 14]. Organizations achieve cybersecurity policy awareness by attack simulations such as fake phishing emails, newsletters, etc. [1, 14]. Phishing simulations test employees' understanding of the post cybersecurity policy training to ensure that they can spot malicious links and attachments [1, 14]. A one-size-fits-all (cybersecurity awareness training) approach means providing the same training material to all employees in an organization, regardless of their roles, responsibilities, or existing knowledge of cybersecurity. The training may cover general cybersecurity principles, basic security practices, and common threats, but it may not address the specific risks and challenges faced by different departments or job functions [15–17]. Cyber criminals' target employees for different agendas and identify various employees with various vulnerabilities. Therefore, to minimize cybersecurity risks, organizations must provide employees with CSPTAPs relevant to their job roles for more efficiency [15, 16]. Organizations should therefore conduct a gap analysis prior to developing cybersecurity policy training and awareness programs to assess what knowledge employees lack regarding the CSP [7]. The gap analysis should include an assessment of the appropriate delivery method of CSPTAPs that employees prefer such as video-based, text-based, and game-based including delivery content [1, 7].

Moreover, CSPTAP must be continuous and reviewed periodically to cover emerging cyber threats [1, 15]. The improvement of the CSPTAP is a growing need in the cyber space to keep employees informed and understand the need to comply with the CSP developed by their organizations [1]. To enhance the effectiveness of the CSPTAP, incorporating employee behavior change in the cybersecurity programs is vital. According to Alshaikh, Maynard, and Ahmad [7], BCW framework and COM-B model are effective tools for determining and facilitating behavior change and their discussion follows in Sects. 2.3 and 2.4, respectively.

2.3 BCW Framework

The BCW framework is a tool that assists organizations focus on employees' behavior that needs to change through the use of COM-B model components [7]. BCW framework is important in this paper because it analyzes and uncovers the behavior of employees, and helps in determining and selecting the suitable CSPTAP that would assist organizations to achieve the intended objective of ensuring employees' compliance with CSPs [7]. For example, the objective could be to ensure that employees know the procedures that they should follow in the event of an incident and breach of CSPs [7, 16]. It assists in investigating what warrants change in the workgroup and individual behavior [7]. In addition, BCW informs policy development and amendments to existing policies to align with changes identified in the behavior of employees. Furthermore, it informs the implementation of the organizational strategy [7]. Moreover, BCW helps in analyzing and understanding the behavior of individuals [7].

2.4 COM-B Model

COM-B model is a BCW fragment which suggests that there are three components to any behavior. The components are capability (C), opportunity (O), and motivation (M), and they influence change in employees' behavior [7]. According to Alshaikh, Maynard, and Ahmad [7], the three components of COM-B model that determine behavior change are discussed as follows:

Capability: An employee to comply with cybersecurity policy must feel psychologically (appropriate knowledge) and physically (proper physical skills) to do so. Employees must be provided with effective CSPTAP to acquire appropriate CSP skills and knowledge. When employees lack appropriate CSP skills and knowledge, they lack motivation to comply with CSP.

Opportunity: An employee must be provided with CSPTAP by their employers at no cost and they can also attend with their colleagues. Physical activity would seem more feasible and sensible to their daily work activities and hence the motivation to comply with CSP.

Motivation: When employees have CSP skills and knowledge, they are likely to feel a need to comply with CSP more than other any other behavior.

COM-B model is used to identify the targeted behavior to accomplish after CSPTAP, and further indicate how targeted behavior could be achieved [7]. The identification of targeted behavior can be performed on the data collected by the trainer/practitioner (IT personnel/information security personnel), human resources and security champion [7]. The COM-B model components assist in establishing the psychological effects that need resolution to realize the targeted behavior change [7].

3 Cybersecurity Policy Compliance Framework

The framework was developed by combining attributes and concepts of capability, opportunity, motivation and behavior (COM-B) model and behavior change wheel (BCW) framework. COM-B and BCW are appropriate starting points for CSPTAP as they lay down what determine behavior change, and how the change in behavior can be facilitated, respectively [7]. The COM-B model and BCW framework discuss how organizations can enhance the effectiveness of CSPTAPs to influence employees' behavior to comply with cybersecurity policies [7]. The cybersecurity policy compliance (CSPC) framework is a cyclical process that is comprised of two main layers, where inner layer being COM-B and BCW are the subset of the outer layer which is the overall CSPC framework. The CSPC has seven stages, namely the foundation layer, audience layer, assessment layer, strategic layer, delivery layer, implementation layer, and monitoring and evaluation layer. For effective implementation of the CSPC framework that incorporate cybersecurity culture, each of the seven layers is implemented with employee cybersecurity behavior change in mind. Behavior change is key to addressing human-caused flaws. The layers depict the process followed in building the CSPC framework as presented in Fig. 1.

Each layer as depicted in Fig. 1 will be discussed as follows.

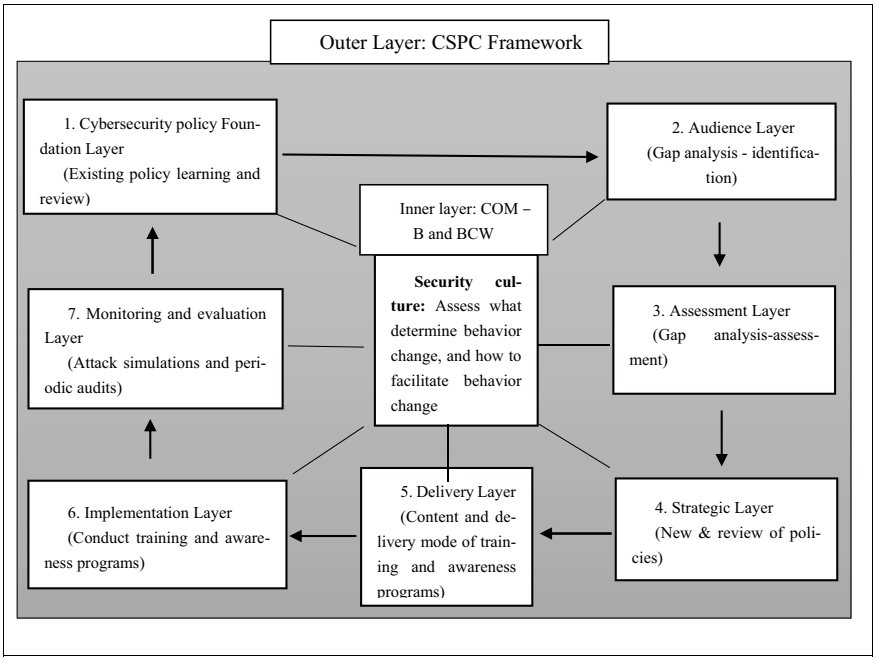

Fig. 1 Cybersecurity policy compliance framework

3.1 Foundation Layer

The cybersecurity experts learn and review the existing CSP prior to deciding on what kind of CSPTAP should be provided. It is a learning point in whereby experts interrogate the existing CSPs and inform the need for an upgrade or development of a new CSP in the event if it is not there. However, it has been noted in the literature, that learning and adoption of CSP should start by providing generic training that involves the basics of the CSP [7]. These are the contexts that are required to be known and practiced by every employee in the organization. The contexts include password management and email management to name a few [7]. Understanding the employees' cybersecurity behavior at this stage is critical. Once the foundation has been laid, the knowledge gap analysis is carried out to identify employees' knowledge gaps that need to be considered during the development of CSPTAP and the process is discussed in the audience layer, in Sect. 3.2.

3.2 Audience Layer

The employer must set targets, including the targeted behavior, to be achieved by development of CSPTAPs for his/her employees. Therefore, there is a need to conduct a gap analysis to determine the knowledge gap that such employees possess. The gap analysis, which includes cybersecurity behavior change analysis, will inform the content and delivery mode of the CSPTAP [7]. The exercise can be undertaken by cybersecurity experts. The results acquired in the exercise are prepared for assessment in the assessment layer, in Sect. 3.3.

3.3 Assessment Layer

The experts interrogate the results to identify the knowledge, cybersecurity culture, and experiences that employees have. This is dependent on the study and the set targets by the employers. The results inform the management on the need to improve on existing CSP or development of a new CSP. The results which are compiled as assessment report are submitted to the management of the organizations to strategies on the CSPTAP, under strategic layer as discussed in Sect. 3.4.

3.4 Strategic Layer

In this layer, the organization's management sits and discusses a way forward to enhance the CSPTAP to ensure employees comply with CSPs. The assessment report

enables them to develop the policies and/or update the existing ones to improve CSP compliance and instill cybersecurity culture in their workforce. Creating cybersecurity behavior change does not happen overnight. Permanent change necessitates a clear vision, strategy, delivery, and continuous organizational awareness. To achieve the strategic cybersecurity compliance targets, the management then shares the revised or new policy with the experts to create the appropriate content and mode of delivery of the CSPTAP. In addition, they approve the resources needed to carry out the CSPTAPs. The plan regarding the content and delivery mode is implemented under the delivery layer, as discussed in Sect. 3.5.

3.5 Delivery Layer

The experts plan on the content and delivery mode that is suitable to meet the objective set by the management [7]. The content and delivery mode can be noted on the CSPs that the management reviewed. The content can be role-specific with real life experience for efficiency. The delivery mode can be text-based, video-based, or game-based [1, 16]. This is dependent on what experts found valuable as per need identified. Once the experts have established the suitable content and delivery mode, they will collaborate to plan on how to implement the CSPTAP under implementation layer as discussed in Sect. 3.6.

3.6 Implementation Layer

In this layer, the experts collaborate with human resource specialists, security champions, and industrial organizational psychologists to conduct the CSPTAP, that target behavioral change. They collaborate because the skills and expertise they each have differ and are all required for the success of the exercise. Human resources have the expertise in overseeing the need for skills and knowledge development of all employees in the organization [7]. "Information Technology has expertise in CSP environment" the reason is that the clarity was being made on the expertise of different representatives participating in the implementation layer. Security champions are representatives of employees and are knowledgeable of their colleagues' behavior regarding CSPs. Once the CSPTAPs have been conducted, knowledge, skills, and cybersecurity behaviors imparted to the employees should be monitored and evaluated to ensure the effectiveness of the exercise under the monitoring and evaluation layer as discussed in Sect. 3.7.

3.7 Monitoring and Evaluation Layer

The IT/cybersecurity experts can monitor and evaluate the effectiveness of CSPTAPs through attack simulations and periodic audits [1, 15]. It has been argued that CSP awareness can be enhanced among users with phishing simulators [18]. Phishing simulators give the organization a view of how employees behave when they encounter threats. If employees fail to spot the phishing emails, the experts get the report of the failures. The report of the failures informs what training is needed for employees to ensure they know and understand CSPs [1, 15]. If the results of the monitoring and evaluation layer indicate issues of non-compliance to CSP, the organization will then review and update the policy, if necessary, under the foundation layer. Further monitoring can be done during weekly team-building sessions held by divisions, where CSPs issues can be discussed with ease by colleagues [10].

4 Limitations

The effectiveness of the CSPC framework in the provision of the CSPTAPs has not been empirically tested. The development of the CSPC framework is based on interpretations made from the literature. Future work for this study is the empirical testing of the proposed CSPC framework.

5 Conclusion

This section concludes the paper by reflecting on the process followed in developing the proposed CSPC framework. The motivation for the development of the CSPC framework was provided in Sect. 1 by identifying the gaps in the employees' CSP compliance. The need, which can at least improve effectiveness of CSPTAPs is identified. The employee cybersecurity behavior change is identified as critical to manage human-caused cyber flaws. The motivation for the development of the CSPC framework was further provided in Sect. 3.

This paper has introduced various important suggestions for practice. The paper has proposed a framework that can be used by organizations to develop effective CSPTAPs which can change employees' behavior. The framework has provided guidance on how to develop effective CSPTAPs incorporating BCW framework and COM-B model aspects. BCW and COM-B are used to assess the determinants of behavior change and facilitate the process of implementing the behavioral change. BCW indicated the importance of involving all employees in the organization in the development and implementation of CSP, through conducting employees' behavior analysis. Behavior analysis could be conducted using the COM-B model, which gives an idea of employees' intentions to comply or not comply with CSP. In addition, the

CSPC framework has indicated the importance of providing training that is relevant to employees' job responsibilities and roles. Furthermore, the framework emphasized the importance of providing and reviewing CSPTAPs on a continuous basis. However, since the framework has not been tested, future research will entail conducting action research to gather opinions of organizations on how they provide CSPTAPs and gather how CSPTAPs influence employees to comply with CSP. Research will be conducted in large organizations with mature systems such as those that use digital devices like computers connecting to the network to perform their daily job activities.

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Logistics Dashboard for Transport of Fragile Goods

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Abstract During the transport of boar semen for artificial insemination (AI) of pigs, there is currently no system for monitoring and documenting of the entire transport process of this fragile product. Based on a survey of artificial insemination center, this paper describes the requirements for a logistics dashboard for monitoring all relevant impact factors during the transport of insemination doses. Visualization concepts for the most important impact factors of boar semen as well as a user guidance and a system architecture for the implementation of the dashboard are presented. The implementation of the dashboard was done as a WebApp with React. With the presented dashboard, a complete monitoring of the transport of insemination doses for pigs is possible.

Keywords Dashboard · Transport optimization · Fragile goods · Insemination doses · Pigs · Boar sperm

1 Introduction

During the transport of fragile goods, damage to the transported goods occurs regularly. There are numerous product solutions for minimizing transport damage (e.g., padding, cushioning). However, in the event of damage, the question remains: Where

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did the damage occur and how can the damage be prevented in the future? Existing solutions in the logistics sector focus on the traceability of the shipment, but not on the condition of the goods during transport.

During the transport of insemination doses for pigs, which is a highly fragile product, there is a need for an efficient and complete monitoring and documentation of the entire transport process in real time. For this purpose, preliminary work has already been done by the authors of this paper (see research project "IQ-TranS") to record the transport stress during a delivery tour [1]. However, there is still a lack for an efficient system to monitor and ensure the product quality of the insemination doses while shipment to the customer by the boar insemination station as the sender.

Exemplified in the case of insemination doses of pigs—as a fragile good—a dashboard for the transport of fragile goods will be developed. With this dashboard, it should be possible to manage and monitor the transport of insemination doses and to ensure that product arrives undamaged at the customer site. Using the dashboard, it is should be possible to identify problems during shipping and prevent potential damage to the transported goods by intervening at an early stage.

The requirements for a system to support the logistics process were collected through a qualitative survey of six selected insemination stations. Business use cases and system use cases were defined and used to model the technical and functional requirements for a dashboard for fragile goods as part of the requirements analysis for the development process of the dashboard. In addition, visualization concepts for the most essential impact factors of boar semen were developed. Further results of this paper are a user guidance through the dashboard and a system architecture for the implementation of the dashboard. In the last step, the dashboard was implemented as a WebApp using React.

The paper is structured in the following way: In Sect. 2, the background of the monitoring system for transporting boar semen is presented. Then, related work on dashboards and data visualization is described in Sect. 3. The results of the requirements analysis are described in Sect. 4, and the concept based on the requirements analysis is presented in Sect. 5. The implementation is shown in Sect. 6, by presenting the implementation decisions and the developed user interface. The paper closes with the conclusions and planned future work in Sect. 7.

2 Background—Transport Monitoring System

The logistics dashboard which is designed and presented in this paper is part of a transport monitoring system for quality assurance during the transport of insemination doses for pigs. Therefore, the background of this transport monitoring system is presented below.

The transport of insemination doses for pigs demands high standards to maintain the quality of this very valuable and highly sensitive product [2]. So far, an efficient and seamless monitoring as well as documentation of the entire transport process of

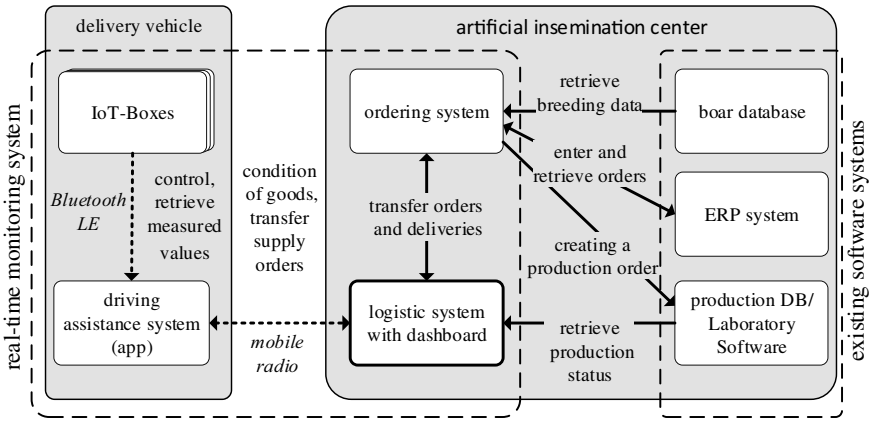

Fig. 1 General architecture of the transport monitoring systems

insemination doses is not possible. This is caused by a lack of knowledge about the exact transport parameters.

To develop such a transport monitoring system, the requirements were identified on basis of a user survey within the research project "IQ-TranS". Following this, a general architecture of the transport monitoring system was created, which consists of the modules driver assistance system, **logistics system**, ordering system, and IoT transport boxes. The dashboard that is developed and presented in this paper is part of this logistics system.

The effects of transport on the semen doses are recorded in real time by temperature-controlled IoT transport boxes and transmitted to the logistics system via the driving assistance app. The **dispatcher** can view all the necessary information about the status of the order and the delivery process in the logistics system dashboard. In Fig. 1, the general architecture of the transport monitoring system is shown.

3 Related Work

There is no clear definition of dashboards in the literature. They are overwhelmingly described as a method of displaying information required to achieve one or more objectives, using a consolidated view on a single screen, so that this information can be easily viewed and controlled [3–5]. This definition can be extended by the time aspect, in which historical information is taken into account in addition to the current status [5].

Dashboards have evolved continuously over the last few years. While they were originally intended to present current information to the user, a dashboard nowadays fulfills more advanced functions. Dashboards distinguish themselves from other explorative visualization tools through a variety of use cases [3].

Dashboards can be classified according to their purpose as strategic, analytical, and operational, which has an influence on the visual design. [3, 4, 6]. Strategic dashboards are used at the management level and focus on high-level measures of performance including forecasts. The challenge is to derive appropriate metrics that do not distract the decision-maker. Due to the focus on long-term strategic decisions, real-time data is not required for strategic dashboards. [4, 5]. Other forms of presentation are necessary to support data analysis. The goal of an analytical dashboard is to provide support for the exploration of complex data and relationships. The data has to be put into context for analysis, for example by using historical data or comparative data. Additional and more sophisticated analysis tools as well as graphs can also be used of the analysis in such dashboards [4, 5]. The monitoring of processes requires other dashboards. The primary goal in this case is to display the dynamics and immediacy of the operations within an observed process. The challenge is to clearly display all activities and events that require attention and reaction. The ways of visualization have to be very simple and easy to read, especially in emergency situations. Furthermore, such dashboards must offer the possibility of providing warnings when predefined threshold values are exceeded or not reached [4, 5]. In praxis, there are fluent transitions between these dashboard types, which depend on the purpose of the dashboard [3, 5]. Besides these "classic" dashboards, which are used for decision-making, communication and learning dashboards have the goal of providing information or knowledge to the user [3, 7].

Another aspect that has an influence on the design of a dashboard is the potential target group with their respective and highly individual domain and visualization experience. Too much complexity of the visualizations can limit their comprehensibility [3, 5, 8]. The authors Sarikaya et al. 2018 classify the required visualization competence into three levels (low, medium, high). According to their classification, basic visualizations such as bar and line charts require low competence. More advanced visualizations such as combined double axes, scatter plots, and heat maps already require medium competence [3].

In summary, a good dashboard is characterized by offering a well-designed and efficient presentation of the most important data in a small form factor, depending on the target group. Complex relationships have to be presented in a clear and precise way in order to enable a decision by the user. The methodological competence of the target group or the users must be taken into account.

So far, there are numerous scientific publications and product descriptions from the field about dashboards in logistics [9]. However, these approaches focus on the presentation of information about the route and the condition of individual vehicles or entire fleets. A consideration of the condition of the transported goods does not take place so far. Therefore, it was necessary to develop a dashboard that is adapted to the special conditions of the transport of fragile goods, in which information about the condition of the transported goods is also included.

4 Requirements Analysis

For the requirements analyses of the dashboard, interviews with different insemination stations (production companies for insemination doses of boar semen) were carried out and evaluated (see [9]). In the following analysis, relevant stakeholders and their goals were identified and requirements in the form of business use cases were derived. These business use cases were used to define system use cases in form of functional requirements for the dashboard.

The following stakeholders were identified for the dashboard: **dispatchers** of the insemination center, management of the station, logistic partners or external logistics companies as well as customers. The dispatchers are the main users of the dashboard. This stakeholder's goal is to manage and monitor the transportation of insemination doses and to ensure that this product arrives at the customer's site without damage. By focusing on a logistics dashboard, the other stakeholders do not come into direct contact with the system and are not included in the further analysis from this point on. The most important objectives of the stakeholder "dispatcher" are

- Scheduled, current, and future shipments should be displayed with all relevant information (recipient, driver, start time, arrival time, and status).
- For each finished shipment, the entire transport history including driver, vehicle, route, and, if applicable, handovers should be visible.
- It should be possible to view the handover details for each shipment. This includes person present, handover location, temperature of the products, and photo documentation.
- For a retrospective analysis, the measured impact factors on the product should be displayed in a clear way; in case of boar semen, these are vibrations and temp.

The stakeholder analysis revealed that the dispatcher is the primary stakeholder of the planned dashboard. Therefore, the business use cases are presented below only from the dispatcher's perspective. Figure 2 shows the business use cases as a UML use case diagram.

The identified business use cases are described in more detail below:

- **"Identify problem cases"**: If problems occur during shipment, e.g., increased vibrations or deviation from the specified temperature, these problem cases must be identified and detailed information has to be provided. This includes information about the entire shipment and the delivering tour.
- **"Check claim"**: When a customer has a claim, it should be checked if this could have been caused by the transport. This use case extends the use case "identify problem cases".
- **"Coordinate deliveries"**: If there are irregularities during the current shipments, e.g., due to the failure of a vehicle, the current shipments should be coordinated and changed if necessary. The dispatcher should be able to view all active shipments with the respective cargo lists and available stock volumes. The drivers should be easily contactable from the system.

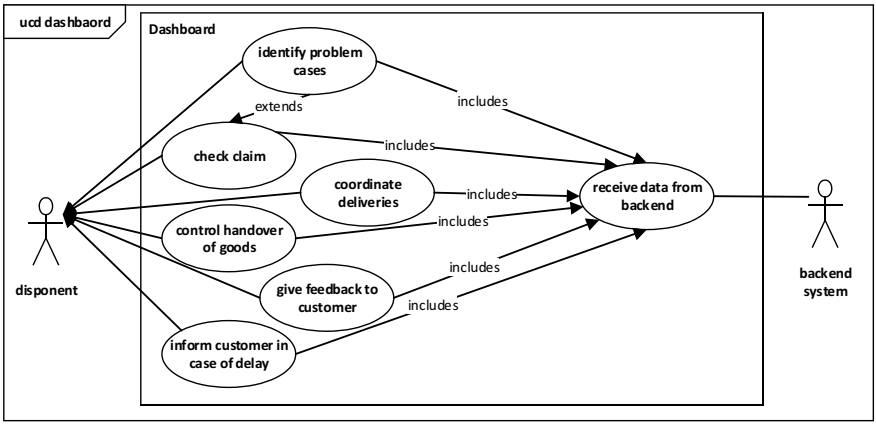

Fig. 2 Business use cases of the dashboard (UML use case diagram)

- **"Control handover of goods"**: To provide documentation of a successful handover, the handover details should be displayed. This includes the temperature of the product, the persons involved, the time and place of handover, and, if necessary, photographic documentation.
- **"Give feedback to customer"**: In the event that customers contact the dispatcher, he should be able to provide information about the respective shipment immediately. This requires efficient filtering by current delivery routes as well as a search for customers.
- **"Inform customer in case of delay"**: The dispatcher should be able to identify irregularities on the current shipment and have the possibility to inform the customers about a delay if necessary. For this purpose, all necessary customer data must be displayed.

System use cases are developed from the presented business use cases above. These include functional requirements, performance requirements, and quality criteria for the planned dashboard. The individual components of the system are described in detail in chapter "Rehabilitation of the Lower Limb Motor Skills for Patients Using Cable-Driven Robot". The following functional requirements are specified for the dashboard:

- **Presentation of all relevant parameters/measurements**: Suitable views have to be developed to display all parameters that have an influence on the quality of the boar semen.
- **Clear visualization of relevant parameters for every IoT transport box**: All relevant and measured as well as derived parameters should be displayed on a single page for each transport box.
- **Real-time monitoring and retrospective presentation of shipment data**: The measured impact parameters of the current and finished shipment have to be displayed as graphs.

- **Summary feedback for parameters**: The relevant parameters have to be aggregated using a traffic light system for each shipment.
- **Display of the live locations of the transport vehicles**: The locations of the transport vehicles have to be displayed on a map. Individual vehicles shall be selectable.
- **Provide detailed information about shipment**: The dashboard should provide information about shipment details. These include goods transfer details, shipment size, and drivers.
- **Information about the estimated time of arrival at the customer site**: The ETA should be calculated automatically and should be displayed.

Non-functional requirements are requirements that describe the quality of a software system. The following non-functional requirements are specified for the dashboard:

- **The dashboard fits on a single computer screen**: All essential information which is needed for a reliable decision-making has to be displayed as a one-pager.
- **Privacy and security have to be ensured**: Sensitive customer data and data on shipment routes must be protected. Role-controlled access is supposed to enable access rights for individual data.
- **Easy maintainability and extensibility of the dashboard**: The architecture as well as the implementation should allow an easy maintainability and extensibility.

5 Concept

In this chapter, the visualization concepts, the user guidance, and the system architecture are presented as well as the data and indicators that have to be displayed.

5.1 Visualization Concepts

The requirements analysis (see chapter "A Study of the Potential of Online Learning of Kasetsart University Faculty Members") concluded that the following parameters should be visualized by the dashboard: temperature, vibrations, location of the vehicles, loading capacity, route of the delivery vehicles, time of delivery, order details, handover details, and customer details. The appropriate visualization of the data is developed according to the recommendations of the "International Business Communication Standards" (IBCS) [10]. Well-known diagram types are used first, and diagram types that are difficult to grasp are avoided. A high information density is aimed in all cases [11].

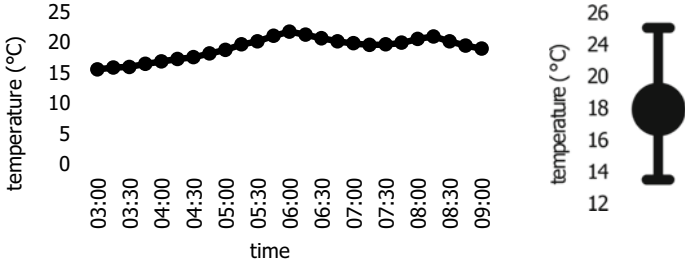

Fig. 3 Two different types of diagrams to display the temperature. Left: line chart to show temperature depending time. Right: Modified box plot to show min–max and average temp

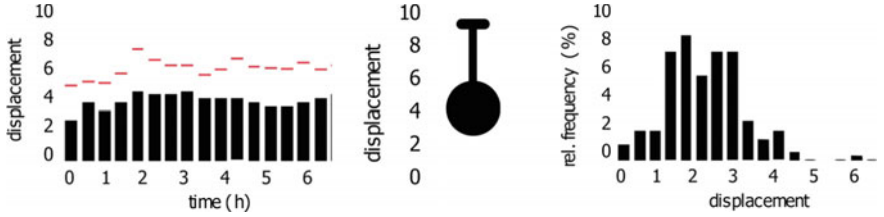

Fig. 4 Three different types of diagrams to display the vibration as displacement. Left: A bar chart was extended with horizontal lines above the bars to show the maxima. Center: A modified box plot to show max and average displacement. Right: A histogram to show the relative frequencies of displacement

A line plot and a modified box plot (box-plot-light)[1] are used to visualize the **temperature**. Figure 3 shows the different diagrams for displaying the temperature. The **vibrations** are displayed as a displacement index[2] using a bar graph, a box-plot-light, and a histogram. The diagrams for displaying the vibrations are shown in Fig. 4.

A map view is used to display the **location** of the vehicles as well as the shipping **route**. All other relevant information (delivery time, order, handover, and customer details) is displayed in text or table form.

5.2 User Guidance

A UML activity diagram is used to specify the user guidance through the dashboard. This modeling makes it possible to identify a "workflow" of prospective use and define user interaction with the software.

[1] In the modified box plot (box-plot-light), the min–max values are shown as whiskers and the median is shown in the center. All other parameters of a box plot are not displayed.

[2] The displacement index (d_i) is the average distance of all measured acceleration vectors within one second (see [9]).

The user guidance through the dashboard is as described below. After the launch of the dashboard, a live map with all active shipments is shown. In addition, the shipment can be filtered according to the customer (select customer) and the delivery tour (select delivery tour). Depending on the selected filter method, an overview of a current or completed shipment is displayed (show tour overview). Within the tour overview, the average measurement data for temperature and vibration can be analyzed in the form of diagrams (show average parameter). After selecting a particular parameter, detailed information about the selected parameter is displayed (select single parameter). Depending on the status of the shipment, the expected time of arrival (show ETA) or details about the handover (show order and handover details) are displayed. Figure 5 shows the main steps of the user guidance through the dashboard.

5.3 Architecture

The dashboard appears in the overall architecture of the transport monitoring system (see Fig. 1) as a single layer within a layered architecture. The layered architecture is one of the most common architecture types for dashboards. From this point of view, the frontend is the most visible but not the most important part of the overall system [5]. The layered architecture connects the components loosely, so that they can be replaced without having to redevelop the entire system. [12].

The dashboard is developed as a WebApp, which can be opened by the user using any web browser. The WebApp retrieves the data, which has to be displayed, from the backend and can also send data to the backend. The map views are integrated and displayed live in the WebApp via a map provider. The backend has a connection to the database with stores all measured values as well as having a connection to the ordering system. The described architecture concept can be classified as a client–server architecture from the dashboard's point of view, whereby the dashboards should provide as little business logic as possible. All evaluations as well as the aggregation of data are handled by the backend. The layered architecture of the transport monitoring system, in which the dashboard is integrated, is shown in Fig. 6.

6 Implementation

Based on the concept (see chapter "Rehabilitation of the Lower Limb Motor Skills for Patients Using Cable-Driven Robot"), the following section describes the implementation decisions of the dashboard and presents the implemented components as well as the dashboard as a WebApp.

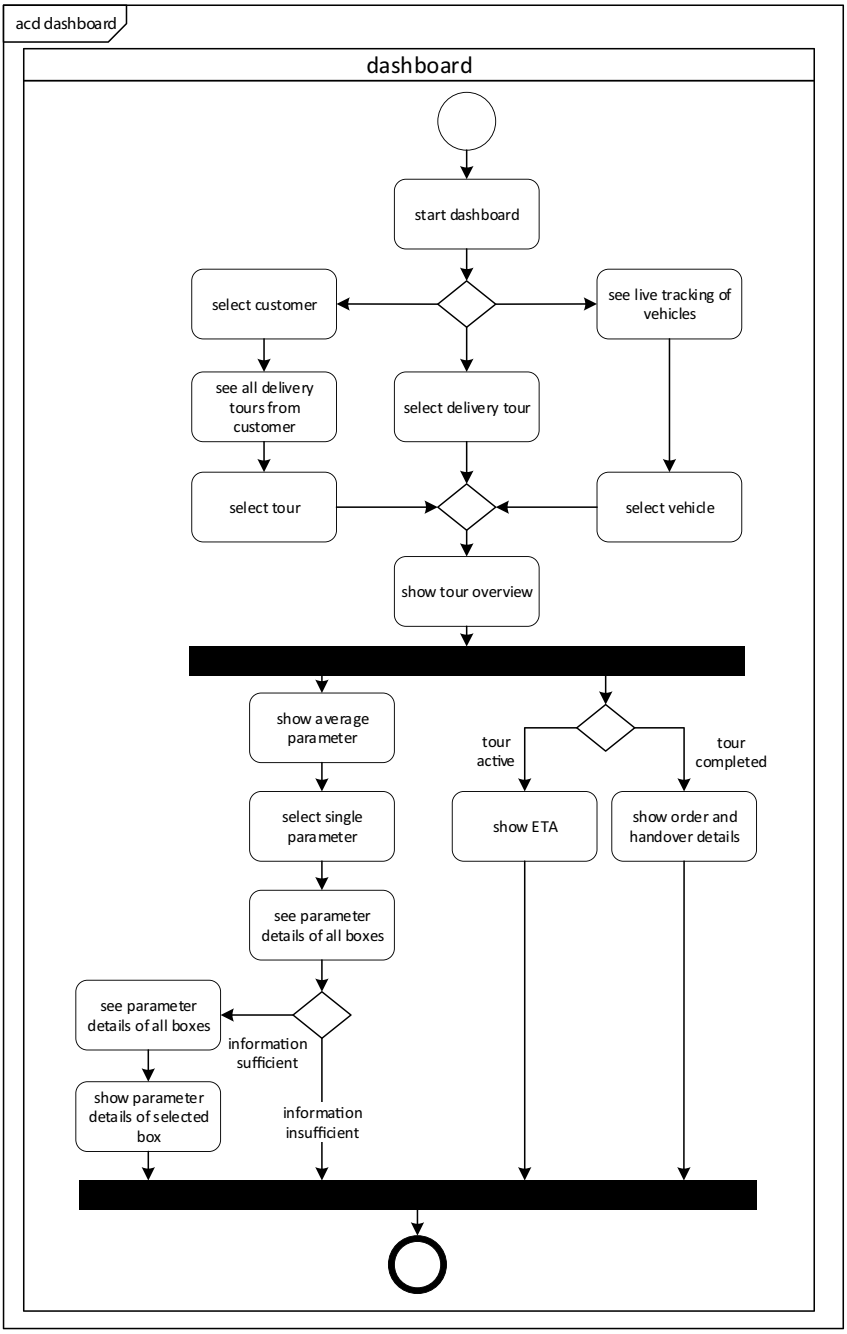

Fig. 5 UML activity diagram to visualize user navigation through the dashboard

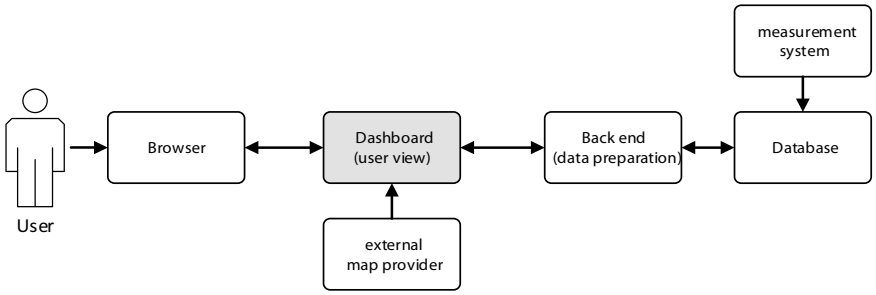

Fig. 6 Layered architecture of the transport monitoring system

6.1 Implementation Decisions

The implementation of the dashboard was done using the JavaScript web framework "React".[3] In contrast to other JavaScript frameworks, "React" has fewer constraints to solve a specific problem. "React" does not provide routing to navigate to the different pages within the dashboard, so the "React Router" was used as an external package to provide this functionality [14]. The dashboard communicates with the backend using a "REST" API. For this purpose, three endpoints "customer", "tour", and "parameter" were defined for the backend. Via these endpoints, all data which has to be displayed can be queried in "JSON" format and finally prepared for the view.

The implemented dashboard consists of several components, whereas the views (screens) are implemented as a single component. Each of these components can receive data from the backend via the available interfaces. For this purpose, the interfaces "customer", "tour", and "parameter" were created, which correspond to the endpoints of the "REST" API. For a simplified data management and to avoid redundancies, the component "CustomerDataContext" was developed, which manages the customer data. Within each screen, there are further components inside them. These are responsible for the display of all the visible components, such as "LiveMap", which is used to display the map view. Figure 7 shows the react components and their relationships to each other.

The styling of the dashboard was implemented using the "styled components" library, which is a "CSS-in-JavaScript approach". This allows to avoid conflicting CSS rules and collisions in CSS class names. [15]. All charts were implemented using the "ApexCharts.js" library. This allows an efficient and reusable implementation of the necessary modifications to the standard chart types [16, 17]. The map component (see Fig. 7) was implemented using "Leaflet" [18] and "React Leaflet" [19] libraries. Leaflet is the most widely used JavaScript library for mobile applications with interactive maps, according to its own statement [18]. Due to the large support of all

[3] React is a cost-free and open-source JavaScript library for developing user interfaces and UI components [13].

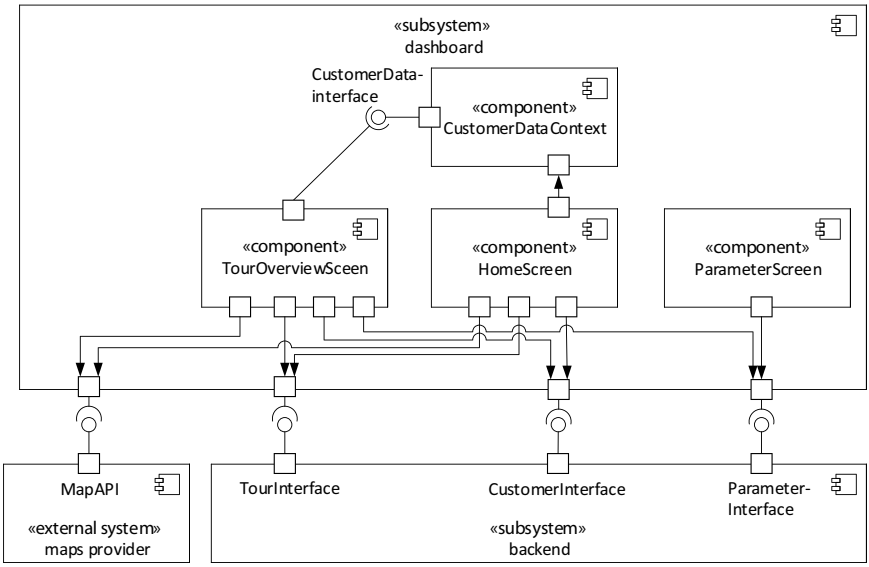

Fig. 7 React components of the implemented dashboard

major desktop platforms, a high compatibility is ensured. The map material comes from the OpenStreetMap project. [20]. The use of this free map material allows an affordable development of the dashboard.

6.2 User Interface

The implemented visualization concepts (see Sect. 5.1) are presented below. Figure 8 shows the implemented diagrams for the representation of the temperature. In both diagrams, the critical areas which should not be exceeded or undercut are shown as red lines. This gives the user a quick overview of the critical threshold values. The implemented diagrams for displaying the vibration in the form of the displacement index are shown in Fig. 9. In the case of the bar chart, the range of the measured values is visible due to an additional graphical element showing the maxima (red lines above the bars). An overall summary of the vibrations for a specific IoT transport box is possible with the "box-blot-light" (see Sect. 5.1). The max range of the measured values is shown by using a whisker. This form of graphical representation helps to evaluate whether an extreme vibration has occurred during a shipment. The histogram can be used to analyze the distribution of the vibrations during a shipment.

The "Home Screen" of the implemented dashboard is shown in Fig. 10. This screen implements the use case: display of all scheduled, current, and future shipments. On this screen, all relevant information (recipient, driver, start time, arrival time,

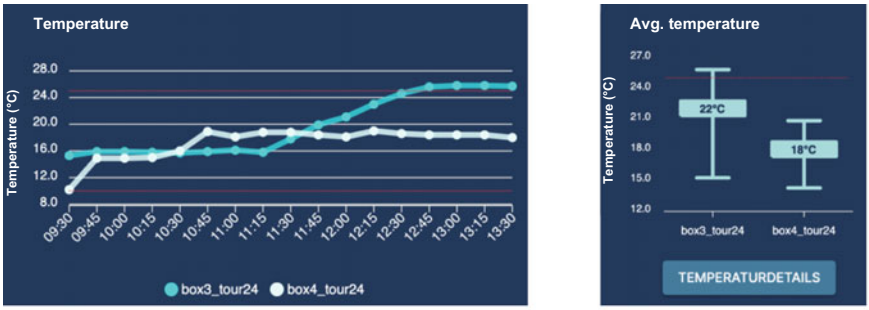

Fig. 8 Implemented diagrams for temperature. Left: line chart to show temperature depending time. Right: Modified box plot to show min–max and average temperature

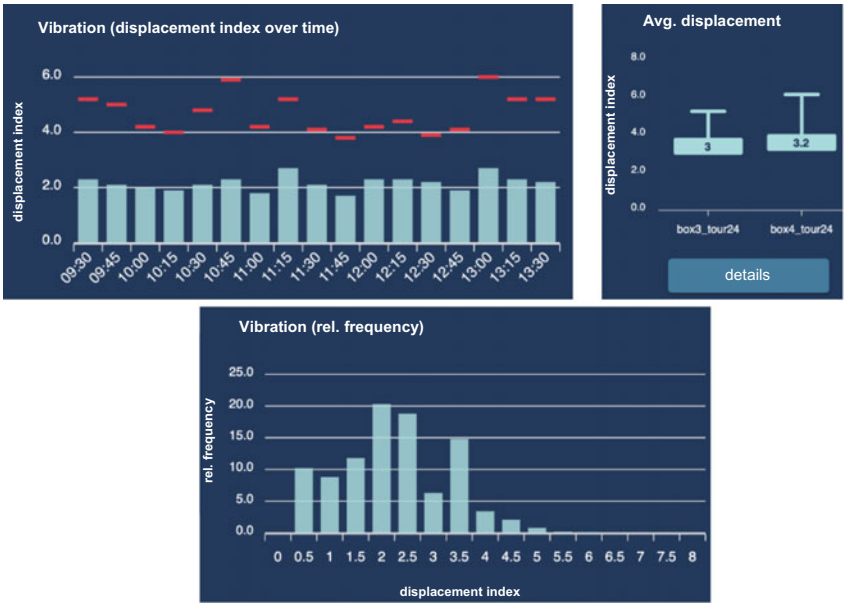

Fig. 9 Implemented diagrams to display the vibration as displacement. Top Left: A bar chart was extended with horizontal lines above the bars to show the maxima. Top right: A modified box plot to show max and average displacement. Bottom: A histogram to show the relative frequencies of displacement

and status) is shown (see chapter "A Study of the Potential of Online Learning of Kasetsart University Faculty Members").

Using a map view, the current locations of the delivery vehicles are shown. It can be filtered by recipients. For the remaining use cases: display of the entire shipping history, display of the handover details as well as the retrospective analysis of the measured impact factors, there have been implemented screens as well.

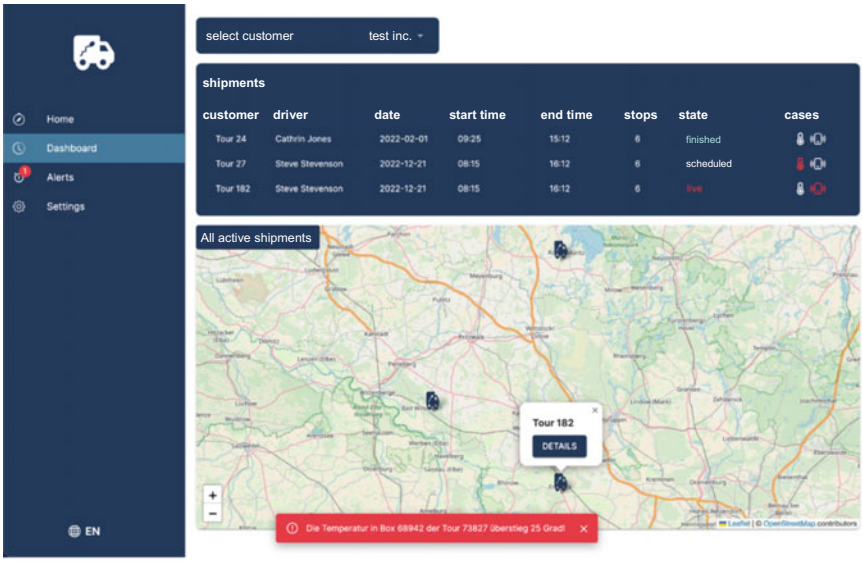

Fig. 10 Implemented dashboard

7 Conclusion and Future Work

With the developed dashboard, it is possible to manage and monitor the transport of insemination doses of pigs as fragile goods and to ensure that the product arrives undamaged at the customer site. It is possible to detect problematic situations during the shipment and prevent possible damage to the transported product by intervening at an early stage. For the dispatchers as the main users of the dashboard, all essential requirements (respectively use cases) could be implemented. It is possible to display all scheduled, current, and future shipments with all relevant information in a structured way. For each completed shipment, the entire transport history with all essential information can be accessed. As further information, the handover details can be reviewed as well. For a retrospective data analysis, all relevant impact factors—in this case for boar semen—are clearly presented. For this purpose, specific diagram types based on the recommendations of the "International Business Communication Standards" (IBCS) were developed [10].

Next work will focus on the development of further functionalities to support artificial insemination centers. It is planned to automatically create optimized and low-vibration delivery routes, taking into account customer requirements (e.g., on-time delivery). In addition, typical functions of a logistics system (e.g., digital cargo lists, delivery bills, and performance analysis) are planned to be implemented.

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Implementation of an ERP System for the Improvement of the Logistics Process in an SME

Nayely Reyes-Abanto, Jenifer Medina-Perez, Joselyn Zapata-Paulini, and Michael Cabanillas-Carbonell

Abstract It is known that to achieve greater productivity and profitability, it is necessary to understand the company's processes and know how to satisfy the needs of internal and external clients. ERP allows either small or large companies to improve their internal processes, leading to innovation and making it possible, for the most part, to improve their enterprise resource planning. The present research aims to determine the influence of the implementation of an ERP system in the improvement of the logistics process of a boutique. The methodology used for the development of the ERP was Spring. To measure the proposed indicators, 20 procurement operations were used; obtaining as a result that, in the pre-test, the purchasing time indicator obtained a mean value of 163.4 and in the satisfaction indicator of those in charge of procurement, a mean value of 1.80 was obtained. After this and with the implementation of the system, we proceeded to perform the post-test, obtaining as a result for the purchasing time a mean value of 90.55, which represents a reduction of 45.6%, and for the satisfaction of those in charge of procurement a mean value of 4.55 was obtained, which represents an increase of 150%. Finally, it was possible to conclude that the implementation of an ERP significantly influences the improvement of the logistics process of an SME.

Keywords ERP · Productivity · Profitability · Logistical processing · Scrum methodology

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1 Introduction

Today's environment is characterized by globalization and a highly competitive environment for companies. Companies are increasingly interested in achieving and demonstrating strong operational performance through the tools at their disposal, including process control and management [1]. The implementation of process management has been revealed as perhaps the most effective business management tool for any type of organization, since it helps the company to obtain better economic results through a proper organization of information flows, better control and time reduction, to avoid rework or reprocessing [1, 2].

Globally, increased competition and the need to constantly adapt to changes have made business process management increasingly necessary, as organizations need to manage their processes and automate them faster [3]. In Peru, there is no standardization of the activities in the business process automation processes, which is useful to improve the orientation of efforts for the development of resources that facilitate the execution of each of the activities of the business process's automation process [4].

In that sense, enterprise resources planning (ERP) systems allow owners and managers of large or small companies to evaluate and improve their internal processes; in addition, it increases the percentage of innovation and technological adaptation of the SME, allowing better planning of business resources [5]. This results in the automation of processes, since it can replace manual processes, speed up execution processes and avoid possible human errors that could occur [6]. Likewise, a typical ERP system has a set of advantages associated with it: vertical extensions for various economic sectors, solid technical architecture, training, documentation, support during implementation, process design tools, etc. [7]. In recent years, different authors have argued that information technologies offer the necessary advantages for business success and are considered a strategic factor [8].

As a solution, it is proposed to design and implement an enterprise resource planning (ERP) system; this computer technology will undoubtedly help to integrate the different processes of the company, optimizing time and reducing costs, as well as having the information updated on time and without losses; it will also help to make decisions that will help to take advantage over others in its field and the power to continue growing. In this sense, the objective of this research work is to determine the influence of the implementation of an ERP system in the improvement of the logistic process of an SME.

This paper is structured as follows: Section 2 contains the bibliographic study. Section 3 details the methodology implemented and its development. Section 4, the results obtained from the indicators studied and the discussions derived from the analysis of the results. Finally, Sect. 5 presents the conclusions.

2 Bibliographic Study

An ERP is a set of management information systems that allows the integration of a company's operations, especially those that have to do with production, logistics, inventory, and costs, while allowing all users to share information and access it constantly [5]. Its purpose is to reduce response times in different situations of interaction with our customers, as well as the management of efficient information that allows decision-making and the reduction of costs of the operations carried out [9]. On the other hand, the implementation of an ERP system in an organization can be defined as the beginning of technological evolution and the continuation of the moment of integration of the system with the company, in all its departments [10].

Internationally, the major contribution of ERP systems is being seen for efficiency dimensions such as organizational effectiveness and inter-organizational efficiency [11]. In addition, regardless of the size of the company and its line of business, we can list the advantages of the use of ERP systems that, through management tools, such as reports, graphs, records, and financial controls optimize various processes and helps decision-making [10].

At the national level, it is important to select the type of ERP to be used and, above all, to be clear about the business processes, since the ERP system will be adapted according to this and the line of business. In addition, the interviewees indicated that the type of report provided by the system is 100% accurate, they can obtain the right information at the right time, mapping the processes from any point with only user access to the system since it automates and simplifies processes that are performed manually, improving operating time, productivity and increasing the competitiveness of the company [12].

3 Methodology

However, recent studies have shown that 92% of ERP projects do not end successfully. One reason for these failures corresponds to the lack of proper tool selection. That is why we consider that studying the ERP selection stage is of great importance for project follow-up [13].

3.1 Comparison of Agile Methodologies

In this research, we are working with the Scrum methodology, since after having made the comparison between the two methodologies (Table 1), it was concluded that Scrum is simpler and more flexible for the team and the project. In addition, there are certain tasks assigned to the developers, where control and monitoring must be carried out to achieve them efficiently and satisfactorily [14].

Table 1 Comparison of agile methodologies

	Scrum methodology	XP methodology
Definition	It defines a main event or Sprint that corresponds to a window of time where a usable version of the product (increment) is created. Each Sprint, as in rugby, is considered an independent project. Its maximum duration is one month	It seeks to guide small to medium-sized software development teams, between two and ten developers, in environments with imprecise or changing requirements. XP is based on five values: simplicity, communication, feedback, respect, and courage
Elements	Sprint planning meeting, daily scrum, sprint review	Planning game, small deliveries, simple design, metaphor, code standards
Roles	Analysts, developers, stakeholders	Analysts, developers, stakeholders

3.2 Research Design and Type

According to its approach, this research is considered quantitative, because through various measurement procedures we will focus on the study and analysis of the problematic reality. To carry out experiments and obtain contrasted explanations based on the hypothesis [15]. The present research is of pre-experimental design with pre-test and post-test design, since according to ref. [16], this design is for a single group whose degree of control is minimal. It is generally useful in reality as a first approach to the research problem. According to its purpose, this research is considered applied, because using applied strategies will be possible to achieve the proposed objectives, allowing us to provide solutions to problems that are in the development process [17], offering elements for technological applications or decision-making.

3.3 Population and Sample

According to Ref. [18], the population is defined, limited, and accessible. For the present investigation, the population will be 20 purchases made between November 2021 and May 2022, at the "Unika" boutique located in Trujillo, department of La Libertad, Peru.

The sample is a representative and finite subset that is drawn from the accessible population [19]. For the present investigation, the sample will be made up of the 20 purchasing operations identified in the population.

3.4 Data Collection Instruments

In this research, direct observation was used to examine the processes involved in the purchasing process, and then to measure the time it takes to perform each operation. An interview was also elaborated on considering four questions referring to the satisfaction after each purchase operation. After applying the instruments, we organized the information in an Excel document, which allowed us to determine employee satisfaction and the total time each operation was carried out. SPSS software version 27 was used for the analysis.

3.5 Methodology Development

Sprint 1. We proceeded to the login, being this the interface to access the system, having to enter with your username and password assigned by the system administrator (see Fig. 1a).

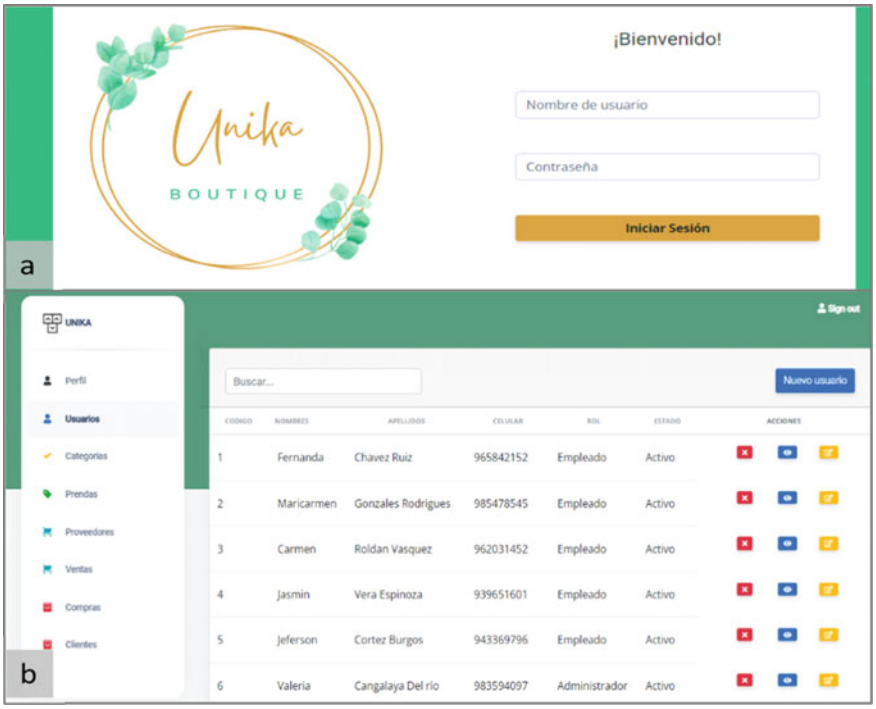

Fig. 1 Interfaces developed in Sprint 1

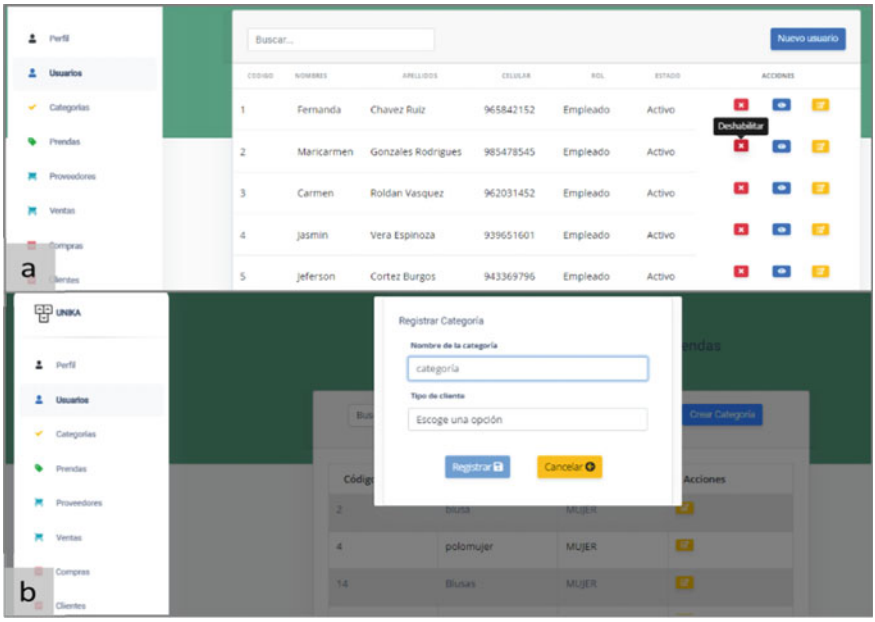

Fig. 2 Interfaces developed in Sprint 2

Manage Users. As shown in Fig. 1b, this interface has the function of maintaining the users (add, edit, disable, enable and view data) and completing the data requested by the system. In the user tray at the top, there is an add user button.

Sprint 2. The actions disable and enable user were developed. The tray shows an enable and disable user action that, when the button is clicked, is green when disabled and red when enabled (see Fig. 2a). *Manage garment categories.* Figure 2b shows the interface that provides category maintenance (add, edit).

Sprint 3. Actions for the garment administration interface were developed. In this section, the categories can be maintained (add, edit, register size) by completing the data requested by the system. In the upper part of the garment tray, the modal for adding garments is shown, see Fig. 3.

Sprint 4. We proceeded to develop the actions for the supplier administrator interface (see Fig. 4a). In this section, suppliers are maintained (add, edit, enable and disable) by completing the data requested by the system. In the supplier's tray, in the upper part, there is an add supplier button where, through a modal, the information is added (see Fig. 4b). The tray shows the action of enabling and disabling the supplier, showing green when it is disabled.

Sprint 5. The actions for the sales administration interface were developed. In this section, sales are maintained (add) by completing the data requested by the system (Fig. 5a). In the sales tray, in the upper part an add sales button is displayed, showing

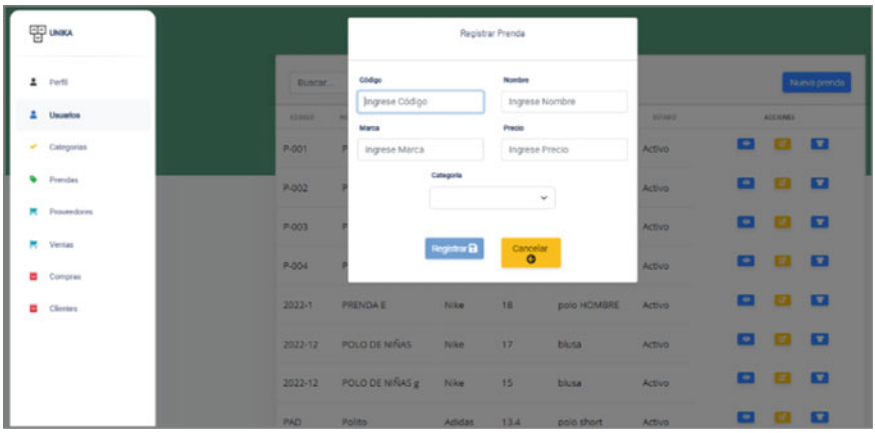

Fig. 3 Interfaces developed in Sprint 3

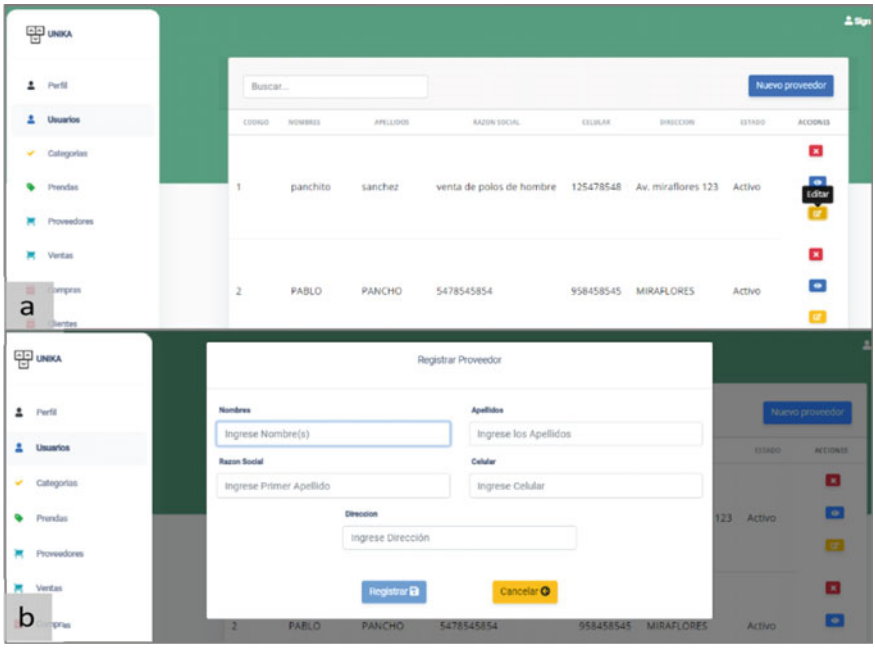

Fig. 4 Interfaces developed in Sprint 4

a modal to add the information (see Fig. 5b). After entering the voucher, the customer and the payment method, the added detail button is enabled.

Sprint 6. The actions for the purchase administration interface were developed (see Fig. 6a). In this section, it will be possible to maintain purchases (add, and export

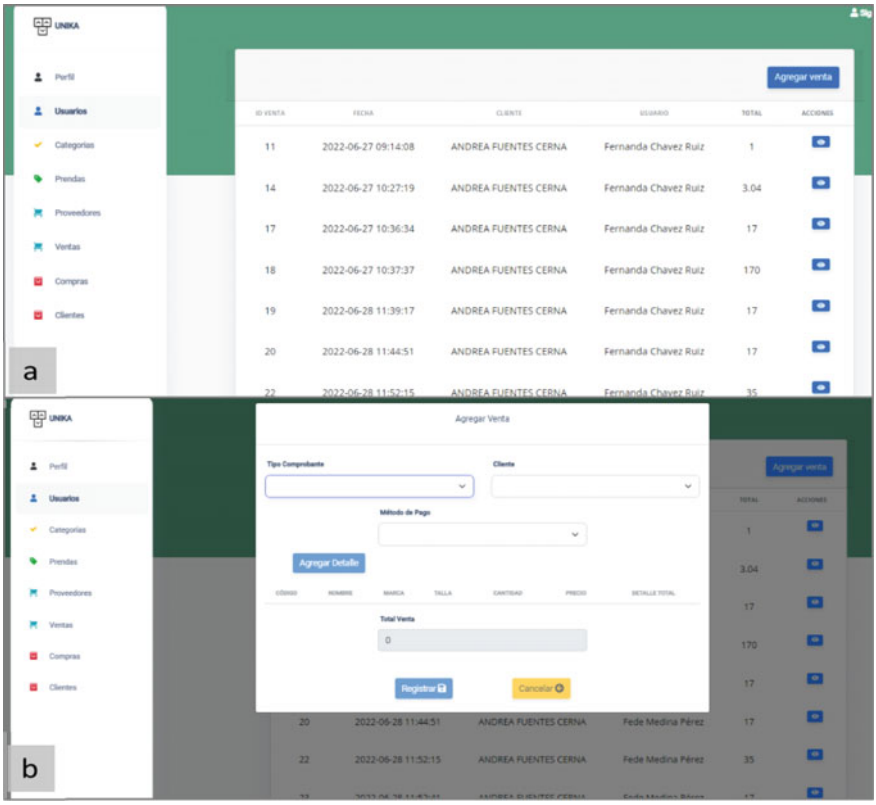

Fig. 5 Interfaces developed in Sprint 5

Excel), completing the data requested by the system. In the purchases tray, in the upper part there is a button to add purchases showing a modal to add the information (see Fig. 6b). After entering the voucher, the voucher number and the supplier, the added detail button is enabled.

Sprint 7. We proceeded to develop the actions for the client administration interface (see Fig. 7). In this section, customers are maintained (add) by completing the data requested by the system. In the customer tray at the top, there is an add customer button showing a modal to add the information.

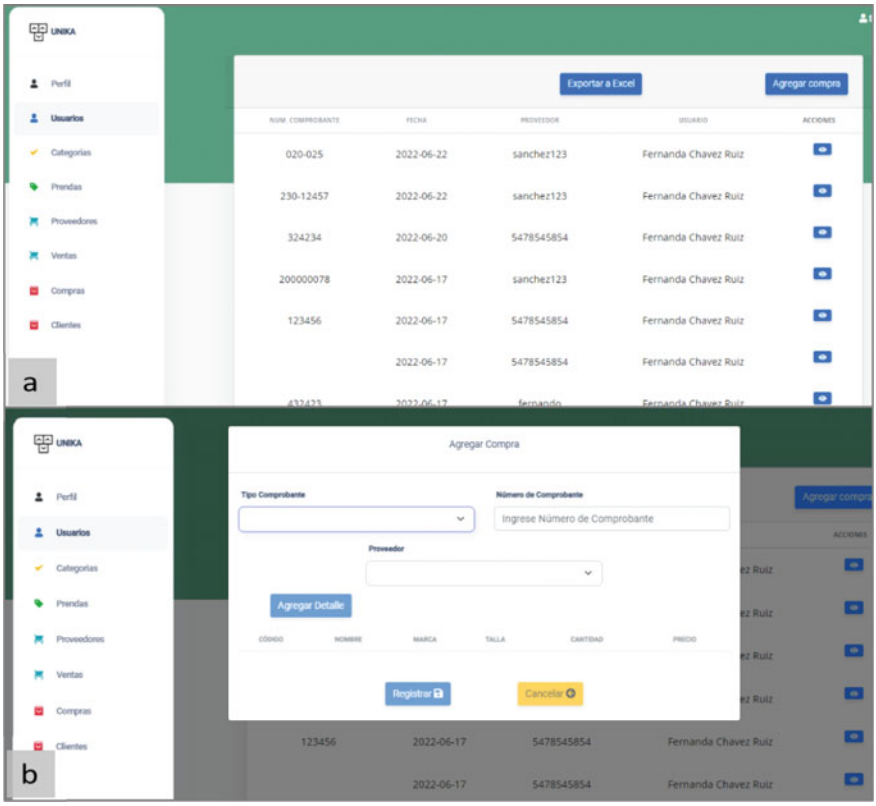

Fig. 6 Interfaces developed in Sprint 6

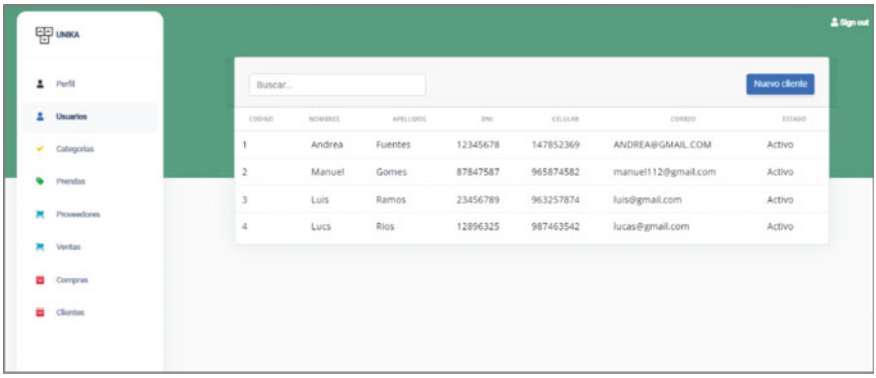

Fig. 7 Interfaces developed in Sprint 7

Fig. 8 Mean of the pre-test and post-test of the time to purchase indicator

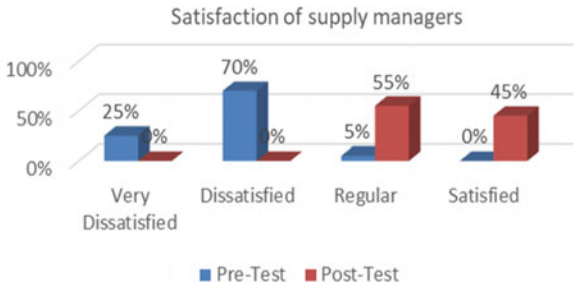

Fig. 9 Percentages of satisfaction of procurement managers

4 Results and Discussion

4.1 Descriptive Analysis

Indicator 1—Purchasing time: According to the results shown in Fig. 8, concerning the dimension of time spent shopping, it can be seen that in the pre-test a mean value of 163.4 was obtained, and in the post-test of 90.55, with these results we can see a reduction of 45.6% in the time spent shopping.

Indicator 2—Satisfaction of supply managers: According to the results obtained, concerning the dimension of provisioning by the satisfaction of provisioning managers, it was found that in the pre-test the mean was 1.8 and in the post-test it was 4.5, with these results an increase of 150% can be seen. Concerning Fig. 9, it can be seen that in the pre-test 25% of the respondents rated as very dissatisfied, 70% as dissatisfied and 5% rated as average. As for the post-test, 55% of respondents rated themselves as satisfied and 45% were very satisfied.

5 Conclusions

Nowadays, SMEs have been forced to develop new strategies that allow them to grow and reach more users. These circumstances led to the objective of this research work, which was to determine the influence of the implementation of an ERP system on the improvement of the logistics process of an SME, based on the "Unika" boutique.

The indicators used were purchasing time and the satisfaction of the employees in charge of procurement.

From the data obtained, it can be inferred that for the post-test of the com-purchase time a mean value of 90.55 was obtained, which represents a reduction of 45.6%, and for the satisfaction of the procurement managers a mean of 4.55 was obtained, which represents an increase of 150%. It is concluded that the ERP system has a positive influence on the purchasing time of the "Unika" boutique, since it allowed a reduction of the purchasing time, thus achieving the objectives expected in this research. In addition, it is concluded that the ERP system has a positive influence on the satisfaction of those in charge of supplying the "Unika" store, since it allowed an increase in the degree of satisfaction, thus achieving the objectives specified in this research.

We hope that it will be of great help to small and medium-sized companies in the clothing sales sector, to obtain knowledge as well as a guide for the implementation and start-up of an ERP system and free software, and obtain benefits without making a costly investment.

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How Can Blockchain Technology Be Used to Manage the COVID-19 Vaccine Supply Chain? A Systematic Literature Review and Future Research Directions

Huwida Said, Nedaa Baker Al Barghuthi, Sulafa Badi, and Shini Girija

Abstract To ensure the success of the COVID-19 vaccination program, vaccine supply networks must become more efficient, secure, and dependable. This paper provides a systematic literature review of current academic work on blockchain-based COVID-19 supply chain management (CVSCM), addressing the role of blockchain in CVSCM and its challenges. The paper's objectives are to comprehensively analyze the literature on blockchain solutions in the CVSCM and propose a future research agenda based on gaps in the present literature. The systematic literature review involved 34 peer-reviewed journal and conference publications published between 2019 and 2022. Using a thematic analysis, we observed that the public blockchain is the most often-used blockchain platform for constructing the CVSCM frameworks. The supply chain data privacy and security are major driving factors. Blockchain technology significantly affects CVSCM by allowing for distributed transaction execution and verification. Blockchain technology enables traceability, digitalization, disintermediation of the supply chain, and enhanced data privacy. However, several challenges were identified, including privacy worries, excessive energy consumption, latency, transactional throughput, and scalability. Our results provide the groundwork for future research aimed at increasing technical integration in blockchain supply chain solutions, cross-chain interoperability, and scalability, the feasibility of commercial applications in real-world industrial settings, data security, and privacy.

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Future research might also closely monitor emerging technologies in CVSCM, such as edge computing, virtual reality, machine learning, artificial intelligence, and blockchain advancements, and provide more impartial support to the many research potentials discussed.

Keywords Blockchain · COVID-19 · Supply chain management · Traceability · Transparency · Digitization

1 Introduction

The severe acute respiratory syndrome coronavirus two outbreak, often known as the COVID-19 pandemic, has been unfolding over the globe for more than two years. The first case of the new virus was discovered in December 2019 in Wuhan, China. Despite efforts to stop it, the virus quickly spreads throughout the rest of China and beyond. On January 30, 2020, the WHO designated the outbreak a public health emergency of worldwide concern, and on March 11, 2020, it was officially labeled a pandemic. Over 6.54 million people have died from the epidemic since September 29, 2022, making it one of the worst in recorded history. The COVID-19 vaccination trials are designed to offer acquired immunity against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which resulted in many deaths. Before the COVID-19 pandemic, scientists understood the structure and function of coronaviruses like SARS and MERS (MERS). This insight facilitated vaccine platform development in 2020. SARS-CoV-2 vaccines initially targeted symptomatic and severe illnesses. On January 10, 2020, the Global Initiative on Sharing Avian Influenza Data (GISAID) revealed the SARS-CoV-2 genetic sequence data. By March 19, the global pharmaceutical sector had committed to addressing COVID-19 through the rapid development of vaccines. Vaccinations have reduced disease severity and fatality; by late December 2021, nearly 4.49 billion people in 197 nations had received one or more vaccine doses. The COVID-19 Immunizations Global Access (COVAX) aims to increase equity, boost transparency, and expedite access to low-cost COVID-19 vaccinations for all countries, particularly those in Africa and Asia [1]. However, COVAX has had problems acquiring significant doses of the COVID-19 vaccine on schedule because of the intense competition among high-income countries for the limited supply of licensed vaccines and the refusal of pharmaceutical firms to share their findings [2]. The intellectual property rights of COVID-19 vaccines are owned by pharmaceutical firms, allowing them to set the price, production volume, and distribution channels for these products. Predicting shortages, rerouting shipments, and keeping tabs on immunizations all need better supply chain planning [2, 3]. Recent research studies have argued that transparency, immutability, auditability, and trust are missing in COVID-19 vaccination supply chain management (CVSCM) platforms [1]. These supply chain systems are also more susceptible to a single point of failure because of their centralization [4]. These restrictions reduce the openness and safety of the COVID-19 immunization delivery system [2]. Against these

pressing supply chain issues, blockchain technology presents a promising technological solution for CVSCM during a great disruption in the pharmaceutical and logistics sectors associated with the COVID-19 vaccines. Blockchain, an immutable digital ledger of transactions, may offer a trustworthy record of COVID-19 vaccine components and completed immunizations [4]. Information stored in a blockchain is immutable since it is a distributed digital ledger [3]. Network nodes or peers link the blocks in chronological order, with each block containing the preceding block's hash to create a chain of information-carrying blocks. When all participating nodes agree on newly produced blocks, such as contact-tracing events, blockchain uses consensus methods. However, the overall state of the chain may be agreed upon by nodes that are not trustworthy [5]. Smart contracts are blockchain-based programs that carry out their terms once deployed. Without a governing body, legal framework, or external mechanism for enforcement, smart contracts allow unidentified participants to engage in legally binding activities and contracts [6]. Indeed, the use of blockchain technology to better manage the COVID-19 vaccine supply chain has been the subject of several studies [2, 4–7]. Vaccine distribution and monitoring during the ongoing COVID-19 pandemic have been investigated by [2] utilizing a cloud-assisted IoMT-enabled blockchain strategy. The "DistVAC-COVID" architecture, developed by [4] and implemented in Bangladesh, provides a blockchain-based SDN-IoT platform for delivering COVID-19 vaccinations. SDN-IoT enables distributed ledger network administration in tandem with other connected devices. Conceptual frameworks were proposed by [4–6] for blockchain-based vaccination management systems that used IoT to enhance CVSCM. Ethereum blockchain technology was one of the popular to develop a prototype [7]. Hence, various studies have attempted to identify blockchain processes and procedures in CVSCM, and each of these studies discusses a different set of sociocultural, technological, and operational processes and activities. However, an integrative view of how blockchain technology is used in CVSCM lacks clarity. To synthesize existing studies, this paper sought to conduct a systematic literature review to assess the state-of-the-art blockchain technology in CVSCM research and provide a foundation for further research. Unlike previous CVSCM-related review publications (e.g., [1, 8]), our study focuses on the variables driving blockchain adoption in CVSCM and the areas where this novel technology may be most advantageous for the supply chain management. Hence, the main study question that underpins the study are

- RQ1: How many blockchain technologies be used to manage the COVID-19 vaccine supply chain?
- RQ2: What are the challenges of blockchain use in CVSCM?
- RQ3: What are the knowledge gaps in CVSCM, and what are the future research priorities for blockchain technology?

This paper progresses as follows: The next section describes the systematic literature review methodology adopted. Following this, we will provide a detailed analysis of the relevant literature and the essential findings in Sect. 3. Finally, we discuss the study's findings, limitations, and potential future research directions.

2 Methodology

Guidelines for Preferred Reporting Items for Systematic Reviews (PRISMA) and Moher's guidance [9] (2009) are two techniques used for systematic review. The study adopted the PRISMA approach, an international standard methodology that uses some specifications to upgrade the completeness of the review progression from different viewpoints [9]. PRISMA promotes high reproducibility and integrity in technique and analysis. Therefore, it is widely used to assess academic work published in the field. PRISMA has a four-stage flowchart describing the scope of review, examination, eligibility, and inclusion [10]. A comprehensive systematic literature review (SLR) is a recognized and planned research question practice. According to Garousi and Mäntylä [11], SLRs are effective in advancing knowledge and understanding because they involve a thought-out, systematic method for gathering information that provides an answer to a particular issue most impartially and accurately possible. In practice, the systematic review includes paper section criteria, search plans, data extraction, and analysis techniques. Figure 1 illustrates the SRL protocol stages.

The paper's primary focus is the COVID-19 vaccine supply chain management topic. However, it also discusses vaccine manufacturing, distribution mechanisms, and recording registration procedures. In addition, the research includes sub-areas such as blockchain architecture, implementation types, functions, and industry focus. Section 3 addresses the research's systematic thematic analysis and discussion.

Our research is based on compact analysis using the Web of Science (WoS), Scopus databases, IEEE, and direct search engines by setting a time limit from 2020 to 2022. The search included specific query keywords (TS = "COVID-19" or TS = "supply chain" AND TS = "blockchain"). The search extracted 64 papers. They screened for inclusion and exclusion in the systematic literature review on the supply chain management of the COVID-19 vaccine area. Most of the research papers were published during the emergence of the COVID-19 pandemic. To produce a high-level literature review, it is necessary to incorporate reasons whenever an article is included or excluded [10]. Based on these criteria, the search yielded a total of 64 articles. During the identification stage, the research produced 13 Scopus indexed, five in the Web of Science, 13 ScienceDirect database-listed papers, and 33 articles from the IEEE index database. After the inclusion and eligibility criteria were applied, the papers were reduced to 34 documents. Furthermore, the filtered research papers were selected for the systematic literature review.

The representation coding consists of different criteria: geographic location, focus, methodology, objective, outcomes, and future research categories. In addition, the schema covers emerging topics, taxonomy, blockchain platform types, actors, integration of other technologies, supply chain workflows, stored/exchanged data, the value of blockchain adoption, and approaches to blockchain challenges. These topics were chosen to be part of the paper analysis criteria. The summaries did not show the diversity, depth of purpose, and findings of the themes, which were very diverse

Fig. 1 Protocol for the systematic review

and inclusive. However, the summaries include a synthesis that lists critical articles, knowledge background, and other potential study prospects. Furthermore, the remaining topics enabled a useful abstraction of the papers' initial contributions, and the study continued on the themes mentioned.

3 Thematic Analysis

The three research questions—RQ1, RQ2, and RQ3—are used to structure the thematic analysis. The primary components emphasized are the research objective, categorization, blockchain platform types, supply chain stakeholders, type of stored data, need for blockchain adoption, capabilities exploited, methods to solve security problems, and contribution to knowledge. Each of these ideas is thoroughly explained in the sections that follow. The classification theme highlights the several parts of CVSCM, such as administering and storing COVID-19 vaccines, registration and management, reporting, and vaccine certificates and immunization passports. The CVSCM workflow mechanism and the responsibilities of various stakeholders are explicit. The shortcomings of the current approaches, the necessity of implementing blockchain, new blockchain capabilities, their downsides, and overall contribution are also covered.

RQ1: How may blockchain technology be used to manage the COVID-19 vaccine supply chain?

COVID-19 supply chain management challenges

According to the reviewed literature, the COVID-19 pandemic has impacted several supply chain activities globally, including causing an increase in demand for a wide range of products and services [8]. The supply chain is under additional stress due to the rising demand for and the limited supply of vaccines [12]. Additionally, the quality and availability of vaccinations to the general populace impact their efficacy [13]. Supply chain resilience is essential to ensure effective vaccination delivery and distribution in the face of disruptions. Based on the reviewed literature, we divided the significant hurdles the CVSCM encountered into five categories: physical constraints, communication difficulties, security issues, privacy concerns, and performance issues (see Table 1).

- **Physical constraints** include issues with the vaccine supply chain's physical and organizational structure. Government policies, vaccine tampering, the challenge of maintaining the right temperature for various kinds of vaccines, the limited availability of raw ingredients, the error-prone centralized database, the lack of storage, and scalability are a few of these [3, 5, 14–19].
- **Communication difficulties**: The engagement of several stakeholders and a lack of communication among them are the leading causes of communication problems. Additionally, improper distributor planning and a lack of public knowledge of the vaccines' effectiveness can impair the supply chain's ability to operate efficiently [1, 3, 20, 21].
- **Security issues** mainly occur due to the presence of sensitive information. Third parties may engage adversaries and cyberattacks to access the vaccine supply chain. Other security issues include resilience, transparency, traceability, and auditing [8, 17, 22–26].

Table 1 Main challenges faced by the COVID-19 vaccine supply chain

Categories	Challenges	References
Physical constraints	Enormous transaction data	[3, 5, 14, 15]
	Limited availability of raw materials	[3]
	Lack of manufacturing capacity	[3]
	Centralized architecture	[15, 17–19]
	Drug counterfeiting	[18, 19, 28]
	Scalability issues	[1]
Communication difficulties	Lack of public awareness	[1]
	Miscommunication between stakeholders	[3]
	disruption in planning	[3, 20, 21]
Security issues	Cyberattacks	[3]
	Transparency, auditing, and traceability issues	[8, 17, 22–26]
	Resilience	[29]
Privacy issues	Sabotage sensitive data	[22, 27]
Performance Issues	High energy consumption	[1]
	Mishandling	[3]
	Lack of digitization	[3, 28]
	High latency	[22, 27]

- **Privacy concerns**: Due to intermediaries attempting to sabotage sensitive data and falsifying vaccination records and passports for immunity, privacy concerns are frequently raised in the vaccine supply chain. Another significant privacy risk is the lack of trust among supply chain parties [22, 27].
- **Performance issues** reveal the effectiveness of the workflow in the vaccine supply chain. The efficacy of the vaccination supply chain can be impacted by excessive energy consumption, improper handling of transactional data, high transaction latency, and a lack of digitization [3, 22, 27, 28].

When the categories of challenges encountered by the CVSCM are examined, it becomes clear that the security and privacy of supply chain data and the difficulty associated with maintaining the ideal temperature for various vaccine vials are the most significant issues. Traceability, transparency, resilience, and auditing are security concerns that must be addressed for the COVID-19 vaccine supply chain to operate without hiccups. Additionally, a distributed architecture is necessary to prevent single points of failure.

A. Values of blockchain adoption

According to the literature, the COVID-19 vaccine supply chain is a vulnerable system that monitors, traces, transports, distributes, reports, and administers vaccine vials [3, 28]. Supply chain actors may be able to solve many of their issues with the usage of blockchain technology in the supply chain for the COVID-19 vaccine

[3, 28]. Listed below are some of the supply chain's numerous components where blockchain can be applied to improve the COVID-19 vaccine program's effectiveness (see Table 2).

- **COVID-19 vaccine storage and distribution**: Vaccine tampering can be avoided using blockchain technology as a proof of delivery chain [8]. Blockchain technology can make vaccine storage and delivery conditions transparent, traceable, and auditable. Intelligent contracts can impose supply chain traceability, ensuring the cold chain for vaccinations that must be kept at low temperatures. For instance, the Moderna vaccine must only be maintained between −25 and −15 °C [17]. Contrarily, the Pfizer vaccination must be stored under controlled conditions and kept at a shallow temperature (between −80 and −60 °C) [30]. The blockchain should securely record any infractions of the delivery terms and conditions. All stakeholders can voice their ideas because blockchain platforms are distributed.
- **COVID-19 vaccine registration and administration**: Sensitive personal information on the vaccine waiting list should be immutable to avoid impersonation. Vaccines can be traded as digital assets between unrelated parties due to the decentralized nature of blockchain. The immutability of transactions is a feature that smart contracts can offer, preventing intermediaries from obtaining access to private information [22].
- **Reporting and vaccine immunity passports/certificates**: It is essential to communicate vaccine effectiveness to the public to foster trust and prevent fear of side effects. The immutable public reporting offered by blockchain technology can help with this. People who have been vaccinated can utilize a blockchain-enabled website to report any adverse reactions or concerns they may have. Transparent and irrevocable data sharing with other participants will protect vaccines from interference. For traveling abroad, some nations now require vaccination records or immunity passports [22, 31, 32]. However, they face significant problems with counterfeit visas and certificates. By integrating certificates and immunity passports into blockchain-based systems, these issues can be avoided, and worldwide data availability can be attained. Intelligent contracts can guarantee the immutability and transparency of these certificates and passports [22, 31, 32] (Table 2).

B. Blockchain platform types

After conducting a thematic analysis, we found that the public blockchain is the most frequently used blockchain platform for creating the CVSCM framework. Contrarily, to safeguard sensitive data and guarantee security and privacy characteristics, real-world implementation frameworks have mainly depended on private permissioned blockchain networks. It indicates a study deficit in hybrid platform objective research. An extensive chain of tamper-proof information on the management of vaccines at every stage, from production through final delivery to the certificate bearer, may be recorded and made available by the system due to public blockchain characteristics defined by [7]. To further reduce complexity and processing costs while

Table 2 Added values of blockchain adoption

Aspects of supply chain	Role of blockchain	References
COVID-19 vaccine storage and distribution	Providing transparency, traceability, and proper auditing	[3, 5, 6]
	Preventing vaccine tampering	[2, 33]
	Maintaining optimal temperature	[30]
COVID-19 vaccine registration and administration	Transaction immutability	[22]
	Preventing intermediaries from gaining sensitive data	[12, 17, 23]
	Facilitating the smooth exchange of vaccine transaction data	[17, 34]
Reporting and vaccine immunity Passports/Certificates	Immutable public reporting	[31]
	Data availability from a global perspective	[18, 26]
	Immunity passports are immutable and transparent	[15, 32, 35]

safely distributing the vaccinations to providers, Rahman et al. [4] devised a three-level distribution architecture that divides the entities into various tiers. They also employed a private blockchain network. Das [2] developed a blockchain-based cloud-assisted secure vaccine distribution and tracking method using a hybrid blockchain platform. Hybrid systems [2] can offer better data privacy, security safeguards, and efficient energy consumption than public and private blockchain solutions [4, 7].

C. Stakeholders involved in the COVID-19 vaccine supply chain

The COVID-19 vaccine supply chain is responsible for large-scale production and distribution to several nations and regions, from the producer to last-mile delivery. The process is performed by several actors, each of whom has a specific role. Based on the analyzed research papers, the pie chart in Fig. 2 illustrates how stakeholders generally participate in the supply chain. The key pieces most frequently refer to hospitals, citizens, vaccine distributors, manufacturers, and suppliers. A noteworthy strength in the literature reviewed is the explicit acknowledgment of actors' engagement in three-quarters of the study studies. A few articles [24, 26, 32] stated that most government officials (the national health authority, customs, and a membership service provider) should be considered stakeholders. Governments frequently enact fast regulations to quell public outrage or counter false information about the adverse consequences of vaccinations [32]. However, this rapid response by governments created problems, including widespread public vaccine anxiety (which could prevent vaccination rates from being high enough to develop natural immunity), had several deadly impacts, and obstructed the smooth running of the COVID-19 vaccine supply chain. However, a lack of communication between these stakeholders is one of the most critical problems in the supply chain [4, 7].

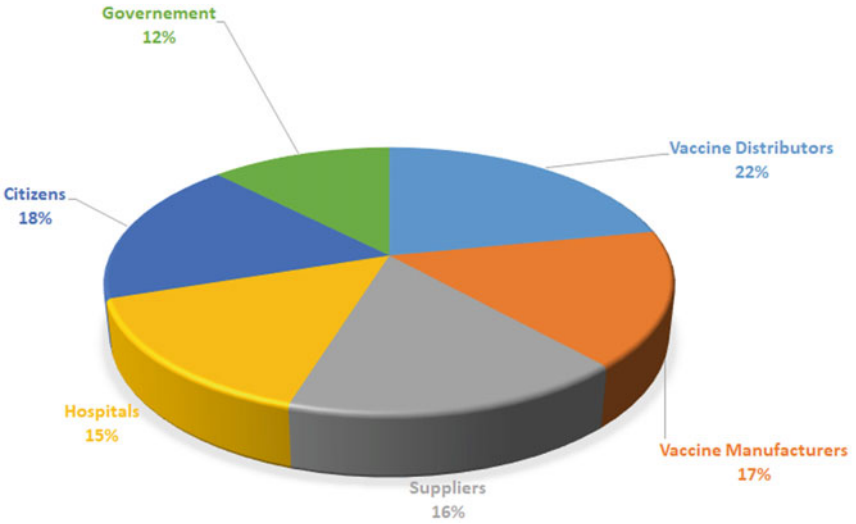

Fig. 2 Stakeholders involved in blockchain-based COVID-19 supply chain management platforms

D. **Blockchain-based COVID-19 vaccine supply chain workflow**

All 34 studies that have been analyzed have a comparable supply workflow for the COVID-19 vaccination supply chain. Figure 3: Standard COVID-19 vaccine supply chain workflow illustrates major CVSCM system components, key process participants, and key working relationships that blockchain can manage. It includes vaccine production, distribution, administration, cold storage, and vaccination certificate generation. The vaccine manufacturer can build smart contracts, and all parties involved in the supply chain could sign up on the blockchain-enabled platform with their responsibilities. Creating the COVID-19 vaccine will start with transferring raw materials from the supplier to the manufacturer. Distributors will then use chilled trucks to deliver the intelligent containers to the vaccination center. In the end, the beneficiaries receive their vaccinations.

Nithin [17] split the supply chain into two sub-supply chains: the intra-country supply chain and the inter-country supply chain. Together with the international

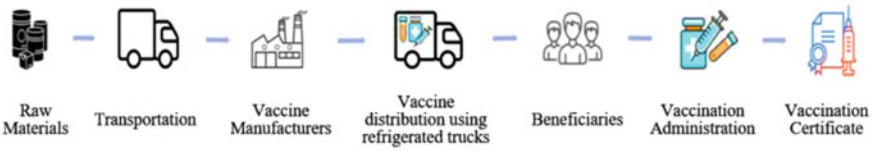

Fig. 3 Standard COVID-19 vaccine supply chain workflow

supply chain, which is in charge of regulating the distribution of vaccines within a nation, the global drug control agency checks vaccinations around the globe. This innovative approach guarantees universal access to vaccine information and transparency. Gao et al. [31] discussed the function of an immunity passport in the vaccination supply chain. This data is recorded in a blockchain and is encrypted. Customs can verify a traveler's vaccination status using the user's key to decode the immunity passport. Table 3 presents the blockchain technology used in implementing the supply chain workflow papers.

Most of the examined papers clearly explain the importance of smart contracts. The blockchain maintains sensitive vaccination information about individual patients by establishing specific conditions among the stakeholders in CVSCM. This issue can be resolved by adding a smart contract to the blockchain. The blockchain ensures that the agreements are protected by encryption and that only users authorized to read these entries can do so. The stakeholders can only reach an agreement once certain conditions are satisfied. Moving on to the next level of CVSCM is difficult if the smart contract has not yet begun to work independently at some point. The detailed workflow of a blockchain-based CVSCM is shown in Fig. 4.

E. Data stored/exchanged in the COVID-19 vaccine supply chain

The transactions most frequently documented in the CVSCM are vaccination order requests, distribution, side effects noting reports, and vaccination certificates/immunity passports. The transaction data covers the interactions between different system stakeholders and the movement of vaccines from producers to administrators via the supply chain. If there is a future contract violation, those records can be used to trace the terms and circumstances of delivery.

F. Theoretical and practical approaches of blockchain in COVID-19 vaccine supply chain management

Only one-third of the leading publications offer a real-world experimental evaluation that could help identify significant problems with implementing a blockchain platform for the COVID-19 vaccine supply chain (see Fig. 5). The remaining research papers featured theoretical frameworks or prototypes ready for implementation.

Table 3 Blockchain implementation in COVID-19 supply chain workflows

COVID-19 vaccine categories	Number of papers	Reviewed papers
Manufacturing	2	[28, 36]
Distribution	18	[1, 6–8, 13, 14, 17, 18, 20, 22–24, 27, 29–32, 34]
Storage	9	[6, 8, 12, 17, 20–24, 30]
Registration	4	[14, 20, 23, 34]
Side effects and reporting	5	[22, 30–32, 34]
Vaccination certificate/immunity passport	7	[19, 25, 27, 30–32, 35]

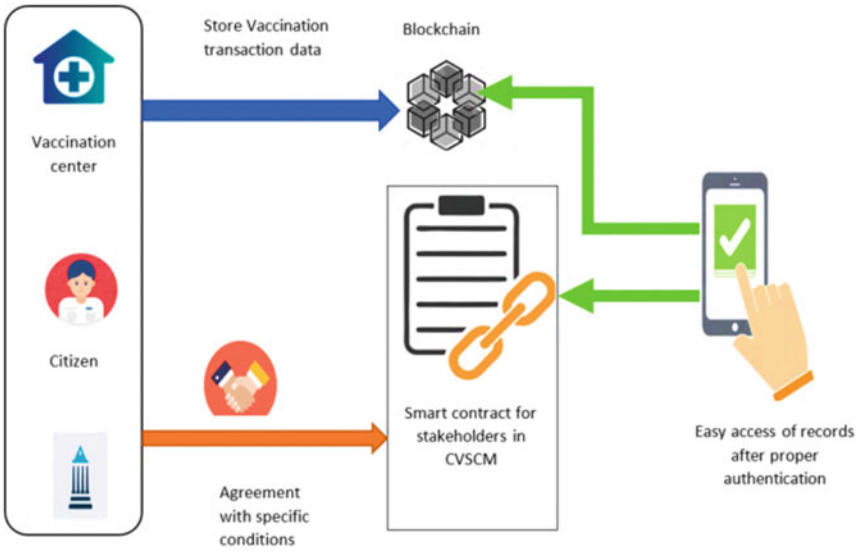

Fig. 4 Blockchain-based CVSCM workflow

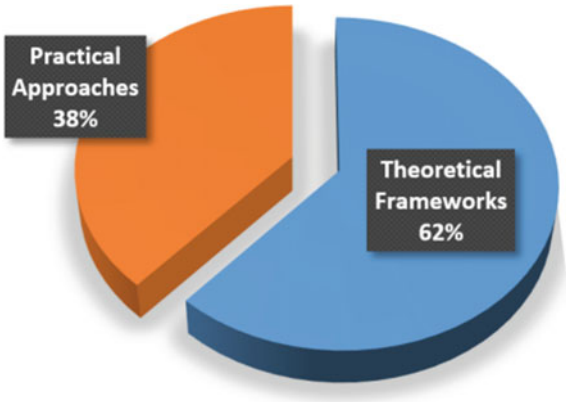

Fig. 5 Comparison of theoretical vs. practical reviewed papers

Theoretical approaches: For the COVID-19 vaccine distribution chain, Kamenivskyy [3] suggested a blockchain system that provides maximum information security and avoids vaccination fraud. The creation of a blockchain-enabled Internet of medical things (IoMT) model for vaccination distribution and the track was covered in several papers [2, 4, 6, 17, 22]. Utilizing the IoT makes it possible to prevent vaccine fraud and accurately track the cold chain for vaccines that need to be stored at specific temperatures. The IoMT connects all types of devices (medical or non-medical) in other health and public networks to facilitate capabilities and processes related to health. IoMT systems' security may be strengthened in different

ways. In addition, IoMT data privacy can be protected using blockchain technology's decentralization, immutability, and security features. A few articles have merged machine learning and a blockchain framework for demand forecasting [12, 23].

To address decentralized network transparency, security, and privacy issues, Rathee [6] created a distributed blockchain architecture known as DApp. DApp ensures the intelligent distribution of vaccines using a blockchain technique and artificial neural network (ANN) techniques. The ANN system provides a practical approach to managing healthcare information. This strategy has been successful compared to earlier methodologies concerning correct reporting and data change parameters. Khan [7] suggested a blockchain-based track-and-trace system to build certificate bearer trust and combat vaccination immunity certificate fraud.

Practical approaches*:* A reference layered architecture for vaccine registration, known as a taco chain, was proposed by [18]. It uses uncrewed aerial vehicles, 5G, and blockchain to help with large-scale vaccination distribution and registration for a sizeable population. The Ethereum-based implementation of the system created by [8] demonstrates the solution's viability regarding gas consumption and transaction throughput. The plan was developed as a decentralized innovative contract-based system for tracking vaccine transit conditions in a cold chain. A COVID-19 vaccination information traceability platform with a high-security QR code interface for managing government workflow was built by [13] using an Ethereum private blockchain. This platform can offer complete information regarding the manufacture and distribution of vaccines. A smartphone application for vaccine registration, stock management, and administration called Immunochain [24] provides a traceability option for India's immunization program.

Furthermore, the cold blockchain is another helpful method for keeping track of vaccine temperature and providing traceability from demand predictions to vaccination administration [34]. IoT sensors monitor supply chain temperature in this concept, conveying vaccine status, location, and current temperature data. A blockchain-based medical data-sharing architecture called Globechain [33] overcomes the technical problems associated with handling the leaking of vaccine records. Bangladesh's government is building a global chain to build a world network for exchanging vaccine information. *Vaccifi*, a blockchain-based COVID-19 vaccination passport proposed by [26], allows the relevant authority to validate an individual's immunization information anytime and from any location.

RQ2: What are the challenges of blockchain use in CVSCM?

Despite the benefits of using blockchain technology in CVSCM, it does face some challenges. We categorized the critical challenges of blockchain adoption into four categories: privacy concerns, physical constraints, security issues, and performance issues (see Table 4). Table 4 shows that the most prominent challenges of the blockchain-integrated COVID-19 vaccine supply chain are privacy issues, high gas consumption, vaccine efficiency, and scalability.

Table 4 Challenges associated with blockchain adoption for COVID-19 supply chain management

Categories of challenges	Challenges	Reviewed papers
Privacy concerns	Substantial risk of disclosure of sensitive information	[13, 15, 17, 22, 28, 32, 35–37]
Physical constraints	Cross-chain	[6]
	Bribing	[5]
	Scalability	[12, 14, 16, 19, 22]
Security issues	Adversary attacks	[2, 32]
Performance issues	Efficiency of vaccines	[4, 23, 30]
	High energy consumption	[14, 18, 22]
	High latency	[12]
	High transactional throughput	[12, 18]
	Communication overhead	[33]

A. **Privacy concerns** are the top challenge associated with the blockchain-enabled vaccine supply chain. They store transactional data related to vaccine distribution, personal information, and side effects reports. Intermediaries will try to leak this sensitive information for their benefit [32, 35].
B. **Physical constraints** describe problems related to cross-chain interaction, bribing, and scalability. Different blockchain types interact through cross-chain, which causes heterogeneity across nodes [6]. Scalability is a significant concern since the vaccine supply chain involves massive transactions of data and nodes, which is challenging to handle [22]. At every level of the vaccine value chain, there is a risk of corruption, including theft, partiality, discrimination, bribing, and disproportionate influence. The stakeholders in the supply chain involved in bribing affect the fair distribution of vaccines [5]. Even after all the transactions are recorded in the blockchain, influencing the stakeholders using bribing can affect the transparency of the vaccine supply chain [12, 14, 15, 19].
C. **Security issues** such as adversary attacks, in which third parties or attackers try to hack the sensitive information stored in the blockchain, are common [2, 32]. For example, in 2020, there was an incident where hackers started using phishing and spear-phishing attempts to access data regarding the cold chain distribution system for vaccines, including information on how the doses were distributed [18].
D. **Performance issues** such as high energy consumption, latency, and transactional throughput are critical since most blockchain frameworks cannot achieve the optimal values for these metrics [12, 18].

RQ3: What are the knowledge gaps in CVSCM, and what are the future research priorities for blockchain technology?

A. **Integrating advanced technologies in blockchain supply chain solutions**

Demand forecasting and extensive data analysis are improved with advanced technologies such as edge and artificial intelligence (AI) [2]. AI technologies and data science can solve many issues, such as data failure rate, distribution, security analysis, and suitable detection of desirable data [4, 20, 23]. On the other hand, to improve supply chain efficiency, virtual reality/augmented reality (VR/AR)-based approaches should also be implemented [8]. Implementing VR/AR could be advantageous for corporate customers who connect virtually among stakeholders and clients, especially during COVID-19 [38]. They can reduce the strains in the supply chain by facilitating interaction between suppliers, manufacturers, distributors, and wholesalers.

B. **Cross-chain, interoperability, and scalability**

Immunization information systems are platforms for tracking vaccination programs' effectiveness. The stakeholders in CVSCM can use them to make informed vaccination judgments and help communities better target vaccination campaigns for improved public health [39]. Hence, maintaining the time required by the ledger to verify each block in the future communication can further enhance the cross-chain [6]. Different consensus algorithms, such as proof-of-stake and proof-of-authority, could be used to improve the scalability of the supply chain [22]. For instance, big-data analysis on feedback can be accomplished to determine the efficiency of vaccination and establish an appropriate environment for storage [30]. Additionally, a pluggable consensus-independent mechanism can target inter-protocol transactions to achieve interoperability among blocks in the supply chain [31, 33].

C. **Assessing/Feasibility of commercial applications in real industrial settings**

Numerous research papers have pointed out the role of blockchain in handling security and privacy issues developed through the deployment of digital immunization certificates and verification processes in real-world scenarios [2, 32, 37]. There is a need to create one global system for cross-country vaccine passports with heterogeneous populations worldwide [35]. It has been challenging to enforce preventative measures in real-world scenarios. Therefore, the most security and privacy concerns relating to commercial applications can be resolved using blockchain infrastructures [2, 37]. The digital immunization certificate registration and verification procedure's security, privacy, and ethical aspects will be prioritized in real-world deployments [32]. Hence, the usage of blockchain may encounter some obstacles in real-life settings, necessitating the development of a flexible solution [20].

D. **Methods to enhance data security and privacy**

Various "on-chain" data encryption solutions are highly recommended to maintain data privacy. Thus, hybrid data storage and a public peer-to-peer network should

be implemented to maximize the chain's security [3]. Other encryption approaches, such as privacy-preserving searchable and attribute-based encryption, can provide data privacy [2]. In addition, to ensure that transactions between entities are only visible to supply chain stakeholders, [22] recommend using Quorum platforms that preserve data privacy. Quorum offers a permissioned implementation of blockchain that supports transactions and contract privacy [40]. Integrating quantum-based key distribution among communication entities ensures the security and privacy of communication among blockchain stakeholders [18]. Likewise, another method to enhance data security is a generalization process that combines a decentralized registry for cryptographic keys, allowing each public key to have a unique address referred to as a decentralized identifier [37].

4 Future Insights for Blockchain-Based CVSCM

The top three blockchain frameworks for CVSCM long-term use are Ethereum, Hyperledger, and R3 Corda [8]. The fact that all transactions are completed in real time, as opposed to other kinds of blockchains, is one of the main advantages of R3 Corda. By isolating transactions in channels or facilitating the exchange of private data in private data collections on a need-to-know basis, Hyperledger Fabric can enhance data privacy. According to its proponents, it also enables quick transactions with minimal finality and confirmation latency. The main advantage of Ethereum is that it supports smart contracts and offers real decentralization. These identified features play a major role in the proper functioning of CVSCM [7].

To enhance the process of transaction verification, blockchain-based CVSCM can be combined with a new consensus protocol based on game theory and machine learning algorithms. Additionally, in the future, any feedback provided by vaccine recipients can be recorded and can be used to facilitate vaccine recommendations based on age, gender, area, and immunogenic response using machine learning algorithms [41]. For business clients who virtually communicate with stakeholders and clients, notably during COVID-19, implementing VR/AR and AI technology may be useful to strengthen the blockchain-based system capability [38]. By encouraging communication among suppliers, manufacturers, distributors, and wholesalers, they can reduce the pressures in the supply chain. Additionally, CVSCM has room for improvement, which can be achieved by adding new technologies like IoT to the system [42]. It would enable the monitoring of numerous additional parameters, including temperature, humidity, physical condition, and other storage conditions. The system might also incorporate real-time GPS tracking, which would be particularly advantageous as it would further improve the system's traceability and transparency.

5 Conclusion

This study analyzed the existing literature to comprehend better how blockchain technology functions in CVSCM. Based on this in-depth analysis of the relevant literature, we have determined the critical drivers of blockchain adoption in CVSCM and the potential applications of this revolutionary technology in supply chain management. Although blockchain technologies are still in their infancy and are just beginning to be employed in managing the COVID-19 vaccine's supply chain, the examined research shows that the security and privacy of supply chain data are the key motivations pushing adoption. Blockchain technology was found to have a significant impact on CVSCM since it facilitates decentralized transaction execution and verification. By using blockchain technology in CVSCM, transparency and traceability can be achieved, as well as digitalization, disintermediation of the supply chain, and improved data privacy. However, more questions are raised than are resolved when blockchain technology is used to create distributed ledgers and smart contracts. Using existing literature, we found many challenges, including privacy concerns, high energy consumption, latency, transactional throughput, and scalability that may affect blockchains' societal and economic ramifications.

This article sheds light on the current trajectory of blockchain technology's use in CVSCM and offers directions for further studies. Future research should investigate the practicality of commercial applications in real-world industrial settings; data security and privacy; cross-chain interaction, scalability; and advanced technology integration in blockchain supply chain systems. Furthermore, future research may provide additional objective support for the numerous study pathways we have mentioned by keeping a close watch on emerging technologies such as machine learning, artificial intelligence, virtual reality, and blockchain advances in CVSCM. In addition, supply chain blocks may be made interoperable via a pluggable, consensus-agnostic method based on inter-protocol transactions. Data privacy in CVSCM requires the adoption of several on-chain data encryption techniques. When taken as a whole, CVSCM and the part played by blockchain technology is a relatively new field of study that offers many exciting avenues for investigation.

The findings of this study also have several managerial implications, as they may help health sector practitioners delve further into CVSCM blockchain features such as the security, privacy, and ethics of digital vaccination certificate registration and verification. This research details various challenges that might prevent the widespread use of blockchain technology despite its many benefits. Consequently, CVSCM experts may use these findings to determine how blockchain technology will be used in CVSCM. With the help of cutting-edge technologies such as machine learning and AI, CVSCM practitioners can improve demand forecasting and in-depth data analysis, accounting for the failure rate, distribution, security analysis, and appropriate detection of desirable data. This research highlights the absence of practical recommendations for incorporating blockchain in CVSCM, the need for an end-to-end perspective, cooperation with policymakers, and the enterprises involved in COVID-19 vaccine manufacturing and distribution.

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The Contribution of Robotic Process Automation (RPA) in Improving Energy Efficiency: Case Study

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Abstract Robotic Process Automation (RPA) is a computer technology that allows automating routine tasks, which are normally performed by people, automatically and simply, allowing companies to be more efficient in business processes. With technology embedded in almost every day-to-day process in a company, it's easy to see advances in computing and technology. In this context, it is important to seek knowledge and adequate measures to reduce expenses and live sustainably. Understanding the relationship between energy efficiency and the implementation of RPA technology can help to achieve the aforementioned goals. This work aims to identify the contribution of RPA implementation in improving energy efficiency. To achieve the objective of this investigation, a survey of RPA project times was carried out in an administrative department of a company. After this survey, a comparison was made before and after the implementation of the RPA, to verify if it was possible to obtain an improvement from the energy point of view. With the results of this work, it was possible to identify that, after the implementation of the RPA technology, a reduction in the volume of energy consumed in the order of 78% was achieved and that RPA also executes all processes in 40% of the time that the processes are executed manually. As a future work, it was suggested the creation of models with

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Key Performance Indicator (KPI's) that allow the quantitative/financial evaluation of the energy effects after the implementation of RPA technology in an organization.

Keywords Robotic process automation (RPA) · Energy efficiency · Project implementation · Sustainability

1 Introduction

Robotic Process Automation (RPA) aims to automate administrative processes by software robots (bots), repeating human tasks using a graphical user interface [1]. These types of robots allow the automation of various processes/works related to the BackOffice that were previously performed by people [2]. Not long ago, a lot of Robot Process Automation approaches were implemented and the RPA software market grew by 60% in 2018 [3]. However, RPA should relieve contributors of tedious work [4, 5].

Sustainability has garnered progressive general attention in many areas of interest. The World Commission on the Development of the Environment (WCED) has shown sustainable development as development that takes into account the needs of the present without blaming the ability of future generations to meet their own needs [6]. Sustainability has been used in structures that seek to reflect on social duties and environmental legislation. Sustainability reveals to companies a paradigm that stands out in negotiations based on social, environmental, and economic responsibilities. Since the term business sustainability emerged, more organizations have emerged that bring sustainability to their businesses, thus improving their economic, environmental, and social objectives [7–9]. Organizations that seek to be sustainable must focus their execution on three pillars: economic, social, and ecological [10–13]. In a special issue of governance and sustainability [14] they reinforce the value of the theme and reinforce the character of the word 'sustainability'.

Currently, most people and organizations have become almost entirely dependent on electrical energy. Energy efficiency is any activity that aims to improve the use of energy sources. It comprises the way in which an activity is performed using the least amount of energy possible. Remembering that saving energy is different from using it effectively. In addition, energy efficiency is the relationship between the amount of energy used in a process and that available for its realization. It is the ability to produce the same or better results using fewer resources [15, 16].

As part of the evolution of Information Technologies, RPA is a technology that is in great growth, and that is why discussions about how to adapt the concept of energy efficiency and a sustainable implementation of RPA become important. The combination of these concepts can be an important aspect to achieve better energy efficiency in an organization.

Next, the central research question underlying this investigation is formulated.

- ***How will the implementation of Robotic Process Automation contribute to an improvement in energy efficiency?***

This work aims to identify the contribution of Robotic Process Automation implementation in improving energy efficiency. In order to achieve the objective of this investigation, a survey of the times of RPA projects was carried out in an administrative department of a company. After this survey, a comparison was made before and after the implementation of the RPA, to verify if it was possible to obtain an improvement from an energy point of view.

The rest of the work is organized as follows. Section 2 presents the research methodology used in the article and presents the case study and the data collection. Section 3 presents data comparison and critical analysis of the results. Finally, the conclusions are presented in Sect. 4, together with a proposal for future work.

2 Methodology

The research methodology applied in this investigation was the case study. The case study is characterized by the detailed study of the objects of investigation, for the contribution of research knowledge, in a broad way [17].

It can be defined as the study of some program, institution, educational system, person or social unit, in order to understand, through inquiries, why and how a certain phenomenon is occurring [17]. This study as an empirical investigation, through the observation of the reality of things. In this way, this study intends to obtain a deep and detailed knowledge regarding the process of the analyzed services, in order to apprehend its characteristics, identify its bottlenecks and the activities that do not add value. [18] lists some objectives in relation to the application of the case study in research with different purposes, they are: knowing the reality of the research scenario, describing the scenario of the investigation context and explaining the variables that determine the phenomenon in scenarios that do not use survey techniques and experiments [18].

The main research instruments used to collect data for the development of the study were direct observation and interviews. According to [18] observation is an essential element in all research processes, however, it is in data collection that its role is most noticeable. Use the senses, in order to obtain the necessary information for the collection of data, through the existing events, in addition to analyzing the phenomenon of study [19, 20].

2.1 Case Study

The case study presented here was raised in the administrative department of a company in Portugal. Robotic Process Automation technology was implemented in the administrative department in 12 projects that were executed manually.

Surveys were carried out on the projects of two people from the same team. Each person was responsible for carrying out these daily tasks. In order to automate tasks that were repetitive and that did not bring added value to the team, these tasks were replaced by others that brought greater added value. These 12 tasks were performed daily and were then replaced by Robotic Process Automation technology.

In order to carry out our investigation, a survey was carried out with the Robotic Process Automation (RPA) team of the department so that it was possible to carry out the energy study after the implementation of the RPA. In the section below, data relating to the 12 projects will be presented.

2.2 Data Collection

In this part of the work, data regarding the projects that were implemented in Robotic Process Automation technology will be presented.

Table 1 shows a list of 12 projects, whose main objective was to insert data into the company's platforms, transfer documents, send emails, among other repetitive tasks that could be replaced by software robots. Table 1 shows the time in minutes of tasks performed manually (before implementation) and the time in minutes of tasks performed by the software robot. These projects were daily and stable, which were a list of good candidate projects to carry out this energy study.

After presenting the execution times of the 12 RPA projects, we present the characteristics of the computer that was used for each of the company's two employees, the lighting lamps and the expenses of the AC, and also the characteristics of the server where they were Robotic Process Automation runs and AC for computer server sales.

The computer used by each of the two collaborators was a Lenovo ThinkPad T480s 14.1 Full HD I5-8250u 8 GB RAM 240 GB SSD. With a consumption of approximately 76.3 KWh/month. The office room had four LED lamps with light sensors (60 W) and a consumption of approximately 43.2 KWh/month. In addition, the room also had an Air-Conditioner (AC) with 12,000 BTU with a consumption of approximately 182.4 KWh/month. The computer server applied to Robotic Process Automation processes approximately 151.2 kWh/month and Air-Conditioner (AC) for computer server sales with 5000 BTU with a consumption of approximately 84 KWh/month.

The regime studied here was for all resources of 8 h of work, which are the working hours of work.

Table 1 Identification of execution times of 12 projects implemented in RPA

Project List	Manual runtime–before RPA implementation (min)	Software robot runtime—with RPA implementation (min)
Project 1	20	7
Project 2	30	14
Project 3	60	22
Project 4	40	12
Project 5	10	6
Project 6	15	6
Project 7	10	6
Project 8	35	13
Project 9	45	17
Project 10	15	7
Project 11	10	6
Project 12	10	5

3 Analysis and Interpretation of Results

In this section, the comparison and analysis of the case study data will be carried out, as well as the analysis of the respective results.

Figure 1 represents a bar graph that corresponds to the comparison between the execution times, in minutes, of the 12 projects that were implemented in RPA technology. This comparison is made through the times that each of the projects was executed manually and with the times that take on average to be executed by Robotic Process Automation automations. Let's see that the total execution time of all processes in minutes before Robotic Process Automation was implemented was 300 min. After the implementation of RPA technology, the total execution time of the 12 projects in minutes is 121 min.

We will now present the calculations related to energy costs for each of the scenarios: manual process execution time (300 min) and process execution time using RPA technology (121 min).

Regarding energy costs, we consider for the purpose of manual execution of the process of the use of 2 portable computers (PC), 4 light bulbs, and 1 AC in use for a total of 300 min.

$$2 * (\text{PC}) + 4 * (\text{light bulbs}) + 1 * (\text{AC}) = \text{total energy} \quad (1)$$

Let's see that we had expenses in the order of 301.9 KWh/month with these devices connected Eq. (1). For the 300 min, there was a total energy expenditure of 188.69 KWh/month.

Regarding energy costs, we consider for the purposes of implementing Robotic Process Automation the use of 1 computer server and 1 AC for computer serves sales

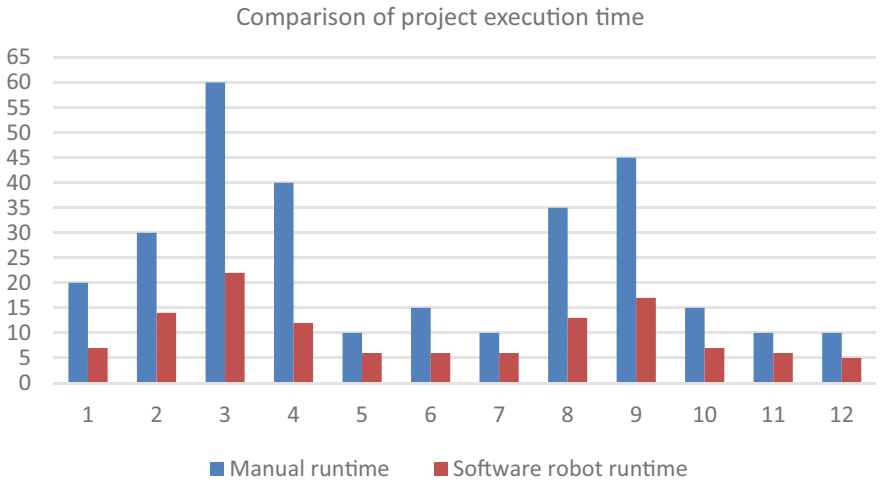

Fig. 1 Comparison of execution times in relation to projects implemented in RPA in the administrative department

in use for a total of 121 min.

$$1 * (\text{computer server}) + 1 * (\text{AC for computer server sales}) = \text{total energy} \tag{2}$$

Let's see that we had expenses in the order of 382.6 KWh/month with these devices connected Eq. (2). For the 121 min, there was a total energy expenditure of 84.24 KWh/month.

Regarding the comparison between the connected devices when the processes were executed manually, and after using a computer server with an AC (server room) to execute these RPA processes, we can see that there is a significant energy gain.

It was considered the same amount of services performed both for the manual part and for the part executed by RPA. Since RPA is more efficient in relation to the time variable and energy consumption, it is possible to verify that RPA for the execution of the same tasks consumes less energy and less time, compared to the same variables for the manual execution of the process.

4 Conclusion

This investigation comprised, through a case study, in the context of the implementation of Robotic Process Automation technology, in an administrative department of a company, the study of energy efficiency in relation to the use of this technology.

The implementation of Robotic Process Automation (RPA) and the concept of energy efficiency is a topic of great interest and importance for research, since there is a relationship between these two concepts, energy efficiency and implementation/use of RPA.

For this work, we concluded that after the implementation of RPA in the administrative department of the company, in comparison to the execution time of the process, for this context, the RPA was verified faster than the execution manual execution, since, the RPA executes all processes in 40% of the time processes run manually.

In order to answer our central research question, we found that after the implementation of RPA in these processes, a reduction in the volume of energy consumed in the order of 78% was achieved, which proves that RPA is a technology that, in addition to being efficient, is an environmentally friendly technology because from its implementation it is possible to have significant energy gains, compared to the manual execution of the processes.

Considering that we are currently concerned with making a more efficient consumption of energy, the implementation of technologies, such as RPA, help to reduce energy consumption and, consequently, the carbon footprint of activities carried out in companies. In this way, we want to show that RPA is one of the technologies to be used, within the context of Industry 4.0, to ensure increasingly efficient and sustainable processes. In view of this, we are here concerned with the ecological footprint and sustainable development, through the generation of responsible demand.

The practical advantage of the work was to develop a study that serves to assist decision-making on the implementation of RPA from the energy perspective, emphasizing that RPA processes are, by nature, more efficient, from an energy point of view, than processes performed manually. In addition, a limiting factor to develop a more efficient analysis of the energy impacts in relation to the implementation of RPA was verified, was the accomplishment of the study considering several processes of the same organization, which in the future can be replicated the same study in other organizations from different segments.

Considering the results of this investigation, it appears that there is room to improve research in this area. It was also possible to suggest as future work the development of models with Key Performance Indicator (KPI's) that allow the quantitative/financial assessment of energy effects after the implementation of RPA technology in an organization.

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The Potential Impact of Central Bank Digital Currencies (CBDCs) on Economic and Financial Sector Development

Simon Meier and Galia Kondova

Abstract Central bank digital currency (CBDC) is a central-bank issued digital currency or "digital banknote" which is programmable and could be transferred peer-to-peer via the blockchain technology. This paper studies several design types of CBDCs according to their implementation model (retail vs wholesale), underlying format (account-based vs token-based) or their distribution model (direct, indirect or hybrid). The analysis focuses on the potential impacts of the different CBDCs design types on the major financial sector actors, as well as on the financial sector development in general. The programmability of CBDCs to include smart contracts is found to be a powerful factor that could foster innovation and efficiency improvements in the financial sector. Major concerns are related to a potential disintermediation in the financial sector as a result of the introduction of CBDCs.

Keywords CBDC · Digital currency · E-government · Blockchain · Economic policy · Financial disintermediation · Smart contracts · Financial sector

1 Introduction

The central bank digital currency (CBDC) is a new concept of central bank money, bridging the gap between traditional central bank issued fiat money (cash) and digital money in the form of bank deposits [1].

CBDC can be described as a digital banknote and can be used by private individuals and businesses for payment transactions (retail CBDC) or by financial institutions to settle trades in financial markets (wholesale CBDC) [2].

A key difference between traditional fiat money (cash) and CBDC is the possibility to programme the digital currency. CBDCs can be programmed to include smart

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contracts so that the execution of payments can be linked to specific conditions and time of execution. Programmable money could be issued not only by central banks but also by private organizations. The advantage of CBDCs compared to programmable money issued by private organization is that it is a "fail-safe" option because it is official legal tender backed by the central bank [3]. Crypto currencies, on the other hand, such as bitcoin and ether are highly volatile and not backed by a liable issuer, which limits their suitability as payment methods.

This paper continues with providing on overview of the different types of CBDCs according to their implementation model (retail vs wholesale), underlying format (account-based vs token-based) or their distribution model (direct, indirect or hybrid). The analysis focuses on the potential impacts of the different CBDCs design types on the major financial sector actors as well as on the financial sector development in general.

The paper concludes with a summary of the identified benefits and challenges association with the implementation of CBDCs.

2 Types of CBDCs

There are several ways of categorizing CBDCs depending on their implementation model (retail vs wholesale), underlying format (account-based vs token-based) or their distribution model (direct, indirect or hybrid) as presented in Fig. 1.

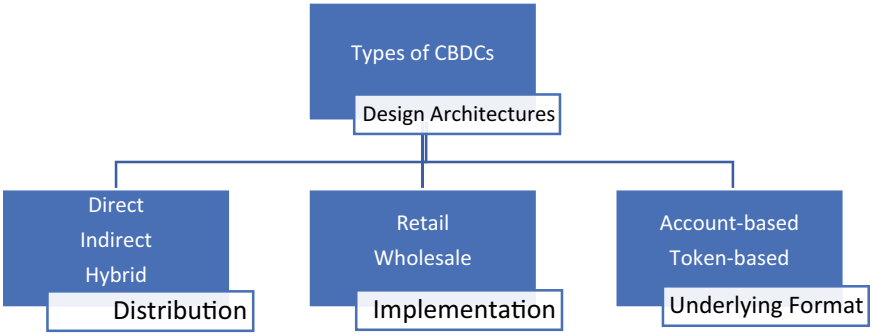

Fig. 1 Types of CBDCs

2.1 Retail vs Wholesale CBDCs: Potential Impacts

Retail CBDCs

Contrary to "digital" bank deposits which are claims on a commercial bank, a retail CBCD (rCBDC) is a direct claim on the central bank like cash [4].

The motivation to issue a rCBDC is to provide the public and businesses with a legal digital tender as an alternative to cash, to increase the resilience of payments by providing a backup system, to promote sovereignty and diversity in payment systems and to enhance the ability to enforce monetary policy by the central bank. Providing a digital currency that is backed by the central bank is also more efficient and cheaper than providing cash to the public, especially in underbanked areas, and thus could lead to greater financial inclusion [5].

In case of any incident leading to outages in the current electronic payments and banking system, a backup medium of exchange such as a rCBDC could improve the resilience of the payment system. Transfer transactions of CBDCs can take place offline and once one of the parties connects to the system the ledger is updated [5].

By introducing CBDCs, more competition in available payment systems would take place [5]. This could lead to decreasing costs for consumers or avoiding credit card or bank transfer fees.

In addition, the implementation of a rCBDC could accelerate the monetary transmission mechanism through which official interest rates are transmitted to the economy [5].

Furthermore, central banks could programme the currency in a way that allows for defining either positive or negative interest rates to the currency, for limiting the amount transferrable from one party to another, and for preventing a convertibility at par [5].

A concern which is often raised about rCBDCs is that it could lead to more bank runs. Bank runs occur when banking clients all at once try to withdraw their money from their accounts, which can lead to banks becoming insolvent. In contrast to the past when people had to wait in line at the counter or at ATMs to make withdrawals, a rCBDC could allow to withdraw money at a simple click [6].

Another concern is that when retail deposits are converted into rCBDCs, it would become more expensive for commercial banks to acquire the needed sources of funding for their operations. Deposits in customer accounts can be used by a commercial bank to create loans and thus earn a revenue, money held in the form of CBDCs however cannot be lent out by the bank [6]. However, the previously mentioned programmable options could enable a central bank to mitigate these possible risks for commercial banks [5, 6].

Wholesale CBDCs

In contrast to rCBDCs, wholesale CBDCs (wCBDCs) are not used by individuals or businesses but are meant for financial institutions that hold reserve deposits with the central bank.

The motivation to create a wCBDC is to increase the efficiency for transactions by reducing operational costs, to avoid the use of collateral and to make it more secure resolving the concern of liquidity and counterparty risk [2]. wCBDC is also referred to as "digital interbank money" and could improve the risk management and efficiency in the settlement process, as it could also be made accessible to players in the financial market, which currently do not have the possibility to hold accounts with the central bank [7].

Financial institutions would gain the opportunity to conduct transactions with wCBDCs also across borders without having to use fiat money in the process, which would lead to cost savings, faster transactions and more convenience. Furthermore, using a wCBDC would allow new forms of conditionality for payments, meaning that transactions are only settled once the conditions are met, for example the delivery of another payment or assets is only settled once all conditions are met. Such conditional payments instructions could improve the delivery-versus-payment mechanism in "real-time gross settlement" (RTGS) systems [4].

2.2 Direct, Indirect, Hybrid CBDCs: Potential Impacts

When addressing the development of a CBDC, one of the key decisions of any central bank is about the distribution model, meaning to either directly or indirectly issue the digital currency [8].

Direct CBDCs

A direct CBDC is issued directly to individuals and businesses. Transactions could take place without any intermediaries in between negatively affecting the business model of banks [6]. In this case a financial disintermediation is the expected outcome.

Smaller countries with underdeveloped financial systems and low financial inclusion rates could benefit from a direct rCBDC, with no intermediaries being needed for the distribution of the new digital currency [6] (see Fig. 2). An example is the Bahamas, which consists of several islands, where it is difficult to establish a good banking infrastructure for the population. The "Sand Dollar" is reported to positively affect the financial inclusion rate in underbanked communities.

Direct wCBDCs are associated with interbank transfers in the wholesale financial system (see Fig. 3). Nowadays, most countries use digital cash transfer systems such as RTGS. However, for countries without such access a single-tier direct CBDC could be of benefit. For example, the National Bank of Cambodia (NBC) uses a single-tier direct wholesale approach, providing safe, affordable and efficient interbank transactions for 11 banks within the country [6].

Indirect CBDCs

An indirect CBDC could be referred to as a two-tier system. This means that with an indirect structure central banks only keep CBDC accounts for the intermediaries

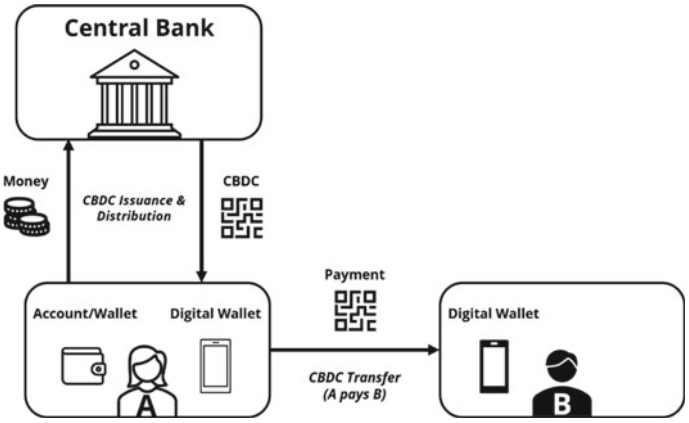

Fig. 2 Direct token-based retail CBDC (based on [6])

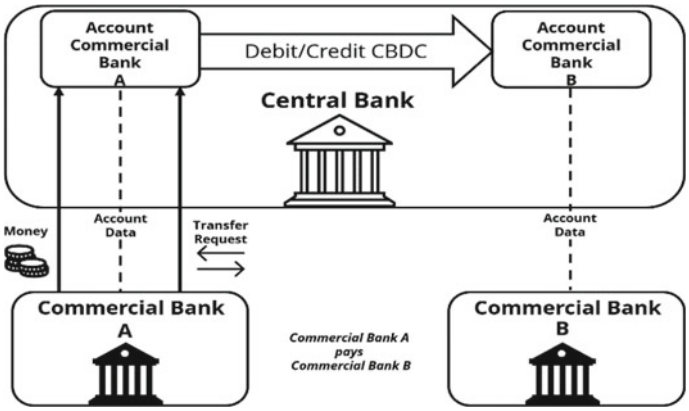

Fig. 3 Direct wholesale CBDC (based on [6])

such as commercial banks, which then handle CBDC claims towards individuals and businesses [6] (see Fig. 4).

By using a two-tier structure, the central bank leaves the management and provision of CBDC accounts or wallets to intermediaries, thus allowing it to concentrate on managing the infrastructure by outsourcing daily business operations to banks. This approach is less disruptive than a direct approach, as the existing financial infrastructure is repurposed and re-used allowing brokers, transfer services and banks to innovate new services and remain in business. In comparison, in a single-tiered system, there would be a financial disintermediation negatively affecting the business of banks as accounts or wallets would directly be provided by the central bank. However, by using the current infrastructure, the domestic financial system is far less disrupted as banks retain an important role in the system [6]. An indirect approach

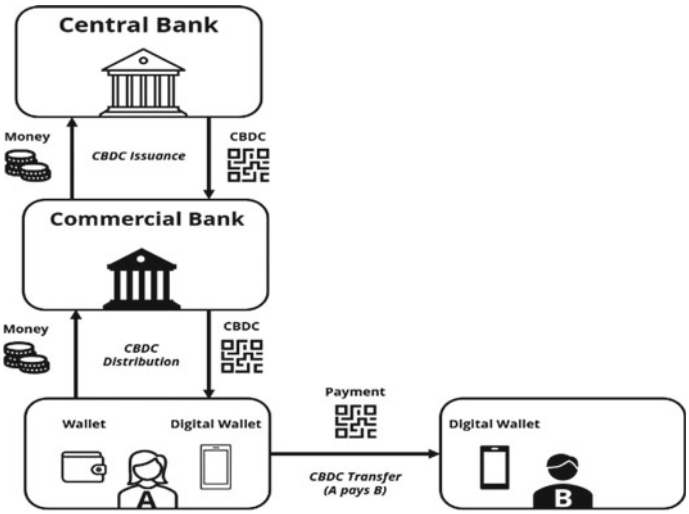

Fig. 4 Indirect retail CBDC (based on [6])

would mean that the claim of the CBDC would be on the commercial bank and not the central bank unlike in a direct approach where the claim is directly on the central bank itself [8].

Hybrid CBDCs

Kayrouz [8] explains that there is a third distribution model, a so-called hybrid approach. In such an approach, the central bank issues the CBDC to an intermediary which handles AML and KYC requirements, but the claim would remain on the central bank itself [9].

2.3 Account-Based and Token-Based CBDCs: Potential Impacts

Another important aspect in the design of CBDCs is the underlying format of either an account-based or a token-based approach [7].

Token-based CBDCs

In the case of token-based CBDCs, the ownership of the digital currency is linked to a proof of information. Cryptography is used to verify digital signatures and to verify transfers of the CBDC. In a tokenized CBDC, the token can be programmed to include rules of payments, meaning that payments can be automated between multiple peers. Additionally, payments can be transferred without an Internet connection, making it very suitable for areas with limited connectivity [8]. A token-based approach

offers higher degrees of anonymity; however, central banks can implement identity requirements to access and use the network. The transfer of tokens depends on the sender's ability to verify the validity of the payment object. Therefore, transferring tokens requires a form of distributed ledger technology such as the blockchain, to verify the chain of ownership in tokens and to validate payments [9].

Account-based CBDCs

Compared with tokenized CBDCs, which are dependent on an object and access to the token requires the proof of information (e.g. private key), account-based CBDCs require the proof of identity. In such a format, the ownership of the digital currency is linked to the identity and a transaction is an update of the balance sheet of a payer and payee, like the current digital payment systems [8]. Access to account-based CBDC and claims are linked to a bank account and the identity of the account holder. Compared with a tokenized approach, account-based CBDC requires a banking relationship [9].

3 Conclusion

CBDC is the virtual form of fiat money and is fully backed by the issuing central bank. The idea is to provide individuals with the security and convenience of digital money while ensuring that the currency is regulated and reserve-backed.

This paper outlined the main characteristics of the major CBDC design types as well as analyzed their potential impact on the financial sector actors such as central banks, financial intermediaries and customers as well as on the overall economic development. These major findings are summarized in the next paragraphs.

With respect to the financial sector, CBDCs could provide financial inclusion to people who are currently left out of the financial system, give central banks the ability to facilitate fiscal and monetary policy directly and faster than nowadays and make cross-border payments faster and cheaper [2, 10]. When designed carefully, CBDCs could thus offer more safety, more resilience, lower costs and greater availability than private forms of digital money [11].

In addition to the potential advantages associated with the financial sector development, the introduction of CBDCs is associated with expectations for economic growth through the creation of new business models for financial intermediation, payment systems and fintech innovations.

Finally, CBDCs can be programmed to include smart contracts, which allow for the automation of many manual processes and thus drive efficiency improvements. Furthermore, programmable digital money underpins many new business models in the areas of Internet of Things (IoT) and decentralized finance (DeFI).

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Hydration Automation (HA): Smart Tank

Navid Shaghaghi, Peter Ferguson, Adam Graham, and Jesse Mayer

Abstract Many agricultural Internet of Things (IoT) solutions focus on the monitoring and management of water in irrigation or storage systems. The hydration automation (HA) automated water monitoring and management system utilizes low cost, small form factor, and sustainable sensing units (SUs) to collect water level reading of water storage systems through the use of an ultrasonic sensor and actuating units (AUs) for automating the control of valves and pumps that are operated via a Base Station. The SUs and AUs are housed in water proof, cost-effective, and environmentally friendly custom-built 3D printed casings and often placed miles away from each other in agricultural lands. This necessitates the existence of a long-range communication subsystem which utilizes the ÂB communication protocol atop of LoRa or other link layer protocols. This setup of the HA system, effective for monitoring and operating multi-tank irrigation systems, is however an overkill for systems comprising only a single water tank. Furthermore, the HA system thus far had not included a mechanism for remote emptying or decreasing of the existing water levels of water tanks. A capability that is, for instance, needed for preventing damage to the tanks when freezing of the water is possible. This paper discusses the implementation of a smart tank for the HA system which comprises an AU for water level control automation and is controlled directly by a minimally enhanced SU rather than a specialized Base Station.

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1 Introduction

Agriculture is dependent on water with farms, greenhouses, orchards, ranches, and vineyards all in need of irrigation systems. Modern irrigation systems are equipped with an assortment of water reserves, sheds, and tanks to store water for later use or to manage the flow, time, or quality of the water delivered to the crops. Furthermore, these agricultural-scale water stores can help prevent flooding that can occur when the water table can no longer accommodate water that is bearing down on it such as during a heavy down poor [1].

Enclosed water stores such as water tanks have a fixed volume. This poses a problem in colder climates, times of the year when temperatures drop below freezing, or even some times over night, when the risk of water freezing is higher. Since water is the only non-metallic substance known to expand when freezing, its increase in volume results in the rupture and bursting of many parts of an irrigation system, from small pipes to massive water tanks, if proper preventative measures are not taken prior to the freezing of the water. This results in very costly repairs and replacements but more impotently can result in total loss of the crops. Either because due to the damage to the irrigation system, water supply is cut off to the crops or because once the water unfreezes in the morning, it floods the crops rapidly. For reference, 250 gallons of water can leak out of a 1/8-inch crack in a single day [2].

This means that in order to prevent the water tank from bursting from within, either enough empty room must be left in anticipation of possible water freezing or the water needs to be prevented from freezing through various methods such as agitating the water [3]. How much room must be left empty in the tank precisely? Roughly 1/10th of the tank, because water expands approximately 9% in volume when frozen [4]. This translates to loss of considerable usable space in water tanks as well as time for making sure that they are empty enough.

However, irrigation systems are a strong candidate for agricultural automation via an Internet of Things (Iot) approach [5–7] as they include many mechanical components such as pumps and valves that lend themselves well to automation and control. An automated system could control the filling and emptying of water tanks and ensure that enough empty space is left in water tanks. A smarter automated system could even maximize the space usage of a water tank by regulating the used volume of the tank based on the calculated, or even predicted, ambient temperature of the environment the system is operating in.

Hydration automation (HA) [8] is a sustainable, cost-effective, low footprint, and modular smart automated water monitoring and management system. HA consists of sensing units (SUs) [9], relay units (RUs) [10], actuating units (AUs), and a Base Station. The units are built using off-the-shelf components that are encased in

water proof, cost-effective, and sustainable 3D printing containers [11]. To control the management of water, the AUs are controlled by the Base Station which is informed by the SUs monitoring each of the water storage tanks. The SUs wirelessly communicate with other system units, RUs and the Base Station, through a robust communication subsystem utilizing a custom in-house developed routing protocol called ÂB [10] which is also in use by other agricultural IoT systems such as DOxy [12, 13] and HiveSpy [14, 15], as well as other environmental sensing IoT systems [16] where the ability to sleep intermediary nodes in the communication network is crucial for saving energy as they may be placed in hard-to-access environments.

This paper reports on the extension of the SU implementation to allow for it to directly control a local AU to create a smart water tank that can determine when the risk of freezing is high and ensure that enough amount of space is made available within the tank in order to accommodate the expansion of the water. These smart tanks are able to be used and integrated into the HA system or used separately as stand-alone water tanks.

The rest of this paper is organized as such: Sect. 2 details existing solutions for preventing water tanks bursting due to freezing and discusses each of their disadvantages. Section 3 delineates the design and implementation of the HA smart tanks, and Sect. 4 reports on the testing results. And lastly, Sects. 5 and 6 provide information on the continuing work as well as some concluding remarks.

2 Existing Solutions

Currently, many solutions exist to prevent the bursting of water pipes and tanks which range from the way in which a water tank is constructed, to how it is used, and how it is enhanced to withstand the cold.

2.1 How the Water Tanks Are Built

1. ***Using steal tanks instead of plastic ones as they will heat up faster under the sun and retain more heat*** [17]: This solution is however less effective when dealing with situations where the heat needs to be preserved over night when the solar rays are not present as the metallic material is just as quick to loose heat as it was to gain it.
2. ***Using round water tanks to reduce the surface area for the water that is exposed to the cold and hence reduce the amount of ice growth*** [18, 19]: This is an industry standard as a simple search of water tanks in any online or store catalog will show that all tanks seem to have a cylindrical design and only differ by the diameter, height, construction material, color, and other unrelated factors. This is a truly effective solution when only an outer surface of the body of water within the tank freezes. The lack of corners eliminates the possibility of having unfrozen

water getting trapped between the tank body material in the corner and already formed ice on its other side, which would leave no room for it to expand when frozen other than to push outward and rupture the tank in the weaker corner seams. This solution on its own, however, cannot address the 9% volume expansion problem as it is only beneficial when only a small amount of the surface of the stored water freezes rather than when the entire body of water within the tank freezes.

2.2 How the Water Tanks Are Used

1. ***Storing water underground*** [17]: This is generally nature's way of keeping it from freezing. Water tanks can be built underground. However, the cost of building an underground water tank will be much higher than purchasing and installing a surface, or even tower, water tank. Hence, this solution would not be applicable for retrofitting existing systems, nor affordable for small and midsize agricultural operations. Furthermore, if the water is stored below the surface, the advantage of using gravity for water extraction is completely lost as in order to retrieve the water, a water pump will be necessary similarly to a well.
2. ***Placing water tanks within green houses*** [17] ***in order to keep their temperature higher than the ambient outdoors temperature during colder seasons or over night***: This is yet another very costly solution and not suitable for retrofitting existing water tanks. It utilizes massive amounts of energy if the greenhouse is heated by any other means than the sun alone which is the case in colder climates or even over night.
3. ***Using larger water tanks than needed*** [17–19]: This solution is possibly the most effective way to prevent damage from expanding ice because it tackles the problem of damage due to the space gain by the freezing water rather than trying to prevent the water from freezing and expanding. This of course translates to higher cost and space usage than needed but may not be of concern in an agricultural field with an abundance of room. However, it does not provide a cost-effective way to deal with existing water tanks as it would simply amount to having to replace the existing infrastructure which costs money and time. A way in which this idea is utilized is that the existing tanks are just underfilled by the aforementioned 9% in order to in effect contain more space than water. But this reduces the efficiency of the system overall and may not be feasible if the reduction of 9% effects the crops or work schedule for the maintainers of the system.

2.3 Enhancing the Water Tanks to Withstand Colder Climates

Heating the water via either a passive heat capture or actively heating the water via heaters is a successful way to combat water freezing within a water tank.

1. ***Painting water tanks darker colors such as black*** [17]: This is a passive way of helping water tanks soak in more of the sun's heat and thus pass on more of that heat to the water within. This solution however is less effective when dealing with situations where the heat needs to be preserved over night when the solar rays are not present, especially since darker colors are just as quick to loose heat as they are to absorb it.
2. ***Using insulation*** [18, 20, 21] ***, for example, in the form of special blankets*** [22]: This solution is another passive way to prevent the tank from losing heat too quickly due to its cold surrounding environment. This technique is very useful for example in plumbing for houses and structures in colder climates as the plumbing is usually burried or within the walls. With a surface water tank, it will most likely also be colored black, so it can capture more of the sun's heat during the day but to trap that heat for a longer time. This solution is effective and will undoubtedly always be part of the equation, but it should be noted that the insulation is only effective in reducing the rate of the loss of the level of heat already existing in the tank and thus needs to be coupled with other heat generating ways to keep the water from freezing eventually. Otherwise, it will be a general gamble that the period of cold is not longer than the amount of time needed for enough loss of heat that would allow enough of the water to freeze to rupture the tank. Hence, this solution is often not used for preventing tank rupture but is rather in place to ensure the existence of liquid water for longer hours into the night. And hence is usually still coupled with the best practice of leaving 9% of the tank empty, just in case.
3. ***Using a water heater*** [20, 21] ***to maintain an above-freezing temperature in the water***: Even though this is an active way to heat the water and thus a sure solution to the problem, it is costly and energy inefficient. Furthermore, if the heater is for example operated via the burning of fissile flues, then it is also environmentally destructive as it contributes to poor air quality and global temperature rise due to producing greenhouse gases. If however it is for example heated using a renewable source such as solar or wind, then it is also in need of an energy storage system such as a battery bank which further increases the initial and maintenance costs.
4. ***Creating a constant movement in the water*** [18, 21] ***by using a motorized agitator, for instance***: This solution is also a sure active way to heat water and address the problem if the temperature does not fall way below freezing, but also requires the addition of constantly on, powerful enough motors to stir more than just a small local volume of the water. Such motors due require a purchase and installation cost but more importantly will use a lot of energy due to their always on status and thus will run up a big bill.

2.4 Adding an Anti-freezing Supplement to the Water

And lastly, a solution not at all recommended for agriculture would be to use some sort of water additive in order to prevent the water from freezing. An example of

where this is effective is the radiator of a vehicle where the addition of anti-freeze to the coolant allows for the prevention of damage to the radiator in colder climates or colder times of the year. It should be clear as to why this would not be an acceptable solution for human consumption [17] or agricultural usage as such additives would be toxic for the plants and animals drinking the water as well as to the humans who will be consuming the agricultural goods down the line.

3 HA Smart Tank

Using IoT systems for monitoring and managing water usage is not a new subject, and many implementations have been made. Unlike the aforementioned methodologies for preventing water tanks from freezing, an IoT solution can be used to, at minimum, prevent damage to the tanks should the water within them freeze, by emptying the appropriate amount of water at the appropriate time prior to freezing. In a way, this is a smart extension to the idea of using a bigger tank than the amount of water needed to be stored, that is, less expensive and space consuming—since a larger tank would cost more and take up more physical space—and installable on existing water tanks.

Notably, an IoT solution can be used to heat or agitate the water as well, but those solutions are very energy inefficient especially as the size of the water tanks increases. Thus, provided that the release of some water from the water store into the rest of the system is not problematic, then the automation of the release of the appropriate amount at the appropriate time presents itself as the best option, which is a perfect task for a low-energy IoT system such as HA.

3.1 HA System Overview

The smart tank is part of the overall HA system, which can be seen in Fig. 1. The system consists of four main components: the Base Station, relay unit (RU), sensor unit (SU), and actuating unit (AU). The SUs collect data from the water tanks they are connected to, then send the data via an energy-aware communications protocol (EACP) called ÂB [10] atop of LoRa (or other data link layer protocols as proposed in [23]) to either the Base Station directly or through an RU (or network of RUs) if the range needs to be extended due to distance or line-of-sight issues. The SUs are designed to be low cost, small form factor, and sustainable. The Base Station collects all the data from the SUs and uploads them either through Wi-Fi or GSM to a web application to store and visualize the data. The system's actuation comes from the AUs in the system. The AUs can either be controlled by the Base Station or a slightly enhanced SU depending on the environment in where it is deployed. More detailed descriptions of the system as well as the evolution of the system over time can be found in [8, 9, 11].

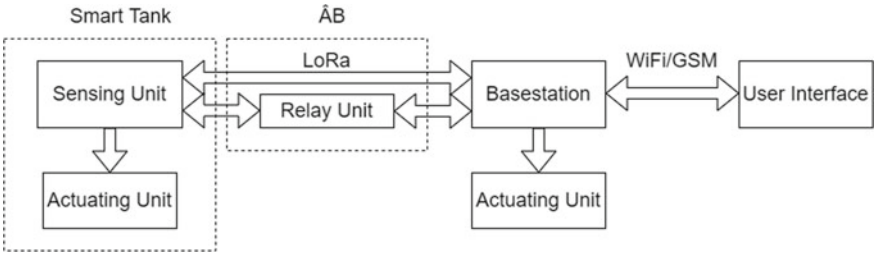

Fig. 1 HA system architecture

3.2 HA Smart Tank System Architecture

The smart tank designed and implemented for the HA system consists of an AU controlled by an enhanced SU. In this setup, an AU uses a valve and/or a pump to control the flow of water out of the water storage device or tank in the same fashion that a Base Station controls the flow of water into each tank. The SU has an ultrasonic sensor to detect the distance to the water in the tank which is used to calculate how full the tank is. Ordinarily, this data is used by the HA system's Base Station to determine how much water is needed to refill the tank and how long it will take to refill the tank, but, as is here, it can also be used to determine how much water needs to be released in order to prevent damage to the tank should the water freeze. For that purpose, a temperature sensor is used to measure the temperature of the environment the device is installed in. An SD card module is attached to keep a local record of the collected distances and temperatures. This system is powered by a battery that maintains a charged status via a solar panel. An overview of the smart tank architecture can be seen in Fig. 2 in which an SU controls an AU.

3.3 Possible Alternate Configuration

The AU in the smart tank system can be set up such that the AUs on all the tanks are controlled by a central Base Station rather than individually by each tank's own SU. Although this configuration would provide more central command of the system, it would use more power since the communication subsystem would be activated. But more impotently, the centralization of the decision on when to release some water from a particular tank introduces a major possible point of failure: unreliable communication. It is easy to deduce that in such a centralized design, the failure of the communication system can result in costly and possibly even irreparable damage to the hydration system and crops.

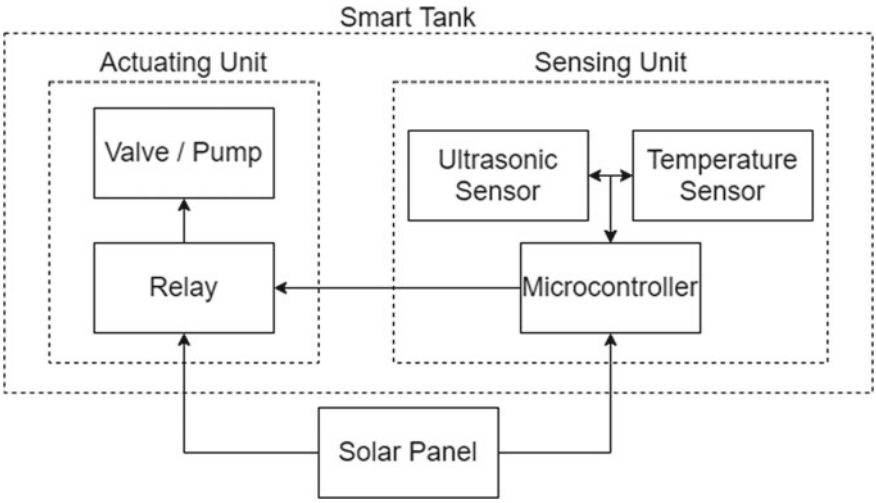

Fig. 2 Smart tank system architecture

3.4 Hardware

The components of an SU include a Wisen Whisper Node [24] board with an on-board LoRa (Long Range) communication module [25], a JSN-SR04t ultrasonic sensor [26], a temperature sensor [27], a voltage regulator, a TP4056 battery charge controller [28], a 5W lithium battery pack, and a 5V 100 mAh solar panel. Using a solar panel makes the system more flexible in where it can be installed, as it does not require hard-lined power in order to work. An improvement to the SU is a MicroSD card adapter module [29] to enable local storage of data and resilience in the case of network failure or device failure. This also allows for storage of things like a device or tank ID or other information about the system. A schematic of the improved SU can be seen in Fig. 3.

Both an alternating current (AC)-operated AU and direct current (DC)-operated AU were built and tested.

3.5 AC-Operated Valve AU Design

The AC-operated AU includes a solid-state relay [30] and an Orbit sprinkler valve [31]. The valve on the Orbit is controlled by a solenoid which moves a plunger that prevents/allows the flow of water. This model is able to handle 120 psi. The Orbit valve has two 3/4-inch female hose threads which enables it to be connected inline with a pipe. It operates at 24 VAC with an inrush current of around 0.35A and a holding current of around 0.23A. This power requirement cannot be provided by the

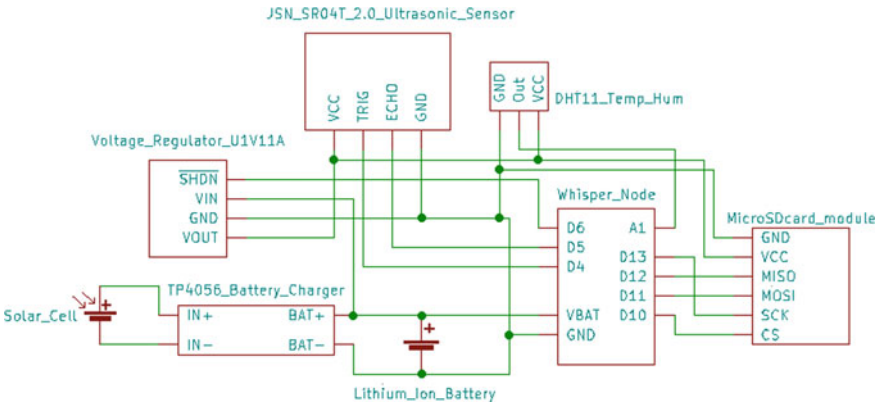

Fig. 3 Sensing unit schematic

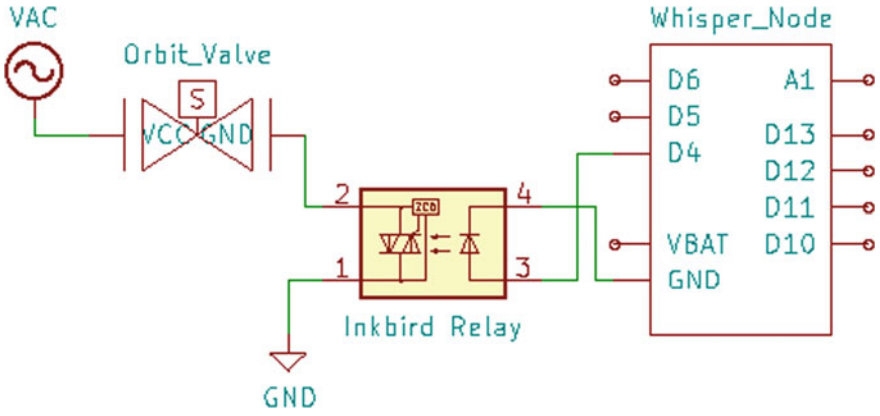

Fig. 4 AU with Whisper Node schematic

Whisper Node, so an external power cable was used for testing, while a solar panel and inverter can be used instead when the system is deployed in the field. For the Whisper Node to be able to control the valve, a solid-state relay was used that was able to handle the voltage specifications of the valve. The relay functions as a switch for the valve that the Whisper Node controls and has four connections: connections 1 and 2 are for VAC (AC voltage), while connections 3 and 4 are for VDC (DC voltage). It is able to handle 24–380 VAC and an input of 3–32 VDC. The Whisper Node uses a digital pin connected to connection 3 on the relay with connection 4 connected to ground. A 24 VAC is connected to the input of the valve, and the common wire of the valve is connected to connection 2 of the relay. Connection 1 is connected to the GND of the 24 VAC power source. The relay has a built in snubber circuit, so it can withstand high voltage surges and prevent damage when controlling the valve. A simplified schematic of this can be seen in Fig. 4.

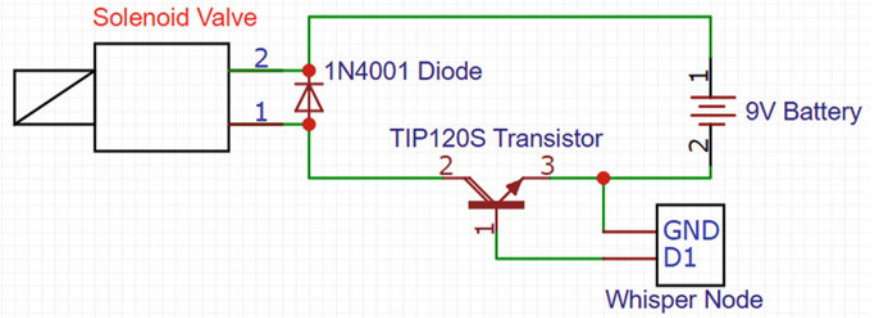

Fig. 5 AU circuit schematic

3.6 DC-Operated Valve AU Design

The DC-operated AU includes a TIP120 NPN transistor and a plastic water solenoid valve from Adafruit [32]. The valve is controlled by a solenoid which, when powered, opens and allows the flow of water. This model is able to handle a range of 0.02 Mpa to 0.8 Mpa of pressure. The valve has two 1/2" nominal non-taped National Pipe outlets making it easy to connect inline with a pipe. The valve can be operated between 6v and 12V. This power requirement cannot be provided by the Whisper Node; hence, an external 9V battery with a 0.24A draw was used for testing, but a solar panel can easily be used instead when the system is deployed out in the field. For the Whisper Node to be able to control the valve, a TIP120 transistor was used that was able to handle the voltage specifications of the valve. The transistor functions as a switch for the valve that the Whisper Node controls. The Whisper Node uses a digital pin connected to the base of the transistor. The collector is connected to the ground of the valve, and the emitter is connected to the ground lead of the battery as well as to a GND pin of the Whisper Node. A 1N4001 diode is used as a snubber diode to withstand high voltage surges and prevent damage when controlling the valve. A simplified schematic of this setup can be seen in Fig. 5 and the built circuit in Figs. 6 and 7.

The AU circuitry was then placed in a custom 3D printed case seen in Fig. 8 using many of the best practices described in [11] for water proofing and other outdoor considerations.

Each smart tank SU + AU costs around US$85 in retail off-the-shelf components with the prices and components of the SU and AU shown in Table 1.

3.7 Software

The Whisper Node micro-controller in the SUs is Arduino compatible and hence programmable using Arduino C. The general algorithm for its operation as a smart tank is as such:

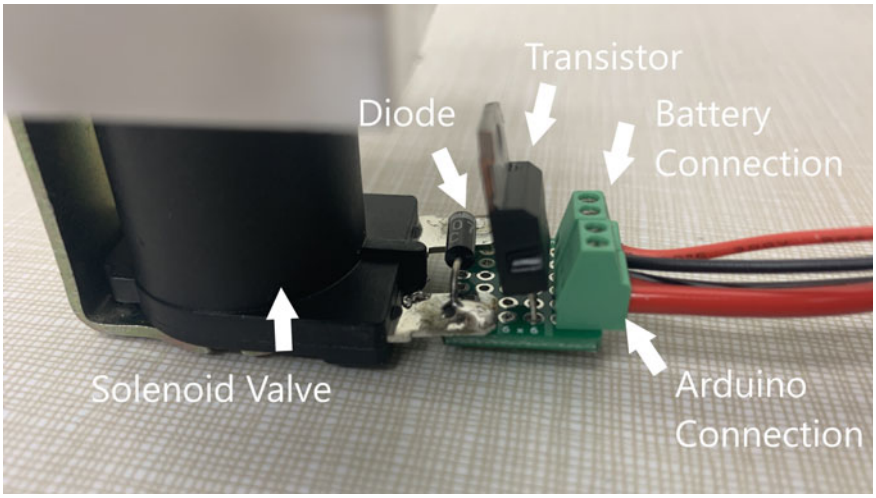

Fig. 6 AU circuit closeup

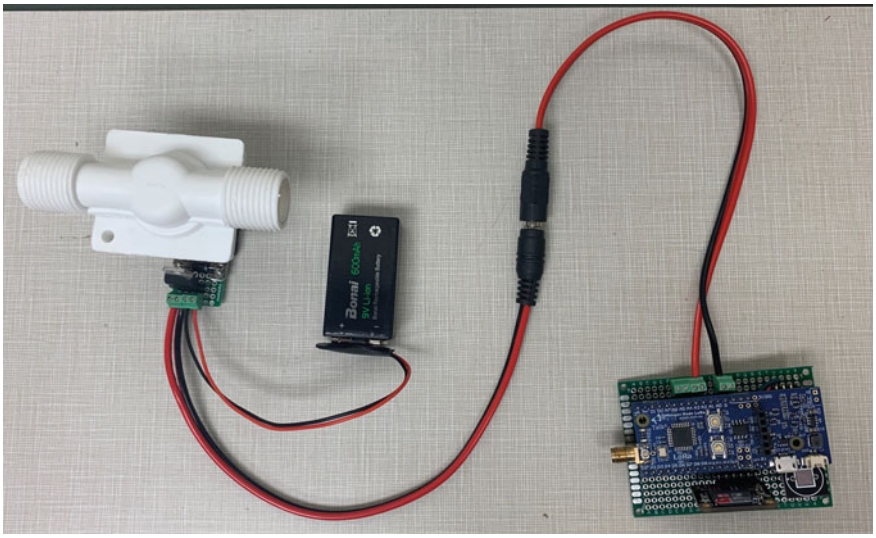

Fig. 7 AU connected to SU

Fig. 8 Solenoid valve in 3D-printed case

Table 1 SU and AU components broken down by price (USD)

SU components	Price (US$)	AU components	Price (US$)
Whisper Node	$30.07	Wires	$0.50
PCB	$0.10	Plastic water solenoid valve	$6.95
Antenna	$6.03	Power source (9 V battery)	$2.12
SMA female edge connector	$1.22	Transistor and diode	$1.00
Ultrasonic sensor	$3.71		
Wires	$0.50		
Standoff header pins	$0.25		
RTC	$8.73		
Solar panel	$1.00		
Battery	$7.00		
Casing	$2.27		
Temp/hum sensor	$2.10		
Charge controller	$0.60		
Card reader	$1.40		
MicroSD card	$8.99		
Total	$73.97	Total	$10.57

1. The SU collects a distance reading of the water height in the tank using the ultrasonic sensor and the ambient temperature using its temperature sensor and logs the values locally to its MicroSD card.
2. The SU calculates the current volume of the water in the tank based on the predefined radius and measured height of the water in the tank and compares it with the total volume of the tank.
3. The SU then determines whether to open the valve based on the ambient temperature reading and the volume calculations if the temperature indicates the possibility of freezing and the volume comparison indicates that less than 9% of the tank is empty.
4. If the decision is to open the valve, then it calculates the amount of time needed for enough water to exit the tank given the volume of water needed to be released and the flow rate of the valve.
5. The SU opens the AU's valve for the predetermined time to release the appropriate amount of water.
6. The SU collects another distance reading of the water height in the tank using the ultrasonic sensor and calculates the empty volume again in order to ensure that at least 9% of the space is available for ice expansion.
7. If the empty volume is still below 9%, then the process repeats until the final measurement indicates 9% or more of the tank is empty.

This process of course can be scheduled as a routine which takes place every night before temperature falls or as a trigger when the temperature reading indicates that freezing temperatures are approaching. But it can also be handled right away every time the water tank is refilled so that no extra work needs to be done until the next filling of the tank. In this scenario, the SU would request 9% less water than needed to completely fill the water tank from the Base Station when initiating the refilling process on every scheduled interval.

In the different setup where the Base Station controls AUs for each tank, the process follows similar steps though includes communication steps between the SU and the Base Station:

1. The SU collects a distance reading of the water tank using the ultrasonic sensor and the ambient temperature using its temperature sensor and saves them locally to its MicroSD card for in case the communication subsystem fails to deliver the values to the Base Station.
2. The distance reading and the ambient temperature are sent to the Base Station via ÂB.
3. The Base Station calculates the current volume of the water in the tank based on the predefined radius and measured height of the water in the tank and compares it with the total volume of the tank.
4. The Base Station checks if current water volume is below a predefined threshold volume of the tank which may be 9% less than the usable capacity of the tank if freezing is expected as either pre-set by the user or dynamically determined based on the received temperature reading from the SU.

5. The Base Station determines which valve needs to be controlled by the sending SU's ID in the message.
6. The Base Station calculates how long the valve needs to remain open to refill the tank to a desired volume using the given flow rate of the valve and the calculated needed volume of water to fill the specific water tank.
7. The Base Station opens the valve, then closes it after the calculated time has passed.
8. The Base Station informs the SU that the tank has been refilled by requesting a new reading in order to ensure that the process was successful.
9. The SU collects the distance reading of the water tank and the ambient temperature again and sends them to the Base Station.
10. If the water level is still below the desired level, the process repeats. But if the water level is above the desired limit, then the Base Station can instruct the SU to release the needed volume of water if the SU has an attached AU to its outflow valve.
11. The Base Station sends the SU how long to sleep until the next filling cycle as set by the user.

One last thing to note: Instead of just using time to determine when to close the valve, continuous readings from the ultrasonic sensor can be used to determine when the tank has been filled/emptied to the desired level. Using this method, however, causes more power consumption due to constant distance readings and use of the communication radios. Furthermore, this would prevent the Base Station from processing the data for another water tank while waiting for the first tank to be refilled and thus would also waste more time. For those reasons, the system was set up to have the SU check after the Base Station informs it that the desired amount of water has been delivered.

4 Smart Tank Testing

To test the smart tank system, an SU and connected AU were installed on a small 50 gallon water tank. A hose was attached to the outlet at the bottom of the tank in order to route the water to the AU-controlled valve in order to remove water when the valve is opened. Another hose was attached to the other end of the valve and routed to a 5 gallon bucket to capture the released water, so its volume could be measured, and the water could be reused for the following test. To gather the water height in the tank, the SU's ultrasonic sensor was installed under the tank lid. Both of the aforementioned AC-powered and DC-powered valves were used for testing. The AC valve was powered with a 24 VAC wall adaptor, and the DC valve was powered by the SU directly.

To simulate freezing weather, the SU was placed next to an air conditioner. Several different thresholds were set and tested back-to-back for the temperature sensor data being read. During every test, as the reading fell below the set threshold, the valve

opened for an enough amount of time to ensure that 9% of the tank was left empty regardless of the starting water level. The amount of released water was verified by both measuring the volume of the water gathered in the bucket and the SU reading of the amount of water remaining within the tank.

Both boundary conditions were also tested. When the tank was completely full, the smart tank released 4.5 gallons of water, leaving 45.5 gallons of water in the tank. And when the tank was filled at any amount below or equal to 45.5 gallons, the valve was never activated by the AU.

5 Work in Progress

This sections looks at improvements for the HA smart tank and overall HA system.

5.1 Releasing only the Needed Amount of Water Rather Than 9%

As aforementioned, water expands 9% in volume when frozen. Hence, in order to ensure that the water tanks are not damaged, the HA smart tank ensures the availability of 9% of the space in the water tank. This however assumes that every drop of water in the tank will be freezing, which is not always the case. In extremely cold climates, that assumption is accurate, but in climates where an over night freezing is possible, it is more so the case that only an outer layer of the water actually freezes and hence the content of the tank grows in volume by way less than 9%.

The HA smart tank can therefore be tuned to leave less than 9% of the volume empty, based on user settings or automated learning. As part of a calibration step, a newly installed HA smart tank's SU can be set up to take readings throughout the night over a period of time in order to gather an array of height and temperature data. Then two things can be done: Either a simple regression analysis can show the highest volume obtained, and thus the 9% requirement can be adjusted to the new <9% value appropriate for that environment, or a machine learning (ML) model can be used to correlate the volume calculations and temperatures that resulted in those volumes in order to dynamically determine the percentage of space needed for ice expansion every night based on the measured temperatures of that night. Furthermore, the HA user dashboard cloud infrastructure can send temperature forecasts from weather agencies to the Base Station which can then be shared with each smart tank and used to adjust the percentage of volume needed for ice expansion that night.

This could be a very important addition for saving water especially in colder yet drought stricken climates where every drop of water matters. The exact amount of the system's water efficiency will however be something that can only be determined over time.

5.2 Water Flow Sensor

The flow rate of the hoses used for testing did not effect testing as the hoses were chosen as tight fits to the valve intake and output nozzles, thus ensuring the same flow rate as the stamped flow rate of the valves by the manufacturer of the valve. However, it is foreseeable that a valve with a higher flow rate could be installed to a smaller diameter pipe with a lower flow rate during retrofitting a hydration or irrigation system either by error or due to time/cost considerations. This would result in inaccurate time estimations for the duration to leave the valve open.

Even though this would not cause any harm, it would reduce the efficiency of the HA system. It would not cause any harm as the HA system requires that either the Base Station or the SU verifies that the correct amount of water is in the tank after both operations of filling the tank or emptying enough of it to prevent damage from freezing. It is however inefficient because it would require multiple cycles of filling/emptying to achieve the same amount of water which should be achieved by a single cycle otherwise. This would both waste more time by taking longer and waste more energy by needing more valve operations and wireless communication—which is the most energy intense part of the process.

A solution to this would be to connect water flow sensors to the pipes that the valve nozzles are connected to and use their readings within either the Base Station or SU to calculate the flow rate in order to get a more accurate timing of how long the valve should stay open for.

5.3 Battery Charge Regulatory Policy

The SU's and RU's current designs do not include a battery charging regulatory policy and charges the battery to its full capacity. Recent studies have shown that battery lifetime can be extended by avoiding full-battery charge cycles [33]. More testing is still necessary to see how the SU's or RU's battery is effected in the long run.

5.4 Custom Printed Circuit Board (PCB)

In order to streamline and standardize the production of the SUs, RUs, and AUs, custom Printed Circuit Boards (PCB) are necessary and well overdue. A custom PCB will substantially reduce the points of failure as well as soldering time. The SUs and RUs share the same chassis and differ only in that the RUs do not have any sensors attached. This substantially reduces the workload and cost for designing, building, and maintaining two different circuits. The AUs, however, will be different as they are substantially smaller and single purposed for operating a valve. Research

is underway to see if it is not simply better to add the AU functionalities directly to SUs in order to further universalize the HA system circuitry.

6 Conclusion

This paper introduces an implementation of the HA smart tank, and the AU component of the HA system as combining the AU system with improvements to the SU system creates the HA smart tank. The smart tank system is able to communicate with RUs or the Base Station allowing it to be integrated into the HA system. Thus, the AU portion of the HA smart tank can either be controlled directly by an SU or the Base Station. And in fact, multiple AUs can therefore be controlled by the Base Station. The HA system helps small- and medium-sized farms be able to afford an automated water management and monitoring system which will help them save water, time, and money; the addition of smart tanks to the HA system allows for further automation of the maintenance and operation of water tanks, specifically preventing their destruction due to the freezing of the water inside of them.

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BellChat: An Inclusive Web Application for Messaging

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Abstract The goal of the web is universal access, but minority groups of web users, such as people with disabilities and elderly people, are limited in their ability to communicate through chat applications. These types of applications include social networking, which are especially used in communication among their users. However, social networks such as Facebook (Messenger), Twitter and WhatsApp are not adapted for these groups, and therefore, they do not fully meet the needs for which they were created. Moreover, for people with disabilities to use web-based messaging applications, they are required to use third-party tools, such as screen readers. For these reasons, this paper presents BellChat, a responsive web application for communication between everybody, adapted for people with disabilities, especially for those ones with visual or hearing disabilities. It was developed following the Scrum development framework with adaptations to very small groups, where the roles were modified to be according to the project team. In addition, developers worked remotely and meetings were held in person twice a week. BellChat is the only application adapted to convert text messages into speech, or speech messages into text, depending on the disability of the user who is connected. The evaluation results confirm the acceptance of the application by users.

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1 Introduction

Although inclusivity goes beyond accessibility, its basis is accessibility. An inclusive web application must first be an accessible web application. This means that an application should be thought of from the design to the building and deployment as an application that is accessible to all people without exception [1]. To achieve this goal, the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) has been established to raise awareness of universal accessibility [2]. The WAI provides developers with guidelines that can help make web pages widely accessible [3]. Considering that websites are designed to serve different purposes such as information, entertainment, advertising, to name a few, and that to achieve this goal they present a wide range of information to meet user needs and they must be accessible to everybody. However, most of these websites do not comply with the web accessibility standards designed by the W3C, making it difficult for part of the population to access to web content [4].

The web is the place where everybody should feel their full right to equality, regardless of their conditions or disabilities [5]. However, what happens with people with disabilities? It is very common to find websites that are not adapted for people with disabilities; for example, they do not have their own content reader, or they do not have a voice command interface. Likewise, not all websites take care of people with hearing disabilities, i.e. the voice files generally do not have the transcription of the content into text to allow for people with hearing disabilities understanding the content [6].

Given these disadvantages, people with visual or hearing impairments face the difficult task of using communication resources. Visually impaired people lessen this difficulty by using screen readers provided by third parties [7], while tools to reduce the difficulty faced by the hearing-impaired people are poorly suited for instant transcription of voice messages by downloading the message and uploading it to the applications for transcription. Some of these tools and the most popular ones can be found at González [8]. Two authors of the present work share with hearing-impaired people, who have shared with them that, when they receive voice messages, they must ask for help from third parties to know the content. This situation is also affirmed by Pereira [9]. In addition, this group of people are joined by older adults who, due to their condition are diminished in their abilities, and therefore do not enjoy all the benefits offered by the web applications for communication [6].

Communication between human beings is what makes people live in society. Currently around 3.4 billion users actively use social media platforms daily for an average of 2.5 h [10]. Social media have become an effective means of communication between people, including for companies with their customers. However, the lack

of inclusive platforms may make people with disabilities feel excluded. As a contribution to achieve the inclusion of this group of people, this paper presents BellChat, a responsive web application that ensures accessibility to the greatest number of people, regardless of their conditions (visual, hearing, physical). Its virtual assistant ensures interaction between the user and the application. It enables the actions allowed on each page to be performed by voice commands; it also allows any user to send messages in any format to people with or without disabilities. In addition, to reach as many people as possible, keyboard commands have been implemented for those who have problems with the mouse and for people who may have problems with the pronunciation of voice commands [11].

BellChat implements the W3C standards and complies with the success criteria to make web pages accessible to as many people as possible [1]. Based on these standards, the communication between people with disabilities and without disabilities is facilitated and communication accessibility problems are reduced. Other communication websites comply with certain W3C standards, but they do not achieve the objective of maximizing the number of people because they do not provide ease of use for people with disabilities. Thus, this document details the development and evaluation of BellChat.

2 Related Work

In digital libraries, such as Web of Science (WOS), ACM, IEEE, Scopus and Elsevier, few papers have been found on the development of accessible web applications. However, there are some articles that deal with the evaluation of web accessibility in public interest websites.

Among the works that present the development of accessible web applications, we can find Web-ALAP, a web-based application for writing mathematical documents in LaTeX developed by Arooj et al. [12]. Web-ALAP supports users with low vision through assistive functions and the manifestation of error indications by voice. To support users with the same disability, Lee et al. [13], introduce TableView, which focuses on solving the problem of users with low vision who have difficulty using the on-screen magnifier. TableView extracts content and information from the page and presents it in a more compact form to make the most of the expanded space. Despite their contribution, these works are focussed on a specific problem: people with low vision.

Likewise, the works that have been concerned with people with profound deafness problems, Lyall et al. [14], developed a smartphone application that recognized six sentences dictated by doctors for post-operative patients. These messages, delivered by voice by doctors, were converted to text to be read by the patients. The results shown in this work, with a clear extension, can be used for telephone conversations and even in face-to-face conversations between people without disabilities and with hearing loss.

Along the same lines, we find the work of Shadiev et al. [15], in which they apply speech-to-text technology in a virtual classroom. Their results were a motivation to propose BellChat. Although Shadiev et al. [15] apply it directly, BellChat does it in a deferred way, in text messages and speech-to-text over voice files. Moreover, a mobile application that enables communication between hearing impaired and non-disabled people (or those who do not understand sign language) was presented by Ali et al. [16], which via Bluetooth allow for exchanging information over short distances.

Alsaif et al. [17] present a very useful application for people with speech problems. It predicts through statistics the words that could be pronounced in a conversation. In addition to converting text-to-speech, the system provides different categories of frequently used phrases that are labelled with a representative image for ease of use. The user can also add images to the system and record the human voice or use the automatic text-to-speech synthesizer. The limitation of this application is that it is smartphone-only and converts speech-to-text and text-to-speech using only Arabic language.

All the papers read before and while BellChat was being designed present solutions that help people with specific disabilities. This is the reason why the authors of this paper present BellChat as an inclusive application as a means of communication between the greatest number of people, supporting the right of equality for which the web was created.

3 Proposal

It can be said that the web is one of the ways to facilitate communication between users and access to services. In this way, it alleviates the disadvantages people face when accessing services in the real world, especially people with visual or hearing impairments [18]. Given this landscape, BellChat is a smart web application capable of converting text-to-speech and speech-to-text depending on the disability registered in the user's profile. Its responsiveness gives it the feature of being easily accessed from a smartphone. This quality allows for reaching a much larger group of users, thus integrating into society those users who have been relegated by their situation. Moreover, the text-to-speech and the speech-to-text conversion help not only people with any of the disabilities; they also help people with full capabilities to perform other tasks while learning about the messages they receive or while sending messages to their contacts [19]. In addition, BellChat has an innovative design to ensure its goal of being accessible to everyone.

BellChat eliminates the most impactful problems for people with hearing impairment such as those mentioned by Pascual et al. [20]. In addition, it includes visually impaired people, allowing them to interact seamlessly with other users regardless of their abilities [21]. Also, BellChat can adapt to any device (smart phones, laptops, desktop computers) with Internet access in a friendly way.

3.1 Requirements

In the development of BellChat, functional requirements have been considered to try to include as many people as possible and non-functional requirements to provide all users with the security necessary in today's web applications.

Functional Requirements. In the development of BellChat, the following requirements were considered:

- *User identification*: To become a user of the application, a person must register as it. Among the information that the user must register is whether s/he has a disability and which one. BellChat will allow the user to enter his/her username and password, by voice or typing on a keyboard.
- *Self-programmable system*: Once the user has logged into the application, the respective functions will be self-programmed in its configuration, for example: the inbox will be prepared to present the user with the textual content of the messages (speech-to-text), or play the audio content of the messages (text-to-speech), the user's contact search format, voice management control, among others, or simply maintain appropriate options according to the user's profile.

Requirements for visually impaired persons:

- *Voice assistant*: The voice assistant must allow interacting with a browser, being always ready to solve user requests.
- *For each page (screens)*, a set of commands must be defined to help the user to perform the respective actions (in this case, the executor of the voice commands starts its work when Lili is invoked).

Requirements for hearing impaired persons:

- *Voice message to text converter*: If a hearing-impaired user receives an audio message, the application identifies the message format and converts it to text, letting the recipient read the message so that he/she is aware of its content.
- *Writing messages*: The user will be able to write in text format the message he/she wants to send, no matter to whom (recipient capabilities) he/she is going to send it.

Requirements for people with motor disabilities:

- *Voice assistant (Lili)*: The assistant should allow users to interact with a browser, always waiting for user requests. Each time a page is loaded in the browser, the respective commands can be invoked by voice to perform the permitted actions.
- *Sending messages*: The user may decide to send a message in text or in audio format, according to his/her capabilities, without considering to whom (recipient capabilities) he/she is going to send the message.

Non-functional Requirements. BellChat eliminates the most impactful problems for people with hearing impairment such as those mentioned by Pascual et al. [20]. In addition, it includes visually impaired people, allowing them to interact seamlessly

with other users regardless of their abilities. In addition, as the largest number of people access the Internet from their smartphone [22], BellChat should have no restrictions on the type of device from which it can be accessed and should do so in a friendly manner.

4 Methodology

BellChat was developed following the Scrum development framework, which is considered the most widely used in agile software development. The first task after defining the objectives of this project was the assignment of roles [23]. The first author played the role of product owner, the third author played the role of Scrum master and the second and fourth authors played the role of developers (development team). As the team was very small, the roles were expanded and interchanged, with the product owner also playing the role of Scrum master who also was part of the development team.

Another adjustment made to Scrum was the frequency of face-to-face meetings. Scrum specifies that they should be daily, the team of this project considered that the meetings should be less frequent, always considering the needs of the development team to responsibly fulfil the assigned sprint in the estimated time. In addition, the sprints had a maximum duration of two weeks while Scrum estimates that two weeks is the minimum time they should take (two to eight weeks) [23].

The advantage of working with small teams is the level of control in both compliance and attention to prioritization of activities by the developers, and attention to the developers by the product owner. Also, in small teams, the distances between team members can be short improving communication [24]. The daily dedication for the development of BellChat was on average two hours per day for each team member. In addition, developers worked remotely, and meetings were held in person twice a week. The Sprints (Sprint backlog not shown due to lack of space) that had to be executed to achieve the successful development of BellChat determined its duration which was in a total of 326 h. The time spent on the project by the product owner is considered only when the activities are to be executed by the project team. The time spent on the project by the product owner is considered only when the activities are to be executed by the project team.

5 Results

5.1 Requirements Elicitation and Analysis

The requirements were taken as the needs of real users (who are related with some of the authors of this paper) with their own visual and hearing impairments. In addition, we analyzed messaging applications currently in use, despite they have poor accessibility and do not comply with W3C standards. In this part of the methodology, use case diagrams and user stories were used for preliminary requirements elicitation and were used as a tool for eliciting the system requirements.

5.2 Bell Chat Architecture

BellChat has been developed following a three-tier architecture: client, application server and database server.

Client layer: The client-side layer is given by the view or interaction with users. Users can interact from any device that has Internet access and a browser (the browser preferred by them). Browsers must be enabled to execute JavaScript and CSS. The browsers that have been tested and have performed very well are Chrome, Opera Gx, Microsoft Edge and Brave (current versions as of October 2022).

BellChat client is a responsive web application, for which CSS was used. Responsiveness gives the application the ability to adapt to any device regardless of screen size. For voice interaction between a user and BellChat, the SpeechRecognition application programming interface (API) was used. In addition, it employs WebSockets for the exchange of messages between users. WebSockets allow the client in client/server applications to receive unsolicited information, which is not normally the case in a web application [25].

BellChat's login interface allows a user to log in with his own account of the application, for which the user had to register beforehand, or with a third-party account (Facebook or Google). Figure 1 shows the screenshot of the chat screen. The logged in user is a hearing-impaired person. The user has sent a text message to his contact *johannapea.* Likewise, he has received an audio message as a reply from this user. BellChat has automatically converted the audio content to text so that the user is aware of its content. BellChat shows both the original message (audio) and the text of its content.

Server layer. In web applications it is usual to have at least a three-tier architecture, which is the case of BellChat. The second layer, i.e. the layer with which a client interacts is the application server (also the web server) where BellChat is hosted. The web application was developed in Java with its JSF 2.3 framework. Moreover, it was developed using the model-view-controller (MVC) model, which makes the web application has all the advantages of this model [26]. In addition, in this layer

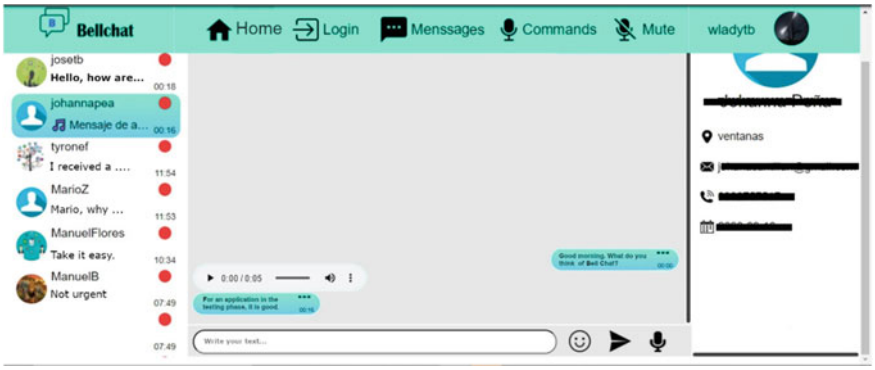

Fig. 1 Screenshot of the message receiving and sending tray in BellChat

we find the sockets endpoint, which makes it possible to send and receive data in real time [25]. All this runs on the Glassfish Server 4.1 application server.

Data layer (database server): The third layer of a three-tier architecture is the data persistence layer [27]. PostgreSQL 13 was the database server on which the BellChat data persistence was implemented.

The tools and technologies used in the development of BellChat are free tools for education and research, so that the cost of producing the application would be the purchase of the domain, server rental and maintenance. In addition, as it is for vulnerable groups of people such as the visually impaired, the hearing impaired, the mobility impaired and the elderly, it is possible to try to obtain all services free of charge.

6 Evaluation of BellChat

Both the elicitation of requirements and the evaluation were carried out through an indirect survey. The answers expressed by the participants were taken directly by the researchers. Among the questions asked to elicit requirements for the implementation of BellChat were demographic questions such as age, disability or not, type of disability, percentage of disability, experience in the use of computer applications, among others. Questions to identify user needs included the difficulties of using third party tools for screen reading (in the case of people with visual impairment), tools for transcribing audio to text and captioning a video for people with hearing impairment.

On the other hand, the questions to obtain the acceptance criteria of BellChat and the possible improvements that can be implemented sought to know from the respondents the importance for them of the functionalities implemented in BellChat and the ease of use of these functionalities. In addition, we wanted to know what

features BellChat lacks, what features could be improved and a general opinion of BellChat as a whole.

Six people accepted to take part in the evaluation. Three of them have a diagnosed visual disability. An elderly person had reduced vision and tremor in his hands. Two people have a hearing disability. There was no collaboration from people with motor disabilities.

The opinion of 100% of the respondents on the implemented functionalities is they are very useful, both the transcription of text-to-speech messages for visually impaired people and voice-to-text messages for hearing impaired people. In addition to considering the auto-configuration of the application according to user profile to make communication between users with different disabilities more transparent, one suggestion everyone made was BellChat should be implemented as a mobile application. The assessment of the user-friendliness of the functionalities of BellChat is related to the experience in using computer applications and to the percentage of disability of the respondent. People with little experience in using computer applications in general and with a high percentage of visual impairment were a bit self-conscious about using the application, but in the end they found it easy to use. While people with a lot of experience in using computer applications needed a brief guide in the use of the application; in the end they stated that it was very easy to use.

7 Conclusions and Future Work

This paper has presented the development and a first evaluation of BellChat, an application for interpersonal communication aimed specifically at people with visual, hearing and motor disabilities, and older people with some pathologies. It is very useful for people considered by society to have normal abilities, who can be doing other tasks while listening to or sending messages to their contacts. Without a doubt, the social group with disabilities is only recently being considered when developing web applications open to the public. The use of web applications for interpersonal communication makes people feel that they belong to a group or society.

BellChat was developed following the Scrum development and project management framework, with some adaptations. Scrum proved to be a framework capable of adapting to a project with a very small team. For the development of BellChat, the team consisted of four people: product owner, Scrum master and two developers. The experience of developing the same between the Scrum master and the developers makes the developers more collaborative to the project goals.

The evaluation of BellChat has motivated the project team to propose soon an application that uses WhatsApp services and has an inclusive interface especially for people with visual, hearing and motor disabilities, as well as elderly people, without leaving out people without physical disabilities and to try to include people with intellectual disabilities. Also, the authors plan to develop a native Android and iOS application as a future work for the convenience of users. Although the current web application is responsive, the user must use a browser to access it. As BellChat was

developed using the MVC development model, its business logic can be reused in other types of applications.

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Characteristics Improving of an UWB Circular Monopole Antenna by Applying Geometrical Design Modifications

Jonnathan M. Ayabaca-Espinoza, Pablo F. Cochancela-Solorzano, Luis F. Guerrero-Vsquez, Jorge O. Ordoez-Ordoez, and Paul A. Chasi-Pesantez

Abstract This paper presents the application of different design techniques to a circular patch antenna with resonant frequency of 3.5 GHz. The techniques used in the monopole modification were ground plane modification, feed line modification, insertion of slots, and notch filters. After applying the above, the designs were simulated getting the antenna to operate within the Ultra Wide Band (UWB) range. Simulation results show how the antennas characteristic values change, such as their bandwidth, gain, and the resonant frequency where they are best coupled. To test their performance, antennas were built using an FR-4 substrate, with a thickness of 1.5 mm. Fabricated antennas results are in accordance with the parameters obtained in the simulation. In this way, it is determined that depending on the antenna application, one or another technique can be applied, thus improving its bandwidth, gain, or maximum sensitivity to the resonance frequency.

Keywords UWB antennas · Design techniques · Patch antenna · Slots · Notch filter

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1 Introduction

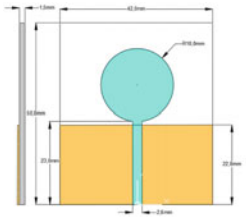
In recent years, society has been immersed in a revolution in telecommunications networks and services that implement wireless technology, thus providing greater ability to communicate with better performance than provided in wired systems [1]. Currently, it is hard to imagine a life without instant communication anywhere [2]. Over the years, different communication technologies have evolved, and along with this, communication standards have been generated that help the development of new systems and applications, reducing limitations and errors when communicating [3].

A way to improve wireless communication is by designing new antennas or modifying existing models, increasing or improving their characteristics [4–6]. Antennas optimization is achieved using different techniques and structural modifications applied to the geometry of radiating elements. Design techniques are mainly focused on generating modifications in antenna shape inserting slots, modifying the ground plane and varying the feed line [7].

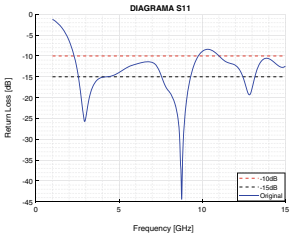
Currently, one of the most used antenna types is patch and microstrip antennas, due to the possibility of obtaining small size designs, with short manufacturing times and suitable gains for current communication systems [8–10]. In the context of communications new generations deployment, devices are intended to be capable of transferring large amounts of information at high transmission rates. Patch antenna designs seek to work within the frequency range known as Ultra Wide Band (UWB), with frequency values ranging from 3.1 to 10.6 GHz [11].

With this in mind, we present the simulation, analysis, and manufacture of a circular monopole antenna designed for a resonance frequency of 3.5 GHz and modified using different techniques, with the aim of improving coupling and generated bandwidth [12–14]. Modifications made in ground plane geometry and power line are presented, as iterations. In addition, slots were inserted in ground plane. With variations made, it was possible to improve bandwidth, gain, and coupling. This work also presents a partial analysis of each iteration, highlighting the results generated by modifications.

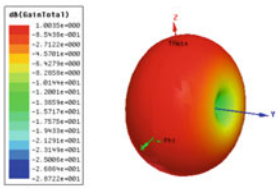
The document is organized as follows. In Sect. 2, geometry and main characteristics of circular monopole antenna used as a starting point for this document are presented. For the development of this antenna, values that generate stable results for transmission were considered. In Sect. 3, we apply three different techniques which are ground plane modification, power line modification, and slots insertion (notch filters). With these techniques, we modify antenna main characteristics described above. Finally, in Sect. 4, results generated from simulations and manufactured antennas characterization are presented.



(a) Circular monopole design.



(b) S_{11} Diagram.



(c) 3D radiation diagram.

Fig. 1 Initial design before modifications

2 Antenna Design

For the design of proposed antenna, we use FR-4 substrate with a thickness of h = 1.5 mm and a dielectric constant $\in_r = 4.7$. Antenna geometry is shown in Fig. 1a, it has a length $L_s = 50.00$ mm and a width $W_s = 42.00$ mm, and it has a circular patch with a radius $a = 10$ mm and a 50Ω microstrip feed line, with a dimension up to the circular patch of $L_1 = 23$ mm high by $W_1 = 2.6$ mm wide [11].

Mathematical process for calculating dielectric permittivity, operating frequency, and radius of circumference is detailed below.

$$\in_r = 4.7h = 1.5 f_r = 3.5 \tag{1}$$

$$F = \frac{8.791 * 10^9}{f_r * \sqrt{e_r}} = 1.1585 \tag{2}$$

$$a = \frac{F}{\sqrt{1 + \frac{2h}{\pi e_r F} ln(\frac{\pi F}{2h}) + 1.7726}} = 0.99\,\text{cm} \tag{3}$$

$$a = 10\,\text{mm} \tag{4}$$

where

- $\in_r$ is the dielectric constant of the material.
- F is given by Hz.
- h is the substrate height (mm).
- f_r is the resonant frequency (GHz).
- a is the radius of the circle (mm).

Through Eq. 3, the radius of 10 mm patch was calculated using dielectric constant, substrate height, and frequency. In Fig. 1b, c, S_{11} plot and antenna radiation pattern are shown, respectively. Bandwidth is in the range of 2.3–9.7 GHz and a resonance peak of −44.39 dB. Radiation pattern is stable, and gain is 1.0035 dB. This serves as a reference for modifications made later.

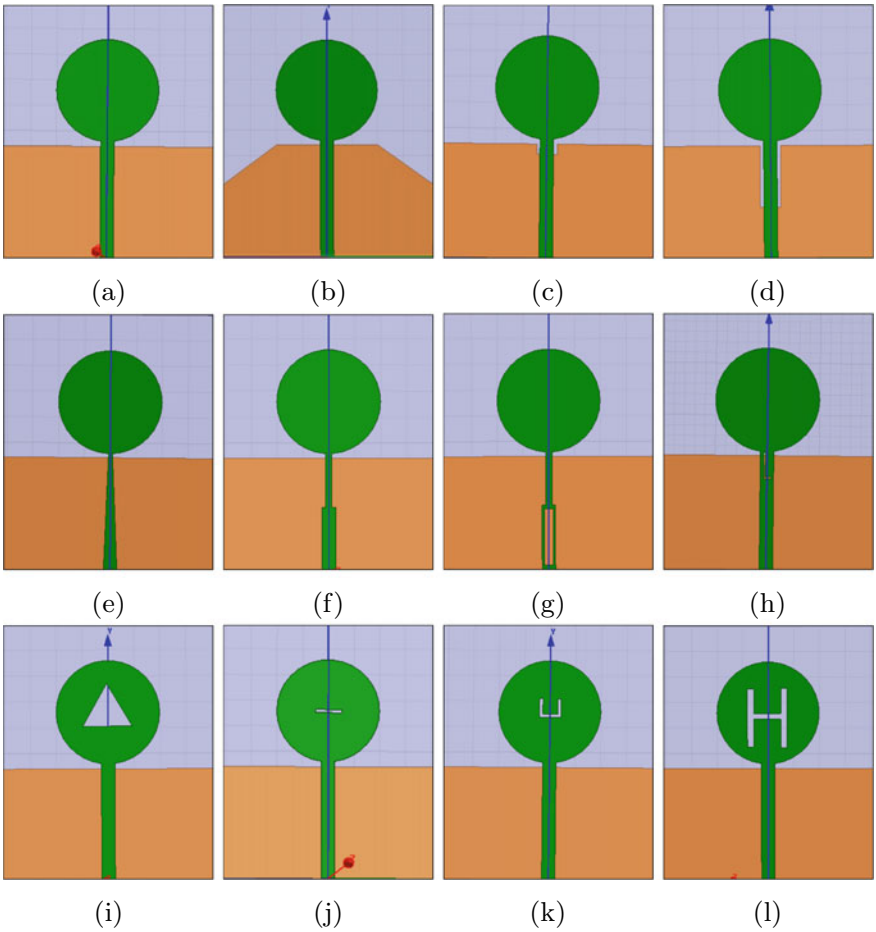


Fig. 2 Antenna designs: ground plane modification [figures (**a**)–(**d**)], feed line modification [figures (**e**)–(**h**)], slot insertion [figures (**i**)–(**l**)]

3 Antenna Modification Design Techniques

3.1 Ground Plane Modification

Modifications made to the ground plane of circular monopole are shown in Fig. 2a–d. Shape and structure of ground plane are varied, thus generating bandwidth growth. Table 1 details values obtained from each iterations, while Fig. 4 shows S_{11} results of all iterations performed. The best result is found in the third iteration (Fig. 2c), which consists of a rectangular insertion in the plane. This insertion generates a bandwidth in the range of 2.2–15 GHz, a gain of 8.42 dB, and the lowest resonance peak of −36.44 dB.

Table 1 Comparative table

Analysis of ground plane modification			
N	Bandwidth (GHz)	Gain (dB)	Resonance (dB)
T1	2.3–9.7	1.00	−44.39
T2	2.5–12.68	9.94	−21.62
T3	2.2–15	8.42	−36.44
T4	2.5–12	8.45	−40.92

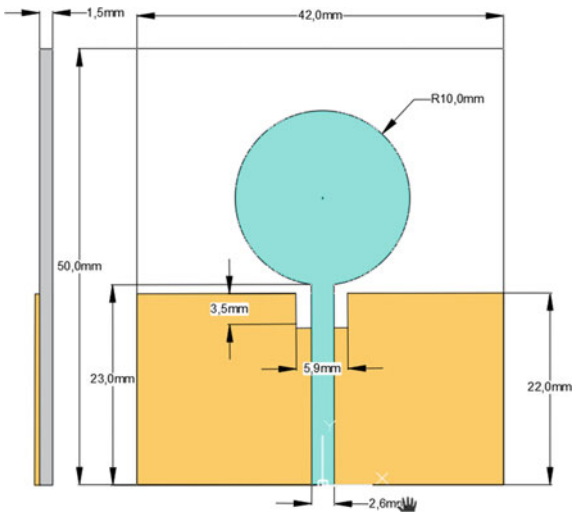


Fig. 3 Ground plane modification in circular monopole

Figure 3 shows antenna dimensions with the best results. It presents a substrate dimension of $h = 1.5$ mm with a dielectric constant $\in_r = 4.7$, length $L_s = 50.00$ mm, and width $W_s = 42.00$ mm. A circular patch with radius of $W_s = 42.00$ mm on substrate surface, line lengths $L_1 = 23$ mm, $W_1 = 2.6$ mm, and insertion in the plane of 3.5 mm × 5.9 mm.

3.2 Feed Line Modification

Figure 2e–h shows iterations related to feed line modification. These modifications generate an expansion in bandwidth. In Fig. 6, S_{11} diagram of each iteration is presented. In addition, Table 2 details the results of all iterations. We can identify that the best performing design is the first iteration, with a bandwidth in the range of 2.7–15 GHz, gain of 6.76 dB and lowest resonance peak −24.94 dB. Figure 5 shows antenna geometry with the best characteristics. Substrate, dielectric constant, length, width,

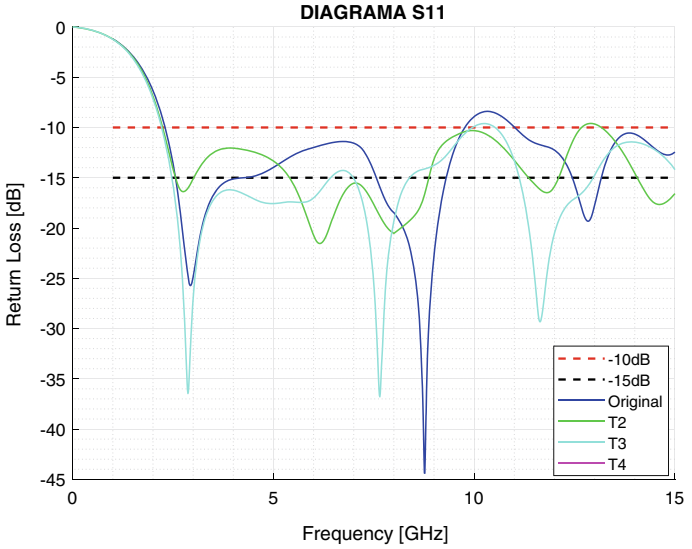


Fig. 4 S_{11} diagram

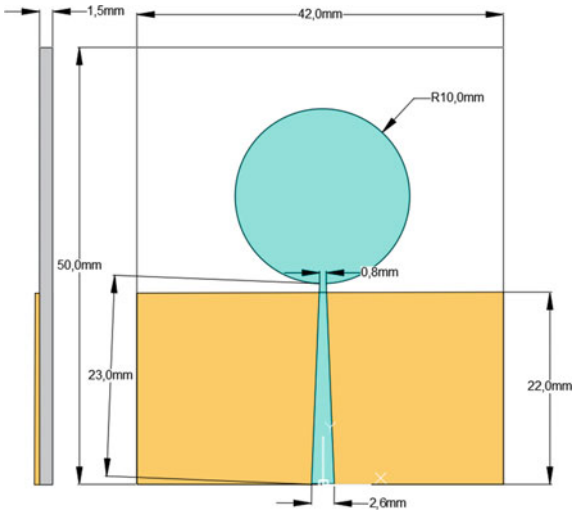


Fig. 5 Feed line modifications in circular monopole

and radius are identical to initial antenna. Dimensions of feed line are $L_1 = 23$ mm, $W_1 = 2.6$ mm with a decrease at the junction with the circular patch $W_1 1 = 0.8$ mm (Fig. 4).

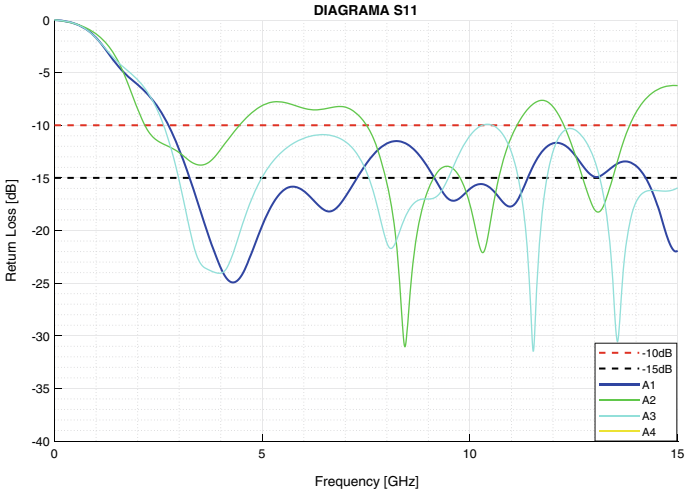


Fig. 6 S_{11} diagram

Table 2 Comparative table

Analysis of feed line modifications			
N	Bandwidth (GHz)	Gain (dB)	Resonance (dB)
A1	2.7–15	6.76	−24.94
A2	7.5–11	6.68	−31.03
A3	2.6–10.4	7.17	−31.45
A4	2.21–10.02	8.69	−35.56

3.3 Slots Insertion

Iterations that modify the antenna based on insertion of notch filter slots are shown in Fig. 2i–l. This type of variation does not improve bandwidth, but variations in the lowest resonance peak are observed. Figure 8 shows values of S_{11}, while Table 3 shows the results of all iterations. It can be identified that iteration 1 is the best, with a bandwidth between 2.2 and 9.8 GHz, gain of 1.65 dB, and the lowest resonance peak at −46.12 dB.

Figure 7 shows the best performing antenna geometry. Dimensions are identical to previous cases with an equilateral triangle insertion at the center of mass of 9.5 mm (Fig. 8).

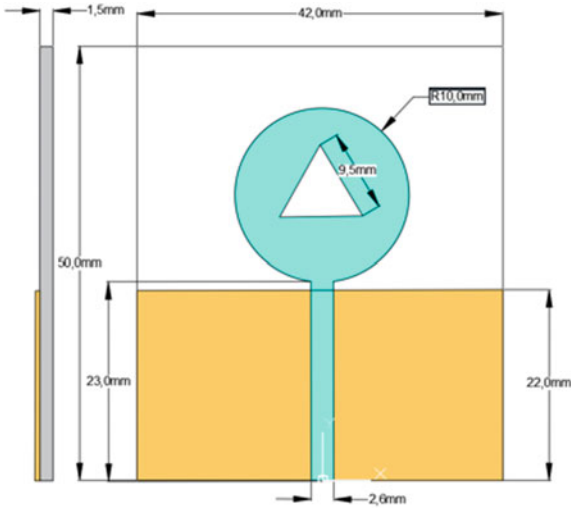


Fig. 7 Slot insertion in circular monopole

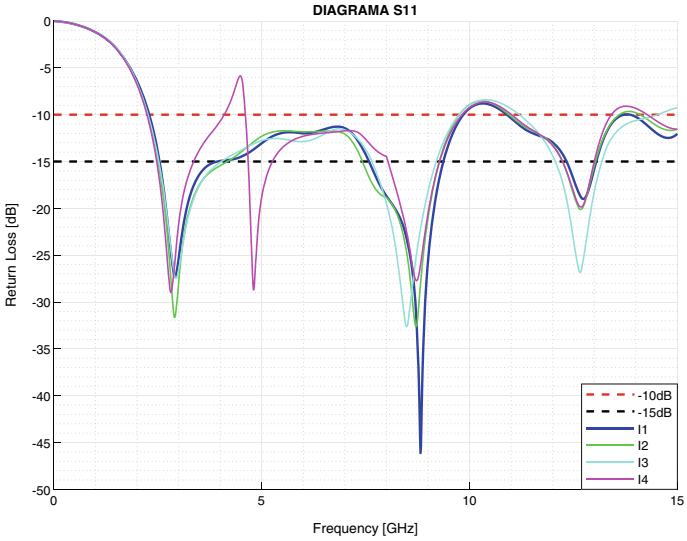


Fig. 8 S_{11} diagram

Table 3 Comparative table

Analysis of modifications based on insertion slots			
N	Bandwidth (GHz)	Gain (dB)	Resonance (dB)
I1	2.2–9.8	1.65	−46.12
I2	2.2–9.7	9.24	−32.50
I3	2.27–9.7	8.85	−32.63
I4	4.6–9.8	−1.89	−38.67

4 Measurements and Results

Figure 12 shows images of manufactured antennas and radiation patterns obtained from simulation and characterization performed in the laboratory. S_{11} patterns were obtained with a VNA working in a range of 5 kHz–15 GHz, while radiation patterns were obtained using a transceiver with an operating range of 500 kHz–6 GHz, in an environment isolated from noise and without interference.

4.1 Ground Plane Modification

Figure 9 shows a comparison between S_{11} of simulated and measured data. A satisfactory relationship is observed, with coherent resonance results and a slight expansion

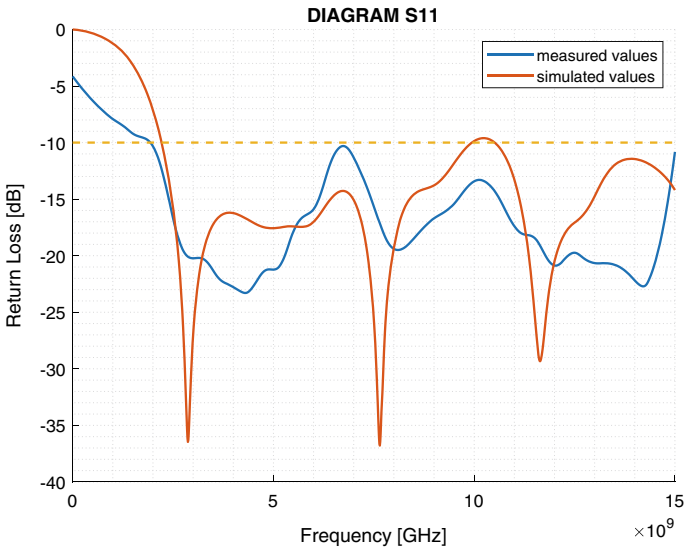


Fig. 9 S_{11} diagram (measured vs simulated) ground plane modification

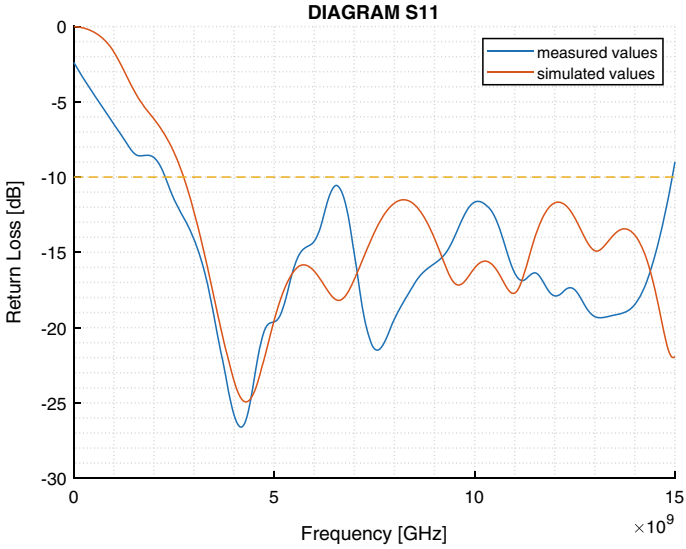


Fig. 10 S_{11} diagram (measured vs simulated) feed line modification

in bandwidth. Radiation patterns show much stability and do not differ widely from the patterns generated by initial monopole.

4.2 Feed Line Modification

S_{11} comparison of simulated and measured data obtained from the feed line modifications is shown in Fig. 10. Measured results show that antenna complies with UWB characteristics, although toward 15 GHz, S_{11} exceeds -10 dB, while in the simulation they remain below. Radiation patterns are stable and have omnidirectional behaviors in both cases.

4.3 Slot Insertion

Figure 11 shows that according to S_{11} diagram, bandwidth of manufactured antenna was higher than in simulated antenna. It is observed that antenna coupling increased, and although considerable resonance peaks are not achieved, it maintains a good performance and UWB characteristics (Figs. 12, 13 and 14).

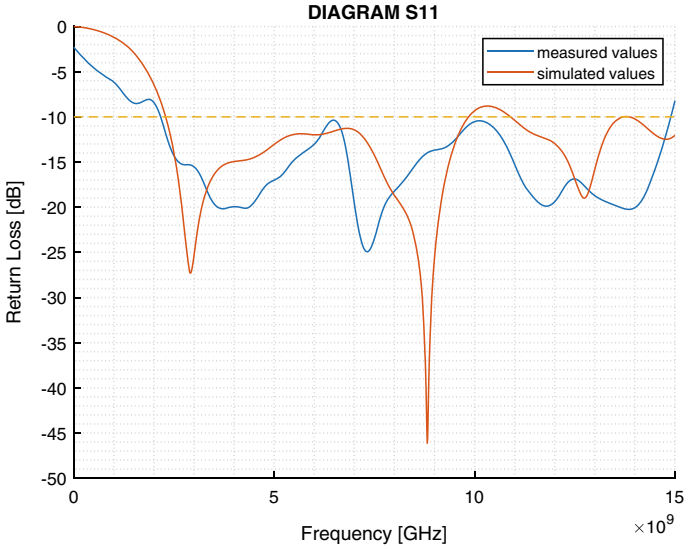
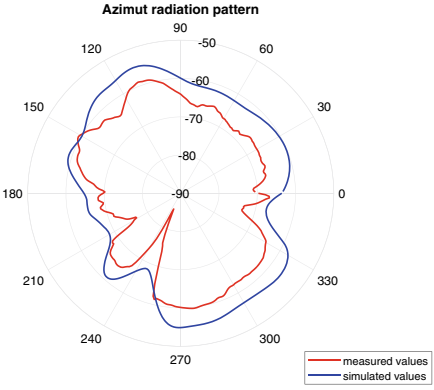


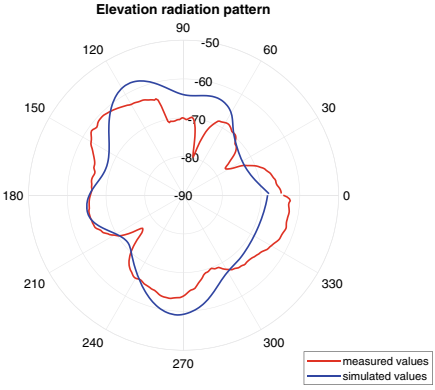
Fig. 11 S_{11} diagram (measured vs simulated) slot insertion

(a) Patch.

(b) Ground.



(c) Azimuth plane.

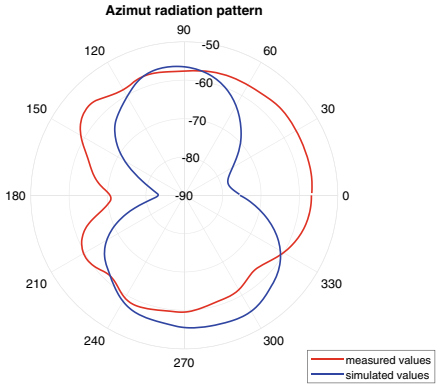


(d) Elevation plane.

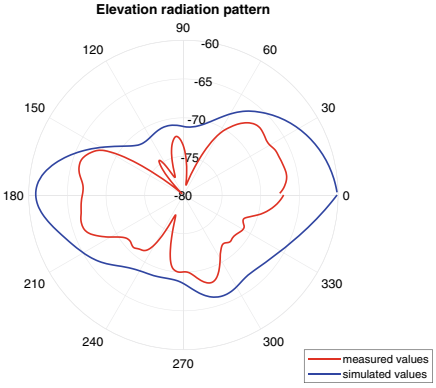
Fig. 12 Ground plane modification: manufactured antennas and radiation patterns

(a) Patch.

(b) Ground.



(c) Azimuth plane.



(d) Elevation plane.

Fig. 13 Feed line modification: manufactured antennas and radiation patterns

5 Conclusions

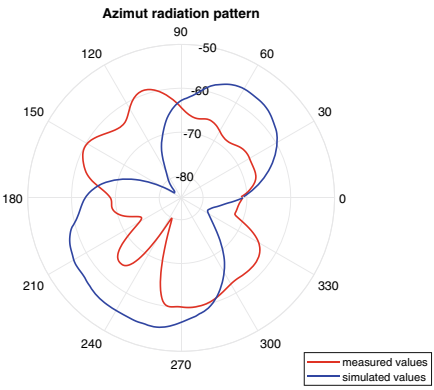
The analyzed techniques generate relevant changes in the patch antenna characteristics. Mainly, they help to improve antenna characteristics related to bandwidth, coupling, and gain. These results provide guidance regarding the modifications that can be performed on the antennas to obtain specific results. Although the modifications start from a UWB design, it is possible to improve the final characteristics; however, the processes to obtain the improvements are based on empirical processes with constant modifications. To avoid this process, it is possible to use optimization algorithms that perform the modifications automatically.

Modification of the ground plane generates a greater number of coupling peaks, where the antenna will perform optimally. In addition, it greatly expands the bandwidth. This modification is used in most designs in the literature and is essential to achieve UWB characteristics. The trend indicates that a good bandwidth is obtained with the partial ground plane at the junction of the feeder and the patch.

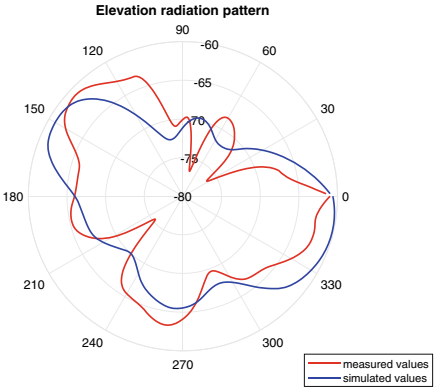
The feed line modification contributes considerably to the bandwidth broadening, achieving UWB characteristics. A reduction in peak coupling is also observed, where the antenna has increased functionality. This tells us that feed line modifications directly influence the antenna coupling.

(a) Patch.

(b) Ground.



(c) Azimuth plane.



(d) Elevation plane.

Fig. 14 Slot insertion: manufactured antennas and radiation patterns

With the slot insertion technique, we obtain an antenna with higher coupling at a single frequency, but due to this our bandwidth was reduced. We experimented with various slot designs, each generating higher coupling at different frequencies depending on their shape and size. In this case, we can compare the results with those obtained with the insertion of notch filters. Although certain point characteristics are improved, we could have the rejection of specific frequency bands.

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Real-Time Multi-Class Classification of Water Quality Using MLP and Ensemble Learning

Essa Q. Shahra, Shadi Basurra, and Wenyan Wu

Abstract The major goal of water management planning and the iterative evaluation of operational policies and procedures is to ensure that good water quality is always maintained. Effective water monitoring requires examining many water samples, which is a time-consuming and labor-intensive process that takes a lot of effort. This paper aims to evaluate the quality of drinking water samples with high accuracy by using multi-class classification models: multilayer perceptron (MLP) and ensemble learning. Real datasets with different sizes that include the essential water quality parameters have been used to train and test the developed models. The results showed the effectiveness of the developed models in detecting water contamination with high accuracy in both datasets used. The results demonstrate that bagging ensemble learning outperforms the multilayer perceptron with an overall accuracy of 94% for station-A and 92% for station-B compared to MLP, which shows an overall accuracy of 89% for station-A and 87% for station-B.

Keywords Classification · Ensemble learning · MLP · Water quality

1 Introduction

It is difficult to maintain water quality in water distribution system (WDS) because of the impacts of vast distances and long periods spent traveling from the water supply to the consumers [1]. In addition, the nature of WDS renders it susceptible to external disruptions, such as sabotage, because of its design. Therefore, researchers

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in academia and industry have been looking into creating contamination warning systems due to these considerations [2]. Two essential components to creating these systems are sensor placement techniques in a WDS and data processing methods for analyzing the collected data [3]. It is possible to evaluate water quality with the help of water quality sensors installed on a WDS. The optimum sensor placement technique will enhance detection efficiency by gathering all the data. Sensors generate large quantities of data streams, which need to be analyzed in real time to identify anomalous occurrences, particularly those that may result in water contamination in WDS [4]. Furthermore, the procedure of detecting water contamination was characterized as being very difficult [5]. It includes using common water quality indicators such as turbidity, electrical conductivity, pH, and the concentration of residual chlorine to identify pollution [6]. In light of these measures, it is also necessary to develop a detection model that, based on these data, accurately detects changes in water quality. The development of multi-parameter water quality models is complex due to the massive data and the many factors that must be considered [7]. Numerous classification methods based on statistics and machine learning have been proposed, including linear discriminant analysis (LDA), regularized discriminant analysis (RDA), support vector machines (SVM), quadratic discriminant analysis (QDA), and k-n, and neural networks (NN). This paper aims to investigate how ensemble learning helps enhance the accuracy of predicting water contamination in the water distribution system. This paper's organization is as follows: Section 2 reviews the relevant work conducted in the area, Sect. 3 explains in detail the methodology of the models applied in this work, and Sect. 4 presents the results and the discussion. Finally, Sect. 5 concludes the work.

2 Related Work

This study looks into the approaches used to assist tackle water quality challenges. In most cases, traditional laboratory analysis and statistical analysis are utilized in research to help determine water quality. Still, some investigations use machine learning approaches to help identify an optimum solution to the water quality problem. Authors in [8] used Monte Carlo optimized artificial neural networks to predict water quality in the Danube River (Serbia). They predicted 18 common water quality metrics (WQPs) on active monitoring sites. Shakhari and Banerjee in [9] proposed an algorithm for an efficient analysis of the water quality data. The proposed method not only monitors continuous water quality, but it also develops a superior classification model for other continuous datasets. Instead of reducing the dataset's attributes, they provide three extra reference indications that depend on the real characteristics. The classification accuracy of the proposed approach is compared to others classification models. In comparison with previous approaches, the proposed method provides higher classification accuracy. In [10], they have created a system for monitoring two water quality indices in real time: chlorophyll-a (Chl-a) and dissolved oxygen (DO). They used CEEMDAN and VMD algorithms with LSSVM and ELM models to cre-

ate a two-layer decomposition. [11] have developed a classification system called the Water Quality Classification Index in an effort to create a four-level pollution index on the water quality of the marine environment. (Dilmi and Ladjal [12]) they proposed a novel strategy to improving water quality classification that is based on the fusion of deep learning and feature extraction techniques. They used an advanced deep learning technology called Long Short-Term Memory Recurrent Neural Networks (LSTM-RNNs) to build an intelligent model for predicting drinking water quality. Authors in [13] investigated a set of supervised machine learning methods for predicting the water quality index (WQI), a unique index for describing the general quality of water, and the water quality class (WQC), a separate class formed based on the WQI. Temperature, turbidity, pH, and total dissolved solids are the four input parameters used in the suggested technique. Several machine learning, statistical, and mathematical models for contamination detection have been reviewed. Accordingly, we aim to investigate and develop two machine learning models: MLP and ensemble learning in a real dataset to obtain high multi-class classification accuracy.

3 Methodology

Two distinct models are used in this work: multilayer perceptron (MLP) and ensemble learning.

3.1 Multilayer Perceptron

A sequential model comprised of three layers was used to construct MLP: Input layer: This layer takes the seven water quality indicators that we utilize in our dataset, and its dimension is 7, but after feature selection, we utilized just six as inputs: turbidity, PH, TOC, temperature, conductivity, and pressure. This layer's activation function is rectified linear. The used method returns the usual ReLU activation maximum (x, 0), the input tensor value, and the maximum of 0. Hidden layers: In this model, two hidden layers were utilized; the first hidden layer had 10 neurons, and the second hidden layer comprised of 8 neurons; in order to activate both hidden layers, it was necessary to utilize the rectified linear function as the activation function. Output layer: The output of this layer is the 5 classes of water samples that are generated. With the softmax activation function, this layer may convert an actual vector into a vector of category likelihood with a single operation. An optimizer, losses, and measurements are all options for MLP implementation in addition to the standard options. We utilized the "Adam" optimizer to build the model. Losses functions are used to determine the quantity of data that should be minimized during training. We used the term "categorical crossentropy" in this instance. Finally, the metrics utilized to assess the model's performance; the accuracy measure is used to evaluate our model.

Table 1 Dataset sample

TIME_ STEP	Cl2	COND	PH	TEMP	TOC	TURB	PRES OP
08/06/2007 00:00	2.06	44.9974	9.52652	14.6669	0.644472	0.18992	35.4681
08/06/2007 00:05	2.07	44.9911	9.52593	14.6564	0.641543	0.191788	35.4726
08/06/2007 00:10	2.07	44.9784	9.53607	14.645	0.650092	0.190603	35.4697
08/06/2007 00:15	2.07	44.9593	9.53467	14.6227	0.625475	0.191484	35.4696
08/06/2007 00:20	2.06	44.9784	9.53114	14.6161	0.64178	0.190641	35.4721

3.2 Ensemble Learning

Bootstrap aggregation, or bagging for short, is a kind of ensemble machine learning used for classification in this study. A bootstrap sample is a random sample from a dataset that has been replaced. Replacement refers to replacing a sample taken from the dataset, enabling it to be picked again and perhaps many times in the new sample. This implies that the sample may include duplicates of the original dataset's instances. The ensemble bagging algorithm is implemented in Python using the scikit-learn machine learning library. The model is constructed using randomness, implying that a slightly different model will be produced each time the method is performed on the same data. The model is evaluated using repeated stratified k-fold cross-validation with three repetitions and 10-folds.

3.3 Datasets

The US Environmental Protection Agency (EPA) provided the dataset used in this research (Koch and McKenna, 2011). This information was gathered from two stations A and B. These datasets can be utilized for both training and testing purposes. For three months, time series at two-minute intervals were gathered. Each station's data include chlorine (Cl), temperature (TEMP), total organic carbon (TOC), PH, pressure (PRES), and conductivity (COND). The datasets for each station are different; station-A has 60,000 time steps, and station-B has 70,000 time steps. See Table 1 which includes a sample of these datasets. The dataset is divided into five classes: Dblue, Purple, Red, Orange, and Yellow. These classifications corresponded to the degree of water contamination. The values were distributed in the range 0–4, with 0 (DBlue) representing clean water (no contaminants) and (Yellow) representing highly contaminated water.

3.4 Feature Selection

The selection of features is one of the most crucial steps in any machine learning task. A feature means a column when a dataset is used. With any dataset, not every column (feature) will necessarily affect the output variable. Feature selection can be made in several ways, but overall, three different categories are available: (1) filtering method, (2) wrapper method, and (3) embedded method [14]. In this work, we have applied the embedded method on our dataset; more detail about this approach is in the next sub-section.

Embedded Method: The embedded method is another feature selection that has been applied to our dataset. This method is iteratively in the sense that the model training process takes care of each iteration and carefully extracts those features which most contribute to the training for a particular iteration [15]. Regularization methods are the most widely used embedded methods that penalize a feature provided a threshold of the coefficient. We have applied the Lasso regularization method, and in this method, if the feature is irrelevant, it will also penalize its coefficient and make it 0. Therefore, coefficient = 0 features are removed, and the remaining ones are taken. Figure 1 shows the importance of all features using Lasso model, and from the figure, we notice that the features are arranged based on their significance, and we can see that the pressure has scored close to zero (0.009) that may remove from the dataset, and we also notice that chlorine got a very high score above 1 this because the output was made based on the chlorine.

4 Results and Discussion

The effectiveness of MLP is discussed in more depth in this section, and the performance was assessed using a confusion matrix that incorporated all metrics. A confusion matrix is an N × N matrix that is utilized to evaluate the outcomes of classification models, where N is the number of desired classes. When comparing actual target values in y-axis to predicted target values in x-axis produced by machine learning models, the matrix may be used to identify differences. This provides us with a comprehensive picture of how well our classification models perform and the kinds of errors that occur. There is a list of rates that are often computed based on the confusion matrix for a classification model called: True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN).

4.1 Multi-class Classification: MLP

Station-A: The confusion matrix of the MLP model for station-A is shown in Fig. 2. This matrix shows the ability of the developed model to correctly predict the samples

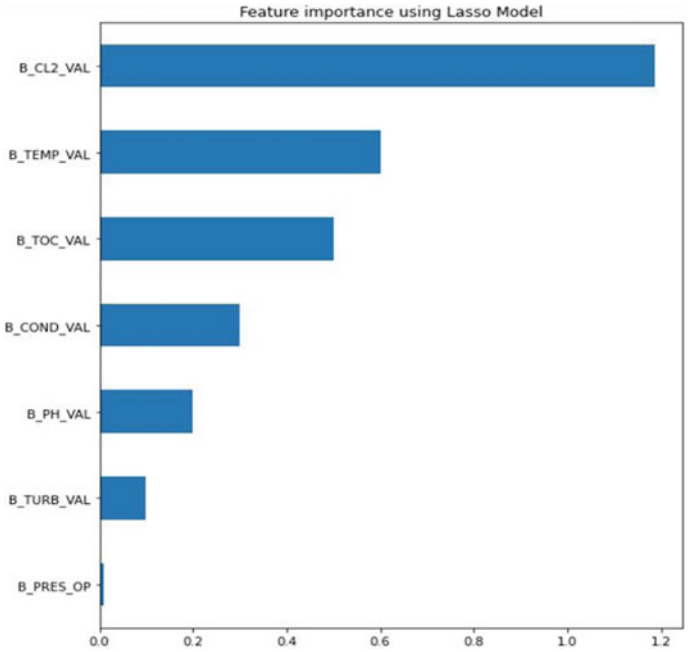

Fig. 1 Feature selection using Lasso regularization

Table 2 MLP performance (station-A)

	FP	FN	TP	TN
DB	826	12864	816	5161
Purple	1042	4261	958	13406
Red	179	472	244	18772
Orange	12	8	41	19606
Yellow	0	3	0	19664

of the water for each class. From this matrix, the model looks a perfect classifier as indicated by the fact that the majority of the values in this matrix are zero. Table 2 presents estimates of the metrics performance (TP, TN, FP, FN, FP) of the MLP-A classifier model, which includes all of the metrics variables. Figure 3 depicts the performance of the MLP in terms of accuracy and loss rate. There is a noticeable reduction in the loss rate as the number of epochs rises, and an improvement in accuracy, until it reaches the SteadyState for both at epochs=100. The accuracy of the MLP model is 94% in total.

Station-B The B-station is the station that contains dataset with the largest size (72,000 sample). The performance of this station was evaluated in the same way of station-A. The confusion matrix was calculated and displayed in Fig. 4, and because

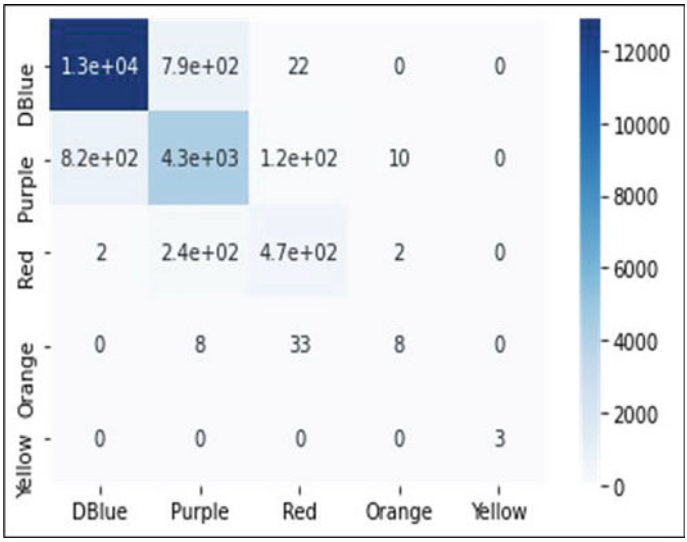

Fig. 2 MLP confusion matrix (station-A)

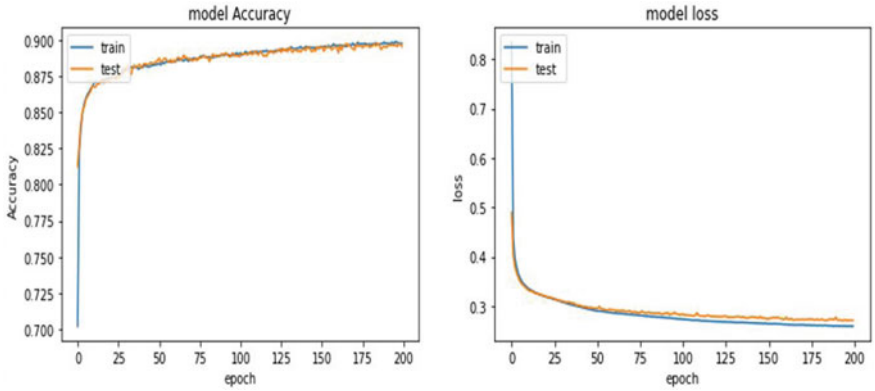

Fig. 3 MLP model accuracy and loss (station-A)

the data used in this station is very large, we will notice the numbers contained in this station are also large, whether they are in the correct prediction or the wrong prediction. Other parameters were also calculated and summarized in Table 3. The accuracy rate of this model and the rate of loss are shown in Fig. 5. The general evaluation showed that the model of this station is estimated at 89.77%, and the loss rate is 30%.

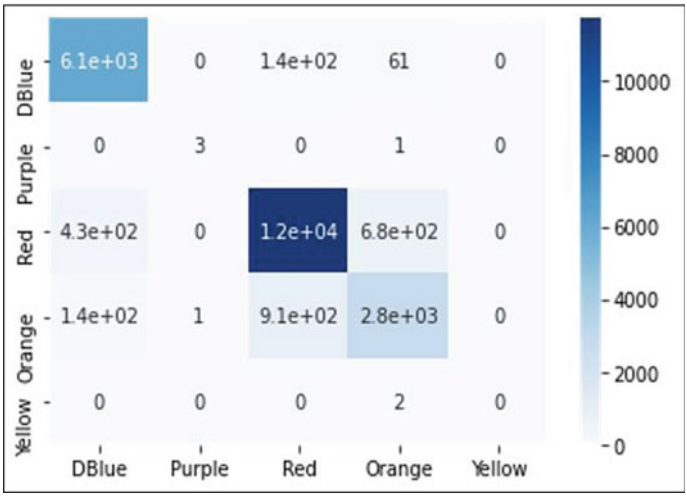

Fig. 4 MLP confusion matrix (station-B)

Table 3 MLP performance (station-B)

	FP	FN	TP	TN
DB	575	6123	196	16151
Purple	1	3	1	23040
Red	1043	11730	1115	9157
Orange	746	2824	1051	18424
Yellow	0	0	2	23043

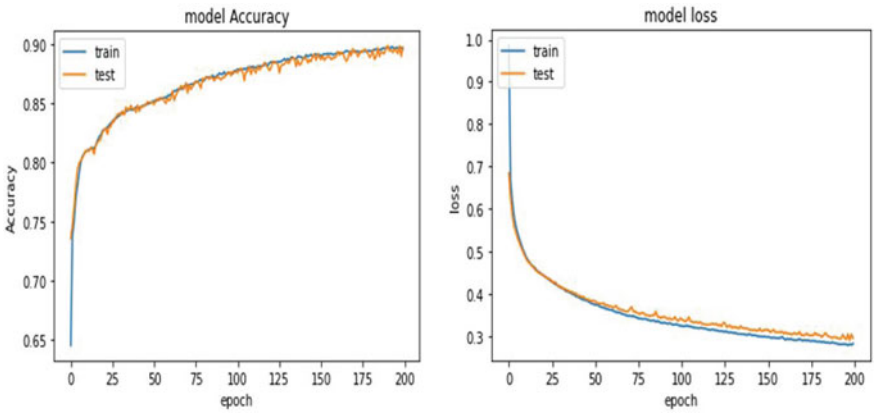

Fig. 5 MLP model accuracy and loss (station-B)

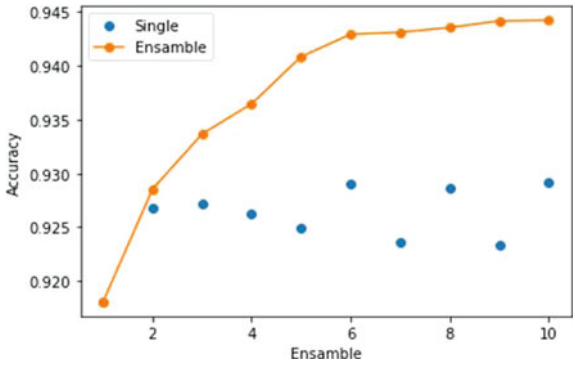

Fig. 6 Ensemble classification, station-A

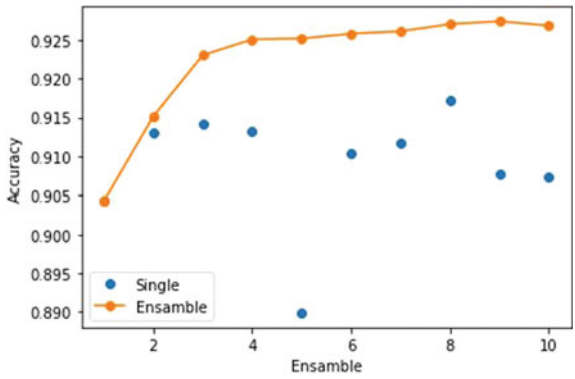

Fig. 7 Ensemble classification, station-B

4.2 Multi-class Classification: Ensemble Learning

Station-A: The accuracy of the model has been compared to the ensemble members as shown in Fig. 6. We can notice that after approximately two members, the bagged ensemble outperforms the performance of any individual model. The overall accuracy of the model has been enhanced using bagged ensemble up to 94%.

Station-B: The performance accuracy of the model is shown in Fig. 7. We can notice that after approximately two members, the bagged ensemble outperforms the performance of any individual model. The overall accuracy of the model has been enhanced using bagged ensemble up to 92%.

4.3 Discussion

We have used machine learning in this paper to accurately detect contaminants in drinking water. Two different methods have been used to accurately test the models' abilities to classify the contamination and these models applied to two datasets of

Table 4 Performance of our classification models

	Multilayer perceptron network (%)	Bagging ensemble learning (%)
Station-A	89	94
Station-B	87	92

different size. In general, the results showed that bagging ensemble learning was able to overcome the MLP models and showed a significant improvement in the accuracy of classification (see Table 4).

5 Conclusion

This paper discusses how to utilize machine learning to classify water quality in a water distribution system. This was achieved by analyzing and comparing the performance of two techniques, namely MLP and bagging ensemble learning. The study was conducted using real-world datasets on water quality from two different areas (A, B) with different sizes. The dataset includes chlorine, temperature, turbidity, conductivity, PH, pressure, and total organic carbon. The data has been labeled into five different categories: no contamination, low contamination, medium contamination, above average, and highly contaminated. The results showed that bagging ensemble learning overcame MLP and showed a significant improvement in the accuracy of classification. The results showed that our models used multi-classifications with high accuracy using MLP and ensemble learning (89%, 94%).

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Improving the Resume Verification Process of Financial Professionals Using Blockchain Smart Contracts

Adel Khelifi, Ali Deeb Khalil, and Hurma Ehtesham

Abstract Traditional verification of professional credentials is time-consuming, lacks formal interaction, and is forgeable. Therefore, unethical behavior may infect the profession as its membership grows. However, new technologies make accounting and auditing of resumes easier to compile and validate. Blockchain eliminates unethical issues by integrating members' documents, qualifications, and credentials on a single platform for fast verification. Blockchain-based solutions automate membership application processes for speedy verification, reducing paperwork. The goals of this research are to show how accountants and auditors can meet local and international standards by using Blockchain, how regulators can build a secure and trusted platform to register and view members' profiles for verification, how to maintain the integrity of exam-based qualification accreditation, and how to reduce fraud and falsification. This research analyzes Blockchain topologies and smart contracts to improve resume verification for financial professions. This research helps establishing an auditing and accounting Blockchain architecture to authenticate professionals resumes and credentials.

Keywords Blockchain technology · Smart contracts · Resume verification · Financial professions

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1 Introduction

1.1 Motivation

Modern businesses require reliable financial data. According to Gillet, a financial practitioner boosts the reliability of financial data by following IAASB guidelines (IAAB) [1] . Businesses strive to improve their image by giving accurate, long-term information. Professionals must make key judgments to ensure public financial information's regularity. Furthermore, they must be educated and internationally accredited [2]. Universities, institutes, and professional organizations like the AICPA provide students and members with accounting and auditing information. Secondly, they ensure the validity of exams [3]. Exams should fulfill worldwide demand, and those without a global benchmark pass rate should have above-average sectional pass rates. Employers also consider accountants' careers while hiring and accountants experience improves employee quality. Human mistake makes accounting fraud tough despite rules and norms. Thus, Blockchain technology and smart contracts are creative solutions to validate recorded information and make them immutable.

1.2 Aims and Objectives

A national and worldwide agency develops accounting and auditing standards and administers tests. This study aims to analyze accounting and auditing technology advances and construct a Blockchain architecture that matches the profession and automates the process [4]. Blockchain can improve the verification and validation of resumes and qualifications. Smart contracts implement verification and validation algorithms for the aforementioned purpose. There are two main contributions of this research:

1. Creation of a private Blockchain architecture
2. Development of a Blockchain smart contract algorithm to improve the verification process of professionals' resume.

The design is supported by the consensus foundation of Hyperledger Fabric. Using Merkle tree algorithm and GoLang, smart contracts are constructed. The Architecture also facilitates peer-to-peer transactions. The intelligent contracts produce a safe, immutable, and transparent Hyperledger Fabric. Moreover, the architecture accelerates state queries. CouchDB updates states on demand, hence accelerating queries. Docker, Node.js, Golang, Angular, CouchDB, and SQLServer are supported.

2 Methods

2.1 The Proposed Blockain Approach

Blockchain smart contracts increase financial and nonfinancial information security [5]. Encrypted transactions are made possible by cutting-edge technology. The immutability and consensus properties of Blockchain secure data, its qualities make it useful in common situations. Traditional resume checking asks applicants to justify all content that may be wrong. The employer may not realize whether a degree is phony. Such fraudulent documents jeopardize the profession's authenticity. Therefore, Blockchain smart contracts centralize data (Scalability). Financial professionals can research members' information before accepting it. Before joining, members can use stored information to research local regulators. The Blockchain smart contract contains all contract terms and conditions, making them easy to understand and reducing conflict. Smart contracts protect authorship and IP by improving transaction throughput [6]. Throughput measures processed Blockchain transactions in a given amount of time. The financial professional body might advertise memberships for practitioners or aspiring practitioners, improving its income. The data is only accessible to authorized personnel. On Blockchain, the public can obtain accounting and auditing resumes. The works of financial specialists enhance their reputation. Blockchain smart contracts keep document features and minimizes latency. This is deployment-to-completion time or transaction average. Blockchain can store any degree-related information and future degrees and certifications can use this technology. Smart contracts prevent certificate fabrication and reuse. The body can also utilize Blockchain to ban members who disobey contract conditions. Blacklisting helps preserve discipline in a profession. Furthermore, the proposed system addresses the inherent security concerns of Blockchain-based Hyperledger. These include potential for Denial of Service: DOS attacks, Consensus manipulation, Membership Service Provider (MSP) compromise, and Smart Contract Exploitation. These threats are addressed through proactive security intelligence measures [7, 8].

2.2 Architecture of the Proposed System

The proposed architecture displayed in Fig. 1 comprises distinct components that work together to improve system efficiency. The architecture aims to achieve two objectives, which include verification of exam-based professional qualifications and verification of resume information. It examines how accountants and auditors, as well as the accounting authority can use secure and efficient means to process applications. The critical components of the architecture include End User, Blockchain Application, and Blockchain Network.

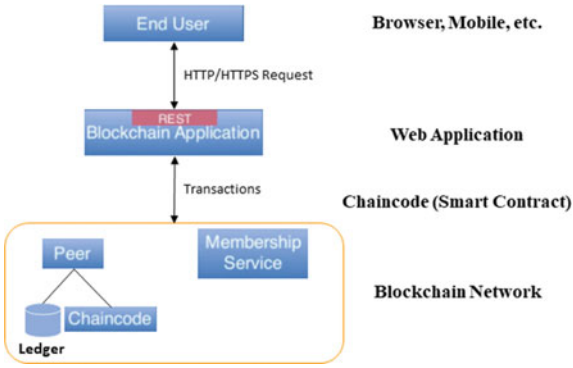

Fig. 1 Simplified architecture of the proposed system

End User The client for the platform could be an educational institution that uploads student certificates to Blockchain, or a professional accounting organization that verifies the credentials of accountants. Users can connect via a variety of devices such as mobile phones, browsers, and personal computers [9]. The platform can be utilized to document transactions, make payments, verify documents, etc. The system accommodates user requirements by identifying and meeting them. The user may wish to verify a resume or membership status. They will utilize mobile devices to access the Blockchain application. However, the end user type is described as follows:

- Regulator: This is a local accrediting organization. A regulator can verify the resumes of members and recognize their expertise.
- Validator: An employer, accreditation body, university, or government agency checks worker submissions such as identification, qualifications, and work history.
- Workers: Individuals who seek to verify the resumes and get recognized in their field.
- Admin: Admin of the platform.

Web Application This is the website that hosts the Blockchain solution. To record a transaction, a client can use an HTTP browser on their computer, mobile device, or any other device to access the web application. The web application can be accessed through many IT devices, hence easy accessibility. Because increased digital advancements have made smart phones more accessible to the majority of the world's population, many people can easily install and use the Blockchain solution.

Membership Service This node allows users to identify themselves for business transactions with other network users. Open-source Hyperledger Fabric requires network participants to be verified. The PKI facilitates identity verification via a chain of trust. CA provides both private and public keys; however, private keys are not made available on the permissioned platform. Membership Service Provider assists with matching orders with keys via local MPS [10]. Members of Channel

MPS can administrate and participate. Thus, the ability of the platform to match a transaction to a specific key increases the data integrity of the network. Private keys are used during transactions. Once the other peer sends an order, the verifier must evaluate both the transaction's validity and the sender's authenticity. Using the public key, the sender's ability to pay for the transaction is verified. The verifier decides if the sender can pay for public key use. The technology sends the sender's digital signature after verification. Because a transaction's signature has 256 bits, forgers must estimate 2 to the power of 256 times, which is impossible.

Peer It's a platform that holds ledgers and smart contracts that record shared transaction information and procedures [10] and creates or deletes peers that can be configured or stopped. Therefore, they must input information from several sources. Administrators and applications will rely on peers to receive Chain codes and ledgers, making peers a critical aspect of the Fabric. According to Androulaki et al. [11], peers serve as validating committers.

Ledger Hyperledger Fabric's ledger keeps reliable information about an organization's items. It shows current and past transaction values that led to the current situation. Peers can add to ledgers but can not remove information. So, data is immutable, thus everyone can observe transaction history and changes. A regulator can add or withdraw certification from a certificate. This updates the smart contract's information.

Chain Code Smart contracts are Blockchain-based rules that guide the owner and users of a system. It regulates the agreement between people who use information or a platform and the people who make it by giving them rules to follow. A company that rents out cars may have rules that if a customer breaks, the car is disabled and sent back to the lender. Members who want to join the regulator's networks may have to meet certain requirements, such as having professional credentials that can be verified, a work history, and at least one exam-based credential, such as "CPA." Our smart contracts help ensure the legitimacy of a transaction, preventing owner-user disputes. Our smart contracts are an important part of enrolling public users, making sure agreement requirements are clear, producing required validations, and analyzing and validating certificates or data. The algorithm compares the city, country, and job of a worker's current location with the regulator that allows transactions. If no data is found, the administrator contacts a new regulator to invite them to join the network.

Orderer This is one of the most critical components of the Hyperledger Fabric consensus mechanism. It makes sure that new blocks of ordered transactions are made and is in charge of putting transactions in the right order. The orderer also distributes newly created blocks to all peers in an appropriate channel. For the current use case, the orderer is responsible for collecting consensus blocks from different organizations in the Blockchain and building consensus to approve or reject a transaction.

3 Results

3.1 Case Study Description of the System Architecture

An example illustrates how the system operates. Suppose Majid is a recent graduate of accounting. Majid most certainly holds a bachelor's degree as well as CPA and CFA qualifications. These certifications are granted by various institutions and governments. Each application must include all credentials, which the employer must verify. The proposed design consolidates validation. Majid obtains a token that is non-fungible and non-transferable following professional certification. This token is the certification's serial number, which is checked when Majid starts a network transaction. Majid and the staffing agency are able to initiate transactions. Transactions include applicant verification documentation, Degree, and CPA and CFA credentials. Every organization in a network is a node. CFA Institute is a node in a network. These regulators approve smart contracts. Nodes can either say "no" or "yes" to the transaction because all professional organizations are part of the network. Majid's profile would reflect his current certifications. Hyperledger offers decentralized authentication.

3.2 Proposed Solution Performance Analysis

The analysis represents a single peer network with a varying number of transactions. Based on the analysis of data for the performance of the Hyperledger smart contract, the metrics used include scalability in terms of time, latency, and throughput. The time in this case referred to the duration between when a transaction was deployed (Query) and the duration when the transaction was completed (Invoke). Scalability refers to increasing the number of transactions on the system. The execution period is the time it takes for a Hyperledger smart contract to execute a transaction. It is the difference between maximum time and minimum time. In this case, "latency" means the time between deployment and completion, or the average of all transactions in the data set. The throughput refers to the number of successful transactions in one second. The REST API tool was applied in the analysis. The API is applicable because it allows for immediate feedback from a transaction. The success in resume validation through the Blockchain initiatives relies on Hyperledger Fabric network models that accommodate peer network topology anchored on the integrated edge computing that provides security, identity management, and authentication services of the documents. The study relies on the built multiplayer's platform of the lightweight Hyperledger Blockchain technology. The incorporation of smart contracts enhances the consistency in document validation relevant to the harmonization of facts desirable in the authentication programs. However, several layers and the sub-network accelerate computation capability relevant in the energy storage capability based on the modification of the Blockchain as per the layer design requirements. The existing

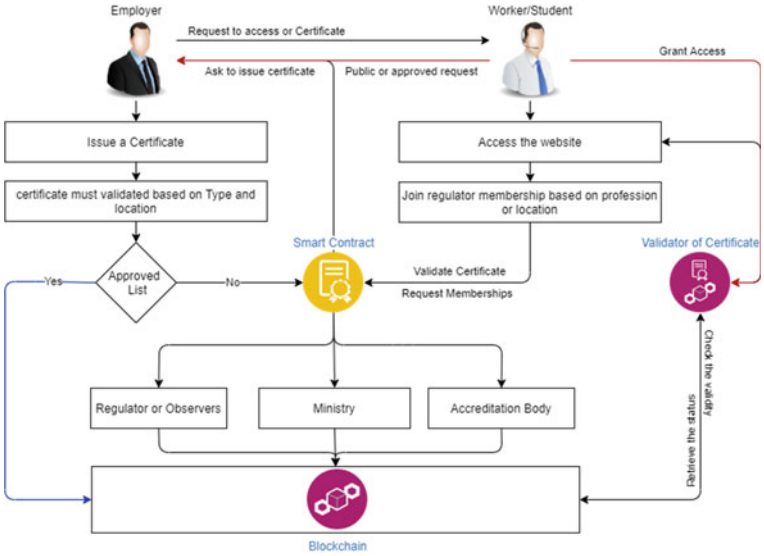

Fig. 2 Comprehensive system models

layers adopted in the structure represent the base station nodes as the edge layers depict cluster head nodes for the institution's devices anchored on the multilayer Blockchain models [12].

3.3 Ledger Implementation

The distributed ledger technology in the network bears the transaction log and state database accessed by involved peers in the platform. Data in the ledger is held throughout the network. No data is held in a central location. CouchDB refreshes states upon request. This facilitates faster querying. The focus on fundamental data stores sustains the adoption of fabric peer programs that sustain the capability relevant in the execution of complex queries relevant in the replacement of state database. Hence, it supports the creation of complex queries to support creation of transaction logs that anchors create, retrieve, updates, and delete functionalities on the state data set [13].

3.4 User Stories

The application consists of many user types with different stories and roles to access the website and Blockchain as shown in Fig. 2 Comprehensive user stories models describe the user access and roles.

Worker Anyone can join the network using a web application and a web browser. Identities, credentials, employment histories, professional certifications, and training programs can be utilized to verify resumes. The employee would be encouraged to join a regulator whose location and line of work correspond to their own. When a worker becomes eligible for membership, the system compares their qualifications, professional certifications, and job certificates.

Regulator Regulators have the ability to create and verify memberships, as well as view all members with the same profession and location. Regulators serve as administrators for their members, evaluating documents, and covering late responses from corporations or verifying information on behalf of an unregistered business.

Employer The second type of user is an employer who can verify or create the worker's employment history; however, if the employer creates an employment letter, it will be submitted to the employer administrator for approval.

University Universities can verify or create worker qualifications; however, if the university creates educational certificates, they must be approved by the administrator.

4 Conclusion

Businesses are just beginning to recognize the potential of Blockchain. The document verification processes of today are slow, burdensome, and immoral. Several investigations have determined that current procedures are false, inadequately structured, and do not meet international standards. As illustrated in the current study, Blockchain technology can play an essential role in improving the verification process of professional documents. This can in turn reduce the instance of falsification and forgery. Blockchain makes verification process easy by relying on a multi-stakeholder consensus platform. For companies, the use of the Hyperledger framework can also lower the cost of conducting manual application verification. This is because the transaction time is relatively short compared to the manual method. Furthermore, the processes can be scaled up to accommodate an increase in the number of membership application. The objective of the study was to develop a distributed ledger platform for document validation. Hyperledger Fabric enables user authentication and secure Blockchain transactions. The Merkle tree algorithm is utilized by Hyperledger to build smart contracts. For business logic execution, the architecture produces transactions to support peer-to-peer message transit. Participants in the network can manage, modify, and approve entries. This configuration allows hundreds of transactions per second. Blockchain technology can enhance document verification. Thus, fraud and counterfeiting are reduced. Hyperledger minimizes the cost of human application evaluation for businesses. The platform encrypts transactions and documents against DDOS attacks, unlike centralized storages. Due to immutable data and a consensus algorithm, members can utilize the network with ease. Merkle tree also verifies papers using secure QR codes. The Hyperledger technology is ideal for verifying documents. The technique solves centralized and manual document verifi-

cation problems. Security, unauthorized modification, forgery, and falsification. The technique facilitates effective communication and expedited decision-making in a variety of professions and organizations. These qualities minimize inefficiencies and lower expenses.

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Auto-Insurance Fraud Detection Using Machine Learning Classification Models

Toluwalope Owolabi, Essa Q. Shahra, and Shadi Basurra

Abstract This work explored six machine learning algorithms: Extreme Gradient Boosting (XGBoost), Logistic Regression, Random Forest, Decision tree, Support Vector Machine (SVM), and Naïve Bayes to determine the best algorithm for detecting insurance fraud. The following were used to evaluate the six models: Confusion matrix, Accuracy, Precision, Recall, and F1-measure. The result showed that Random Forest outperformed the others in terms of accuracy. Extreme Gradient Boosting (Xgboost) had the highest precision and F1-measure scores, while the Decision Tree had the highest Recall score. Although two methods (Analysis of Variance (ANOVA) and Random Forest Classifier) were compared to determine the best feature selection, the significant features were selected using the Random Forest classifier because of the many benefits of using this method. The results of this study will be beneficial to insurance companies, stakeholders and policyholders.

Keywords Fraud detection · Classification · Machine learning · Random forest

1 Introduction

Understanding insurance and insurance fraud are paramount to understanding its significance and effect. Viaene et al. in [1] define insurance as a contractual relationship between an insurer and an insurance taker in which the insurer pays the insurance taker for losses sustained by an insured party. As the number of cars increases, auto-insurance is now increasingly important in the whole economic growth and the lives

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of individuals. The insurance covers natural disasters, vehicle accidents, including accidents caused by a third-party [2]. The market for insurance will therefore experience increase in capital as more insurers place their trust in its positive growth, resulting in more competition between the companies [3]. Insurance fraud has been defined by the California Department of Insurance as the intentional denial of a benefit a person is entitled to, or the intentional lying to achieve an advantage. There are a number of negative consequences associated with insurance fraud, including substantial losses for companies, negative impact on their price strategy and their economic advantage over time. According to [4], the costs of fraud relating to insurance are envisioned to be more than forty billion dollars annually, meaning that the average American family will have to pay between $400 and $700 in increased premiums due to insurance fraud every year. According to [5] there is a notable amount of money associated with insurance fraud worldwide. Due to this, both in the U.S. and around the world, it is imperative to explore the connection between fraud detection and auto-insurance. The severity of insurance fraud may be difficult to estimate due to the fact that it is often not detected and prosecuted, and this could be because auto-insurance companies deal with so many claims. Therefore, it is impossible for them to manually verify each of them for fraud, which makes minimizing the fraud problem difficult. As a result, many use machine learning and data mining methods to minimize the problem of fraud in the insurance industry.

In this paper, we aim to determine the best predictive machine learning model that can be used to detect fraudulent insurance claims and determining the features that significantly influence auto-insurance fraud.

The paper is organized as follows; Sect. 2 presents the literature review. Section 3 demonstrates the methodology in more detail. Section 4 presents the results and discussion. Finally, Sect. 5 concludes the work.

2 Literature Review

Research and academics have been developing robust ways to detect and prevent financial frauds due to the significant losses caused by these crimes. A system for financial fraud classification was introduced by. Ngai et al. in [6] which included four types of financial fraud: securities and commodities fraud, bank fraud, insurance fraud, and other financial frauds. As a result of a different dishonest techniques, auto-insurance fraud has garnered a lot of attention since insurers suffer losses and society suffers as well [7]. There are numerous ways to detect fraud, so therefore, different algorithms are being studied. As technology has advanced, so does fraud detection. In the past, skillful auditing and examination were critical to detecting insurance fraud [8].These days, however, the application of such traditional methods is no longer possible due to significant technological advancements [9]. For this reason, different methods of fighting financial fraud have been developed over the years. Some of these include neural networks [10], random forests, artificial immune systems [11], fuzzy association rules, and deep learning approaches [12] . In recent years, there is a

large and growing body of literature on the application of machine learning (ML) to various financial aspects. For instance, Liu and Pun in [13] recently applied machine learning algorithms to systemic risk measures and found that the predictive power of these measures was enhanced by ML algorithms. Additionally, Carmona et al. in [14] proposed a new machine learning model, Extreme Gradient Boosting (XGBoost), with high interpretability for detecting signs that are useful for forecasting fiscal distress among businesses. Other authors assessed the benefits of ML algorithms on the investor profit function by incorporating misclassification costs into the equation. There may even be evidence that ML models may be superior to linear models in predicting leverage and identifying a wider range of leverage determinants [15]. The accuracy of various fraud detection approaches and their predictive power has been compared in many studies [16]. Adewumi and Akinyelu in [17] surveyed machine learning and nature-inspired approaches and compared their accuracy. Three machine learning methods are compared by Carneiro et al. [18] Random Forest (RF), Logistic Regression (LR), and Support Vector Machine (SVM), where RF was found to have the best performance of the three methods, which is supported by many studies when RF is compared to other methods [19]. Later Van Vlasselaer et al. in [20] discovered similar results while studying social security fraud detection. A large dataset, even one with a high number of transactions, can be processed quickly with RF, which makes it an excellent tool for fraud detection, not only due to its great performance but also due to its ease of implementation and rapid computing time. In contrast, Decision Tree (DT) have been recommended by a number of literature as a powerful algorithm when applying to building insurance fraud [21] and detecting fake news.

3 Methodology

We trained and evaluated datasets' classification techniques: Logistic Regression, Extreme Gradient Boosting (Xgboost), Random Forest, Decision Tree, Naïve Bayes, and Support Vector Machine (SVM), to discover which model performs better. Also, the following methods were employed to identify the features that significantly influence insurance fraud: filter method Analysis of Variance (ANOVA), and the algorithm-embedded method Random Forest classifier. The approach adopted in this work is based on the supervised learning method as shown in Fig. 1.

3.1 Data Collection

Kaggle provided us with the insurance claims data for our study. The dataset includes 15420 claims, with 32 predictor variables and one target variable represents ("Fraud" and "No Fraud"). Each instance of the dataset contains 33 features, as well as 8 numeric entities, 10 categorical entities, and 14 Alphanumeric features. Personal data sheet for insured (age, gender, marital status, etc.), details of the insurance

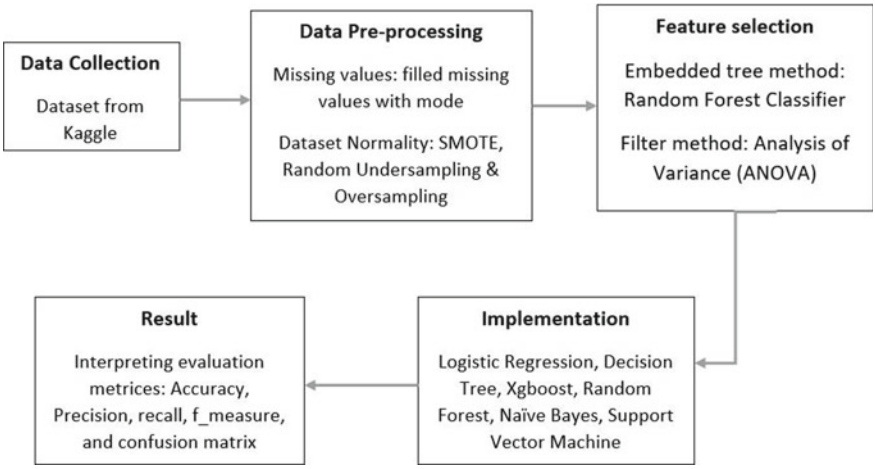

Fig. 1 The method used in this work

policy (type of policy, vehicle category, number of supplements, type of agent, etc.), information about accident circumstances (date, place, insurance report, witness, fault liability, etc.), other insurance data (number of cars, previous claims, driver rating, etc.), and fraud (yes or no), feature to be predicted.

3.2 Data Pre-processing

There is always the possibility that the dataset contains some abnormalities or wrong values. However, by applying some pre-processing techniques to prepare the input data in the best manner possible, it could enhance the performance of machine learning techniques by eliminating abnormalities or wrong values.

Missing Values There are different methods of dealing with missing values. These include but are not limited to deleting the columns with missing data, deleting the rows with missing data, etc. the downside to using these methods could be the loss of sensitive information or an increase in the dimensions of the dataset, and this is not really good for training our model which is why in this paper, we decided to go with the imputation method, i.e., filling the missing values. Missing values could be filled with the mean or median value if it's a numerical variable or with the mode, if it's a categorical value, but because our dataset is a mixture of both numerical and categorical values. It was difficult to use only median or mean, so we decided to use both mean and mode, mean for the numerical value and mode for the non-numerical value; however, it did not work out well as new values were assigned to the numerical values. Figure 2 shows the column "Vehicle_Ownership" before using the mean to replace its null values. Figure 3 shows the feature "Vehicle_Ownership"

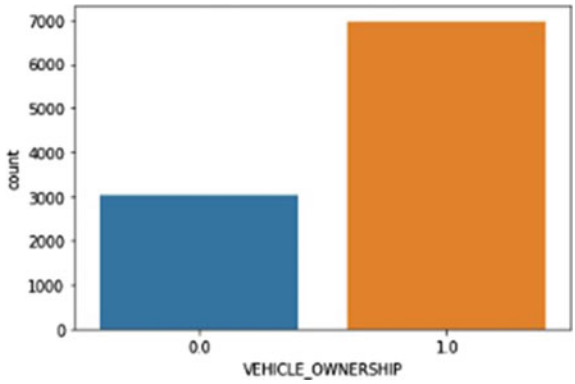

Fig. 2 Feature with missing value

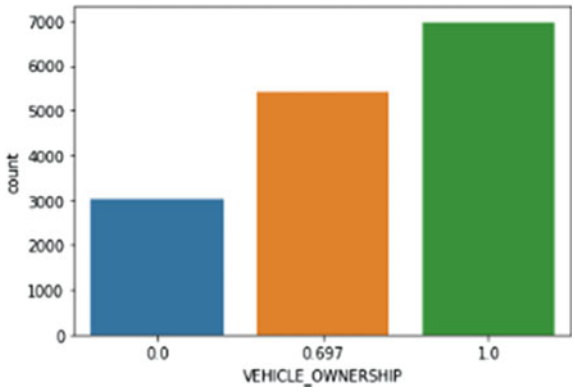

Fig. 3 Feature after filling the missing value with means

after replacing its null values with its mean. From Fig. 3 the feature has three values compared to the original two values before the imputation. The same also applies to all numerical values in the dataset and when we use the median to fill in their missing values. However, the column maintains its original values when we use the mode to fill in its missing values; because of this, we decided to use only mode for both numerical and categorical values.

3.3 Feature Selection

One of our major aims in this work is to identify the features that significantly influence auto-insurance fraud and to achieve this goal. We used feature selection. Feature Selection is an effective way to identify and choose the features that significantly influence insurance fraud from our dataset. In this work, we explored two feature selection methods: Analysis of Variance (ANOVA), a filter method, and Random Forest classifier, an embedded method. These methods were chosen to be explored

	Input_Features	Score	p_Value
8	VEHICLE_OWNERSHIP	4206.258214	0.000000e+00
0	AGE	2608.127695	0.000000e+00
12	CHILDREN	1994.084385	0.000000e+00
1	GENDER	1260.982188	0.000000e+00
14	ANNUAL_MILEAGE	731.318269	0.000000e+00
13	POSTAL_CODE	594.037081	0.000000e+00
7	CREDIT_SCORE	490.768673	0.000000e+00
26	PAST_ACCIDENTS	302.212724	0.000000e+00
6	INCOME	288.181868	0.000000e+00
5	EDUCATION	261.295972	0.000000e+00
9	VEHICLE_YEAR	221.093428	0.000000e+00
21	SPEEDING_VIOLATIONS	212.202093	0.000000e+00
2	RACE	97.203542	0.000000e+00
25	DUIS	95.033324	0.000000e+00
4	DRIVING_EXPERIENCE	67.947232	1.813000e-16
15	VEHICLE_TYPE	45.208758	1.833330e-11
11	MARRIED	6.427653	1.124549e-02
31	NumberOfSuppliments	2.107922	1.465586e-01
27	PoliceReportFiled	1.191631	2.750179e-01
16	Fault	1.135515	2.866187e-01

Fig. 4 Important of the features by ANOVA

because they deal with both categorical and numerical values, and our dataset combines both numerical and categorical values.

Analysis of Variance (ANOVA) ANOVA is a statistical method used to check the mean of two or more groups significantly different. ANOVA can be used for both categorical and numerical variables. It could be called an ANCOVA if the 2nd variable is continuous. By applying this technique, We classified the top 20 features selected by the ANOVA test into these 3 columns in descending order, i.e., from the highest to the lowest as shown in Fig. 4.

RandomForestClassifier Embedded Method Method Random Forest is a Bagging Algorithm aggregating a specified number of decision trees. The tree-based strategies used by random forests naturally rank by how well they improve the purity of the node, or in other words, a decrease in the impurity (Gini impurity) over all trees. After fitting the model, we then used the feature_importances_ function to get the important features then, and we created a visualization to show the important features the classifier selected in ascending order, as shown in the Fig. 5. From Fig. 5 we can see how features are ranked according to their importance. However, we wanted to get the exact 20 features that the classifier selected, and to do this, we used Recursive Feature Elimination (RFE). The RFE helped eliminate the less important features by fitting the Random Forest classifier that we used in the model's core, ranking features by importance, discarding the least important features, and refitting the model.

4 Results

In this work we used 6 models: Logistic Regression, Extreme Gradient Boosting (XGBoost), Random Forest, Decision Tree, Naïve Bayes, and Support Vector Machine (SVM). The efficiency and performance of each algorithm are calculated

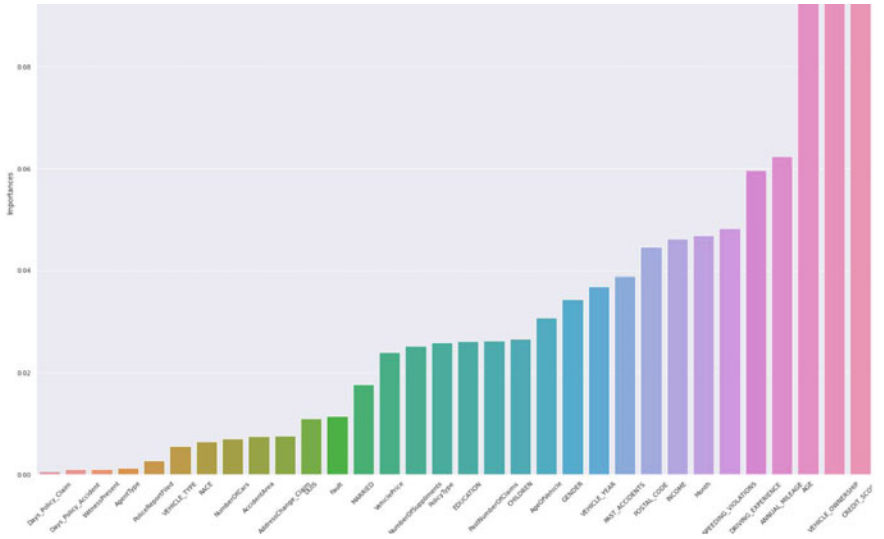

Fig. 5 Importance of the features by embedded method

using the confusion matrix and 4 evaluation metrics: Accuracy, Precision, Recall, and F1-measure. We trained our machine learning models on a 70% car insurance dataset and assessed their performance on a 30% test dataset. An efficient classifier should have higher values for these indicators. Moreover, we have proposed a comparative analysis between the different classification models according to the four performance measures Accuracy, Precision, Recall, F1-measure.

4.1 Logistic Regression

To evaluate the Logistic Regression model, the classification_report() function and the accuracy_score function were used to show us the model's accuracy, precision, recall, and f_score of the model. Over a total number of data instances, accuracy indicates how many instances were correctly classified. The model's accuracy is 88.2%, as indicated by 0.88240 in the classification report. In its simplest form, precision measures how many correct positive results were recorded compared to how many positive results were predicted by the classifier. The model's precision is 72.8% as indicated by 0.728 in the classification report. We measure recall by how well our model identifies relevant information. The classification report shows the recall value to be 0.64 which means that the model can identify 64% of suitable data. Using their harmonic means, F score creates a single metric that combines a classifier's precision and recall. The f_score obtained from the classification report is 0.681, which indicates 68.1.

4.2 Extreme Gradient Boosting (XGBoost)

The classification_report() function and the accuracy_score function were also called for this model to show us the model's accuracy, precision, recall, and f_score of the model. The accuracy obtained from the classification report is 0.896, i.e., 89%, which ties with the accuracy of the SVM model, although the f_score of the xgboost is higher by 2.6% than the f_score of the SVM model, which means that the xgboost performed better than the SVM model. The confusion matrix for this model showed that 3460 and 685 records were properly classified. This means that compared to the Logistic regression model, the xgboost model classified 63 more models correctly. While 309 and 172 records were misclassified, we can see that the number of misclassified records has also reduced by 63 records. It is no surprise because xgboost is said to be the most efficient machine learning model, and we can clearly see it in its results.

4.3 Random Forest

Same as with the first 2 models, we also used the classification_report() function and the accuracy_score to see how well the accuracy performed. According to the classification report, the accuracy of this model is 0.90, i.e., 90%, which is the highest accuracy achieved among all the models. This is quite impressive, seeing as the f_score was only 0.6% lower than Xgboost. The confusion matrix for this model showed 3527 and 637 as properly classified which is 19 records higher than the Xgboost. However, 191 and 271 were misclassified. The accuracy and f_score of this model is quite good, so if an insurance company decides to use accuracy as its evaluation metric for any model, then the Random Forest model will be the best model to use to detect auto-insurance fraud.

4.4 Decision Tree

According to the classification report, the accuracy of this model is 0.87%, i.e., 87%, the f_score is 68%, and the recall is 72.4%, which was the highest among other models. The model did well, seeing as the model only relies on the feature importance given by just a single decision tree as compared to the Random Forest model that leverages the power of multiple decision trees. The confusion matrix for this model showed 3354 and 657 records as properly classified, while 364 and 251 records were misclassified.

4.5 Naïve Bayes

This model had the lowest number across all evaluation metrics. It performed poorly as compared to the other models. The accuracy for this model is 86%, the precision is 62.6%, the recall is 65, and the f_score is 63.8%. No matter the evaluation metric an insurance company wants to use to determine the best model, Naïve Bayes should not be the first model to be considered. The confusion matrix for this model showed 3366 and 590 records as properly classified, while 352 and 318 records were misclassified.

4.6 Support Vector Machine (SVM)

The Support Vector Machine did very well according to the classification reports, its accuracy score 89% tied with that of the Xgboost model, which is quite impressive. The f_score of 71.4% is also the third highest among all the models. This could result from us testing all possible combinations of parameters to determine the best parameter for the model and still using rbf during the optimization. The confusion matrix for this model showed 3434 and 662 records as properly classified, while 198 and 332 records were misclassified.

4.7 Comparisons of the Models Performance

Table 1 shows the summary of the evaluation metrices for all the models.

From Table 1 we find that Random Forest outperformed the others in terms of accuracy, with an accuracy rate of 90%, while Logistics Regression was the worst, with an accuracy rate of 88%.

Table 1 Comparion of models performance

Models	Accuracy	Precision	Recall	F1-score
Logistic regression	0.88240	0.728	0.640	0.681
Xgboost	0.89602	0.799	0.689	0.740
Random forest	0.90	0.769	0.702	0.734
Decision tree	0.87	0.643	0.724	0.681
Naïve Bayes	0.86	0.626	0.650	0.638

5 Conclusion

In this study, we analyzed the six most popular machine learning algorithms and evaluate their performance using four different evaluation techniques to ascertain which one would be most suitable for use in predicting fraud using real-world data. The study demonstrates that all six models' performance is inconsistent across all evaluation matrices. When accuracy is measured, the Random Forest model performs best. In contrast, Xgboost has the highest precision of any model, at 79.9%. This indicates that when a claim is predicted to be fraudulent, the model is accurate in 2/10 of the instances. Additionally, when comparing the accuracy value to the findings of the earlier study by Severino [21] as mentioned in literature, we have earned the highest score with 90% attributed to Random Forest.

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A Wearable Device for Respiratory Diseases Monitoring in Crowded Spaces. Case Study of COVID-19

Rosette Lukonge Savanna, Damien Hanyurwimfura, Jimmy Nsenga, and James Rwigema

Abstract The necessary measures need to be put in place for the fulfillment of good health and hygiene's Sustainable Development Goals (SDG). As reported by (WHO), chronic respiratory diseases are on the rise, especially in developing countries resulting in over four million deaths annually across the globe. In addition to the COVID-19 pandemic, some other highly contagious respiratory diseases include tuberculosis and influenza which can be also monitored. Since it is difficult to identify an infected person in order to avoid transmissions, this research is proposed as a measure to control and minimize the spread of such diseases. It aims at developing an artificial intelligence (AI)-powered system able to monitor the risk of respiratory diseases spreading using a wearable device. In this study, we propose a contactless system to detect an environment with a high risk of contamination. The device applies Internet of Things (IoT) sensing technologies for data collection from the user's immediate surrounding environment (cough sound and body temperature) and machine learning (ML) algorithms for data analysis to predict a possible exposure to respiratory diseases. The user will get alerts to take appropriate actions to avoid possible infections. The collected data is also sent to the cloud from time to time via cellular networks for further analytics and future research. This will be an improvement to existing cloud-based solutions considering connectivity and energy constraints in Africa and the need for real-time response. AI capabilities will move from the cloud to the data source (edge devices) using TinyML.

Keywords IoT · Machine learning · TinyML · Respiratory diseases · Wearable device

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1 Introduction

Respiratory disease is considered one of the most common acute and chronic diseases in the world. They are widespread across all age groups and sections of society, regardless of the degree of development they have [1]. Large populations in rural and peri-urban areas of the world are affected by high levels of indoor air pollution; tobacco use is becoming more common in developing nations, and the HIV/AIDS epidemic is accompanied by respiratory diseases that are the most common symptoms of AIDS [1].

With a population of over 11 million, the prevalence of common communicable diseases in Rwanda is a serious concern [2]. Lower respiratory illnesses are among Rwanda's top ten causes of death, and although unanticipated, it is a severe health concern in Rwanda. According to the World Health Organization (WHO), low and middle-income countries account for nearly 90% of COPD deaths in people under the age of 70 [3]. COPD is thought to be the cause of about three million deaths annually or around 6% of all deaths worldwide [3]. For example, Coronavirus disease (COVID-19) was reported by the WHO as an infectious disease [4]. It has already claimed the lives of 6,266,324 people since the first outbreak [5, 6]. That's why to lower infection rates and limit the burden on medical resources, detection technologies are required to keep people safe because no cure has ever been identified so far, and people must take precautions to protect themselves from this pandemic.

Since the beginning of time, humans have always tried to enhance their living conditions, always wanting to make daily duties easier in order to live a better life. Thanks to new technologies, which help us to achieve that. The Internet of Things (IoT) is a network of objects connected wirelessly that can interact one another without human intervention [7]. In the healthcare field, IoT enables highly effective real-time remote monitoring. Nowadays, early detection and prediction of chronic disorders are critical aspects that many researchers are focusing on. With the global spread of COVID-19, digital health technology has been adopted to maintain healthcare delivery during lockdowns [8]. IoT has been used in healthcare for data collection and monitoring, whereas AI is in charge of analyzing massive amounts of data and taking actions based on what it learns [9]. AI has been used to improve healthcare outcomes, it has been a powerful weapon in to fight against the COVID-19 storm. AI has enabled the creation of strong models capable of automating diagnosis and enabling a highly precise method of medical care by personalizing treatments and other resources timely [10].

In existing related AI-based solutions, for example [11], data has to be sent to the cloud when AI intelligence is applied. Such cloud-based solutions are faced with challenges, especially in the African context, namely: poor connectivity, high costs of connectivity, high latencies, and energy constraints [12] This calls for edge-based solutions; data from the environment is gathered using small electronic devices with restricted energy, computing, and memory resources [13]. TinyML is an IoT framework that aims to provide low latency, effective bandwidth utilization, strengthen data security, improve privacy, and lower costs. TinyML enables IoT devices to

operate consistently without the need for continuous contact with cloud services, while providing accurate machine learning services [14].

This study prototyped a wearable device that can be able to assess the environment for possible COVID-19 risks and give appropriate real-time alerts to users. In the proposed solution, sound and contactless temperature sensors will be used to collect data from the environment with TinyML being used to perform analytics at the edge. This project fits in the context of applying IoT and AI for detecting communicable diseases from the fusion of cough sounds, sneezing sounds, and body temperature data.

Given the risk of contracting respiratory diseases as people interact in public places, Rwanda requires the implementation and realization of IoT for communicable disease detection and monitoring. The proposed system will also go a long way in helping the health authorities collect data that can be used for further research and for planning.

The remaining document is structured as follows, in the next section, the literature is given followed by methodology, system design, and the practical experimentation of the solution and analysis of results.

2 Literature Review

This section presents a review of related research to illustrate the basis for integrating the Internet of Things and TinyML in the monitoring and diagnosing of respiratory diseases.

2.1 IoT in Prevention of Respiratory Diseases

Aside from routine physical exams and a few screening programs for high-risk groups [15], very few clinical research or practices are now focusing on different methods or approaches which are used for disease prevention. However, several studies enroll certain populations with different possible illness developments and apply lifestyle interventions and drive to avoid disease worsening in the future, utilizing mobile phone apps such as Apple Research app [17]. Furthermore, the author in [18] used big data analytic methods to improve Pakistan's vaccination program. They sent out vaccination cards with NFC chips to the local population instead of manually collecting each person's data, and they used a classification scheme to sort through incoming vaccine records and prevent possibly fabricated records in real time. The cost and burden of the vaccination station have been greatly lowered thanks to this method, which has also increased service effectiveness. There is a need for methods of boosting early detection due to the paucity of vaccinations for several respiratory infections.

2.2 IoT in Monitoring and Diagnosis of Respiratory Diseases

In order to automatically monitor COPD patients, Zhou et al. created a novel handheld pulmonary function device in 2016. This system works in conjunction with a number of medical Internet of Things platforms. The results of the pulmonary test might be uploaded to the system's cloud and made instantly available to the doctor on an iPad or smartphone [19]. In addition, an IoT system is created by combining many unrelated apps, argues one research [20]. An environment sensor box, patient monitoring tools, Android applications, and a web graphical user interface make up the additional four main parts of the strategy (GUI). According to [21], patients who have chronic illnesses need to have their vital signs regularly checked. The body's functioning is fundamentally measured by vital signs. One of the most crucial vital indicators that are helpful for patients who are hospitalized in an intensive care unit is the respiratory rate monitor (ICU). Based on the voltage values of the air being breathed and expelled, the respiratory rate is continually measured and computed using an LM35 temperature sensor. If data mining techniques are applied, people could be able to learn about their health without the aid of medical experts [21]. Raji et al. [22] recommend an IoT monitoring architecture for COVID-19. IR sensors can be utilized in public toilets to automate door and water supply functioning. Infrared thermometers and optical cameras with facial recognition technology can be used in airports, train stations, bus stops, and shopping centers to detect sick individuals in crowds by checking their body temperature.

2.3 Use of ML in Predicting Possible Respiratory Diseases

By informing clinicians and caregivers of changes in risk variables for stroke illness, Kumar et al. [23] suggest a patient monitoring system for stroke patients to lower the likelihood of future recurrences. The use of data analytics and decision-making based on the patient's current health indicators enables the doctor to diagnose diseases systematically and then provide patients with individualized restorative care [23]. A review that was published in [24] tried to locate and summarize existing papers on the use of AI and ML for respiratory illnesses. A few more researches on mechanical ventilation, image interpretation on chest X-rays, and the diagnosis of bronchial asthma have been discovered [24]. Another area of interest is the use of AI and ML in the diagnosis of interstitial lung disease. The study in [25] asserts that the application of artificial intelligence (AI) and machine learning, a kind of AI, in medicine is growing. An overview of AI's use in medicine is given in the article [33], especially in respiratory medicine, where it is employed to diagnose fibrotic lung disease and evaluate lung cancer images.

The major objective of a study in [26] is to create and analyze an alternative LUR model capable of assessing the incidence of chronic respiratory disorders, in contrast to existing LUR models, which generally assess air pollution. A system that could

predict whether or not a respiratory cycle comprised accidental noises like crackles, wheezes, or both was discovered during the IeBRI 2017 challenge [27] using a database of 920 recordings gathered from 126 participants. A unique strategy was put out in [28] that focused on creating a new patient-level model that can assess whether a patient sounds ill or not by utilizing the output of the first classification model's predictions as input. As a result, the article [29] highlights several relevant efforts in this area as well as the suggested system for categorizing the respiratory sound database for the International Conference on Biomedical and Health Informatics' 17 scientific challenge. The danger of infection is greatly raised by the ease with which respiratory diseases spread, and as a result, many researchers in a variety of professions are charged with addressing the spread of these illnesses [30]. The most well-known and most recent of these illnesses is COVID-19. This review at [31] looked at specific lung sounds/disorders, subject numbers, signal processing, and classification techniques, and the outcomes of prior researchers' assessments of lung sound using machine learning techniques.

2.4 TinyML and Its Application in Respiratory Health

Due to the convergence of the Internet of Things (IoT) with machine learning, TinyML is a subset of ML whose models are restricted to being implemented on low-resource embedded devices (ML). Due to connection, energy, and cost concerns, the majority of IoT applications in Africa are now built on cloud-centric architecture, making it challenging to benefit from ML-driven intelligence. TinyML is a perfect answer to these issues. Research in [12] explains TinyML and covers its broad uses, responses to concerns about how artificial intelligence (AI) would affect the accomplishment of the Sustainable Development Goals (SDGs), and the TinyML technology requirements for Information Technology for Development (ICT4D).

The study in [32] asserts that one industry that stands to gain from the vast amounts of raw data produced by portable and wearable technology is healthcare. This data must be transferred to the cloud for processing since modern state-of-the-art neural network implementations are computationally demanding. The scientific community has suggested TinyML, a new technology, as an alternate method for developing secure, autonomous devices that can gather, analyze, and warn without sending information to outside parties [32].

Additionally, [33] underlines how machine learning has developed into a crucial part of the current technological field. Embedded devices at the network's edge with limited resources can now benefit from machine learning techniques, thanks to edge computing and the Internet of Things (IoT). The maintenance of learning model correctness, provision of train-to-deploy capability in resource-constrained micro edge devices, optimization of processing capacity, and improvement of dependability are only a few of the difficulties that occur during such transitions. A clear description of these TinyML options is given in [33].

Additionally, it is said in [34] that the IoT has lately attracted a lot of interest due to the application of IoT devices in several industries. Machine learning (ML) models, on which the bulk of these gadgets are built, give them intelligence and decision-making skills. Deep learning (DL) models are complicated ML models that are challenging to implement on IoT devices due to their often-constrained resource availability. Additionally, connecting IoT devices to the cloud to perform processing and transport raw data delays system responses, exposes private data, and increases communication expenses. Tiny machine learning (TinyML), a novel technology, has opened the road to meet the challenges of IoT devices in order to resolve these problems. This technology allows data to be processed locally on the device rather than sending it to the cloud. Furthermore, TinyML allows for the inference of ML models, as well as DL models, on a device such as a microcontroller with limited resources [34].

An investigation on the viability of employing cutting-edge AI to identify respiratory disorders is presented in [35] for the field of respiratory diseases. A system for cough detection created using Edge Impulse Studio and Arduino 33 BLE Sense is another health application suggested in [34]. It can distinguish between a genuine cough and a general unwelcome background signal. In this study, a vast dataset of different samples was trained using Edge Impulse Studio to detect cough and undesirable noise. A machine learning-based approach called TinyML is intended to instantly ascertain the resonance of cough. The suggested approach was found to obtain identification rates of around 97% accuracy.

2.5 Identified Study Gaps

From the reviewed studies, the capabilities of the emerging technologies of IoT and ML have been highlighted. With applications in the healthcare sectors focusing on monitoring and diagnosis of diseases, existing applications with respiratory disease focus mainly involve the use of chest images and sound classifications with the ML being done in cloud-based architectures. The use of cloud-based architecture has been noted to be a challenge in Africa and for health applications due to privacy, latency, and connectivity challenges. Our proposed study tends to fill the identified gaps by not only introducing the concept of data fusion to monitor two or more parameters in diagnosing respiratory diseases but also applying TinyML to enable ML at the edge to overcome the challenges highlighted in the previous studies.

3 Proposed Wearable Device for Respiratory Diseases Monitoring in Crowded Spaces

3.1 Methodology

For the development of the wearable device for respiratory disease risk monitoring, the software prototyping approach was chosen as the software development method. The choice of this model was influenced by the need to understand user needs and develop system requirements at an early stage. Furthermore, user feedback was obtained, allowing the researcher to understand what is expected from the solution.

The machine learning process started with data collection (from open data sources). In preparation for training, the collected data was cleaned. The machine learning mode was designed after preprocessing. The model was then trained, and the test data was used to assess the model's performance on previously unseen data. Following evaluation, the model was transformed into a small machine learning model that can run on an embedded device and is ready for deployment.

3.2 System Design

A sensing unit, a processing unit, and a notification unit comprise the system. The sensing unit will be able to measure temperatures and cough sounds from the environment as the user moves and interacts with others. TinyML is used to perform analytics on the collected data in real time to predict any risk of exposure to respiratory diseases. In the event of a risk, the user is notified via screen notifications, LEDs, and buzzer alerts. For contactless temperature measurement, an infrared temperature sensor is used, with sound data collected by a sound sensor embedded in the microcontroller. A micro OLED (display for wearable devices), RGB LEDs, a five-way navigation button, and a buzzer will be used as user output. To detect proximity to other people, a proximity sensor will be used. The collected data will be sent to the cloud platform as well. Figure 1 depicts the block diagram of an embedded system.

3.3 Machine Learning Model Design

Datasets—Two sets of open data sets were used; in the first set, the dataset used consists of 135 cough files and 52 non-cough files from Google's AudioSet, 40 cough files and 1,960 non-cough files from the ESC-50 dataset, and 256 cough files and 10,801 non-cough files from the FSDKaggle2018 dataset. The second was data collected in an Edge Impulse project to classify COVID and non-COVID coughs.

Data formatting—First, the dataset was divided into three categories labeled COVID-19 coughs, normal coughs, and noise. A total of 600 observations were

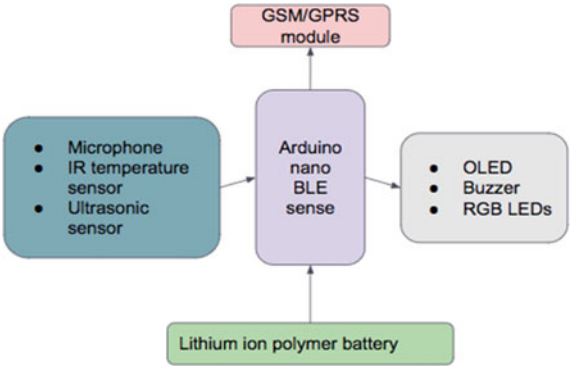

Fig. 1 Embedded system block diagram

made for each class. Each class's data was split into 20% test data at random. The embedded ML training platform Edge Impulse, powered by Edge Impulse was then used to upload data into the digital signal processing pipeline. Additionally, 20% of the data is divided into a validation set and 60% is left as the training set.

Model Training—A neural network classifier based on Keras and tensor flow light was used to train the model. A learning rate of 0.02 with 300 training cycles was applied with a 1D convolutional architecture with eight layers including input, reshape, pool, flatten and output layers. Figure 2 shows the model architecture.

3.4 Experimental Setup

To develop the prototype, we used Arduino nano BLE sense for data processing, on one hand. On another hand, we used a microphone (embedded in Arduino BLE sense), an infrared temperature sensor, and an ultrasonic sensor for data collection. The output is communicated to the user through a micro OLED display. After data analysis, the results are sent to the cloud using a GSM/GPRS module. The infrared temperature sensor and the OLED display use I2C communication and both were connected to Arduino SDA and SCL pins on the hardware and on the software, they used different addresses to work together. For the sim800l GSM/GPRS module, we used the Tx and Rx pins connected to digital pins 5 and 6. Due to the power requirement of the module (between 3.4 V and 4.4 V, and 2A), it is powered by a step-down module and a power adapter. The ultrasonic sensor was connected to digital pins 2 and 3, respectively, for trigger and echo pins. According to the cloud platform, we used ThingSpeak for data visualization on the cloud. We had a channel with four fields where field1 is for the device ID, field2 is for temperature measurements, field3 is for distance measurements, and field4 is for predictions. The developed prototype is shown on Fig. 3.

Fig. 2 Model architecture

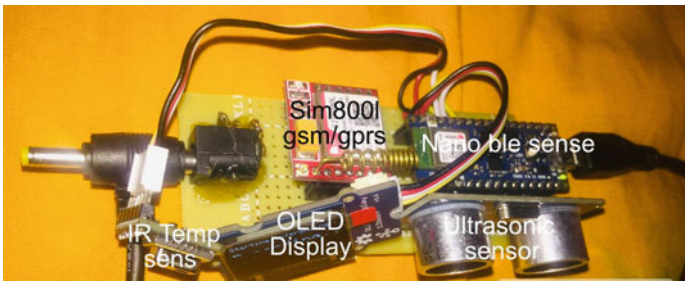

Fig. 3 Prototype

Fig. 4 Model confusion matrix

4 Results and Analysis

4.1 Model Training Results

From the performance on the validation set, the accuracy was 68.2% and a loss of 0.76. Better results would be achieved with more data and additional sets. Figure 4 shows the confusion matrix for the model.

4.2 Device Performance

In order to ascertain whether the model could function as intended on an embedded device, the model's resource requirements on the device were examined. On an embedded device from the cloud training platform, the model's estimated on-device performance was 5.1 Kb of peak RAM utilization, 30.6 Kb of ROM usage, and an inference time of 1 ms. The findings indicate that just minimal resources are still needed. This demonstrates that a large number of commercially available embedded devices that have the necessary ARM cortex M4 processor may use the model.

4.3 Prototype Results

The proposed device was tested in different settings and the results are presented in Fig. 5. The figure shows the detection of noise and cough and how the data are sent to the cloud. The device is able to predict if the environment is safe or not and this information is sent to the database.

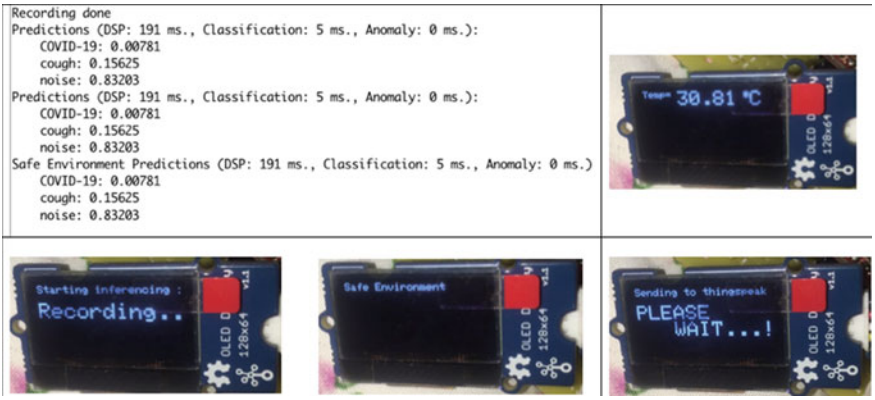

Fig. 5 On-device inference

Figure 6 shows the distance measurements as well as the temperature and the predictions on the cloud.

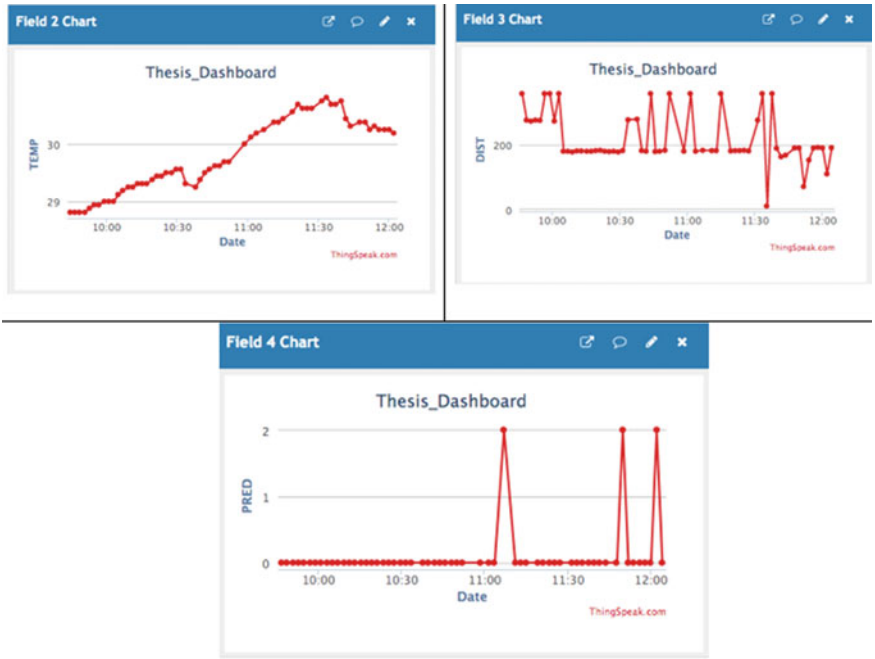

Fig. 6 Temperature, distance, and predictions on cloud

5 Conclusion and Future Work

Respiratory diseases are among the leading causes of premature deaths across the globe. Early prediction of the transmission can help to take necessary actions so as to avoid such untimely deaths. This study presented an IoT-based device to alert citizens of a likely exposure to COVID-19 from the surrounding environment. A machine learning model is used to predict such exposures. The model was trained using open datasets, tested, and validated. The monitoring device senses the closeness to the area of infection and detects high temperatures and coughs from the environment. In case of risks, the user gets on-device alerts. The data is also sent to the cloud for future analytics. The results show that the implementation of the solution will help in ensuring that the general public is safe from unknown contraction of respiratory diseases. Future work will involve improving the model and collecting more data for other diseases.

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Musical Instrument Classification Using k-Nearest Neighbors

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Abstract This work presents the use of the k-nearest neighbors (kNNs) technique to achieve the classification of selected sounds through the use of audio analysis. By implementing some audio spectral analysis, it is possible to establish a unique trace of the sound from each audio file. These traces are used to make computers learn to differentiate between various types of sounds in acoustic scenes by implementing the kNN machine learning technique. Adding the principal component analysis (PCA) technique for processing the data before including it in the classification model is expected to increase the accuracy of the model compared to the case when PCA is not introduced. The results show that the PCA technique improves the kNN model by analyzing the data distribution and reducing the dimensions of the data set keeping the most representative information of the original data.

Keywords kNN · Audio-set-ontology · Classification · Audio-analysis · PCA · Cross-validation · Musical instruments · Waveform

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1 Introduction

Musical instrument classification (MIC) has been described as a complicated problem, regarding audio analysis, because of the high entropy of information inside data samples [2]. Despite these obstacles, MIC can be applied to music transcription, data organization, and annotation in multimedia databases, as well as music retrieval [1].

The features that describe the sound structure of the audio signal, as well as their obtainment method, vary. Some extracted features are: cepstral, constant-Q, and autocorrelation coefficients by [4], zero-crossing rate, delta spectrum (spectrum flux), spectral roll-off frequency, mel-frequency cepstral coefficients, MPEG-7 audio spectrum centroid, envelope, spread, flatness, projection coefficients by [1].

In this work, the implementation of a kNN model is carried out for a MIC problem, where 18 different musical instruments are classified. In addition, the PCA technique is implemented for the processing of data with the aim of improving the accuracy of the classification model.

This paper is organized into several sections. Section 2 describes the data set to be used in the experiments and the explanation of the implemented numerical methods. Section 4 shows the results produced by the methodology denoted in the previous section. In Sect. 5, a benchmark between experiments is formulated, the limitations of the approach are mentioned, and comparisons with related works are carried out. By the end, Sect. 6 contains a resume of the characteristics of implementing the kNN model with two approaches. The first is with an analysis of the impact of each audio feature on the model, and the second is with the previous processing of data by implementing the PCA method. Besides, future work is mentioned to improve the accuracy obtained from the best approach encountered in Sect. 4.

2 Method and Data

For this work, it is going to be used the freesound data set Kaggle 2018 (FSDKaggle2018) [7]. This data set was initially made for the DCASE Challenge 2018 Task 2, which was run as a Kaggle competition titled Freesound General-Purpose Audio Tagging Challenge. The data set is conformed of 11,073 audio files manually annotated [8], divided into a train set (9.5k samples) and a test set (1.6k samples). The samples are unequally distributed among 41 labels of the AudioSet Ontology [9], and their duration ranges from 300ms to 30 s due to the diversity of the labels.

The data set containing the classification of sounds is distributed non-uniformly and has several labels of sounds such as Bark, Meow, Bus, and some others that are not related to musical instruments. Therefore, the input data set for the classification model is required to be cleaned to keep only the musical instrument-related samples.

In accordance with the previous analysis, the labels for the various kinds of musical sounds are the following. In Fig. 1, the corresponding distribution of data categorized in 18 classes is shown, where the maximum quantity of samples of the same musical instrument is 300.

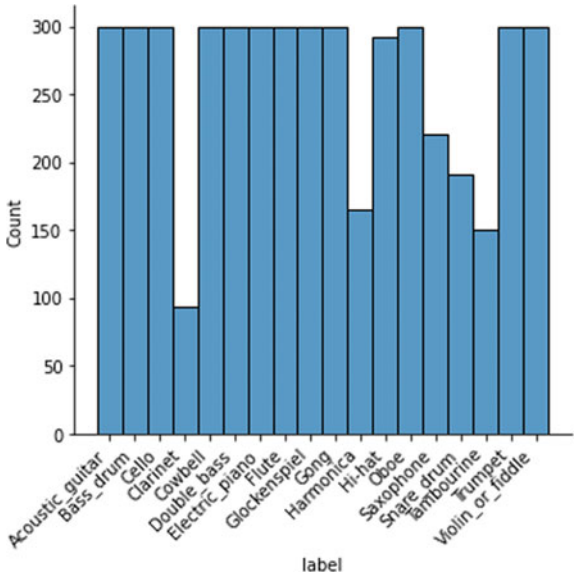

Fig. 1 Distribution of selected categories in the data set

3 Audio Analysis for Feature Extraction

In order to generate a data frame from these audio samples, some information on the waveform of each file was extracted using the Librosa library for audio manipulation in Python [16]. In order to obtain as much information as possible from each audio file, a wide variety of features were extracted. These features display information regarding two types of analysis: statistical waveform analysis and content analysis.

On the one hand, for statistical analysis of the waveform, four features are defined. The zero-crossing rate and the mean square values were obtained for different frames of the waveform, and the mean and variance obtained for each one of them are used as features.

On the other hand, for content analysis, another kind of metric is defined. The chromagram is a metric that allows the detection of the predominant pitches in the audio over time [12]. The spectral centroids and spectral bandwidth are metrics that allow the characterization of a spectrum and are also calculated for different time frames for the waveform [6, 13]. The roll-off and harmonics analysis are metrics that allow the identification of the most and the least predominant frequencies in the audio. Finally, the 20 mel-frequency cepstral coefficients are highly used in the field of voice recognition [15]. Although the tempo is not a characteristic that allows a notable differentiation between types of audio, it is included for the information it might obtain in benefit of the classification model.

In Fig. 2, a graph is showcased, rollof_mean vs chroma_mean. This graph is presented in order to observe how the different data of each label appear. It can be appreciated that at smaller values in the horizontal axis, the data overlaps more than at the larger ones.

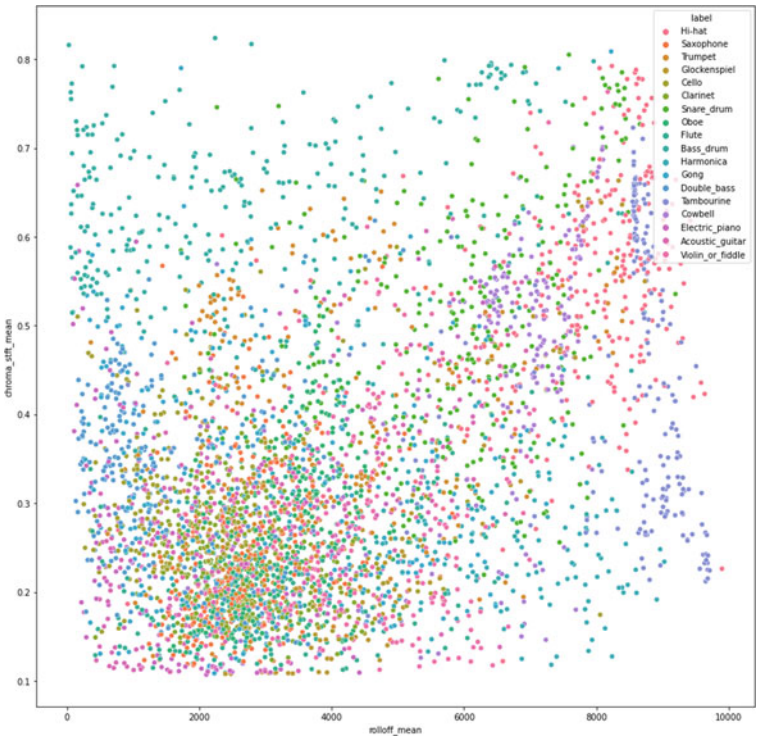

Fig. 2 Roll-off mean versus chroma stft mean

The mean and variance of all the metrics calculated are used as features resulting in a total of 55 usable features.

The duration of the waveform was included in the data frame but not used for the analysis. This is due to the fact that it is not a feature that has to do with the type of audio that is contained in the file and therefore is not of much use.

3.1 Principal Component Analysis (PCA)

Principal components analysis (PCA) is a numerical technique to reduce the dimensions of data by creating new linear combinations of variables preserving the outcome of the original data [14]. This method seeks to retain the principal components with the most variance values, which are uncorrelated, and generate a vector that maximizes the variation of the original data [11]. PCA has been used to process the input data in genetic algorithms [5] or to identify the best variables in medical diagnoses [3], and the results showed an improvement with respect to scenarios in which the approach is not implemented.

Table 1 Features sorted by their value of standard deviation

	Description	Feature name	Standard deviation
1	Mean of roll-off	roll-off_mean	0.2397
2	Mean of the stft chromagram	chroma_stft_mean	0.2245
3	Mean of the spectral bandwidth	spec_bw_mean	0.1961
4	Mean of the spectral centroids	spec_cent_mean	0.1859
5	Variance of the roll-off	roll-off_var	0.1737

3.2 Data Treatment

The PCA model requires that the input variables have a significant magnitude of distribution of the data in order to reduce the dimensions and retain the principal data that the input variables provide to the model. Hence, the standard deviation of each variable is measured and sorted from maximum to minimum value to identify the features with the most dispersion within each variable. In Table 1, the first five features with the highest standard deviation are shown.

From Table 1, the features related to the roll-off, spectral bandwidth, and spectral centroids are the features that have the most significant magnitude of distribution can be seen. In fact, this is beneficial since these characteristics are the most representative for the identification of main frequencies and harmonics generated by an instrument, although the ideal would be to have the Mel-frequency cepstral coefficients.

3.3 k-Nearest Neighbors (kNNs)

k-nearest neighbor (kNN) is a method to classify an unknown sample according to the surrounding known samples. By measuring the distance between samples, the nearest k are selected, and the most frequent class is selected to be assigned to the unknown sample [17].

For the implementation of kNN in this work, $k = 2$, and the weight function is the inverse of the Euclidean distance, which amplifies the value of the closest neighbors and reduces the value from other points.

4 Results

4.1 Best Features Analysis

Table 2 shows the results of trying to classify the musical instruments using only the mentioned features. These experiments were only carried out for certain combinations of the features found as the most distributed according to Table 1.

Table 2 Results obtained from evaluating the estimator using only the most representative features

Features used	Neighbors for best estimator	Score obtained
All features	2	0.7793
MFFC, roll-off, spectrogram	2	0.7609
MFFC	2	0.7553
Roll-off, spectrogram	6	0.4943
Chromagram, ZCR, tempo	6	0.4094

From Table 2, it can be concluded that the more features are used, the better the classification result will be. Also, the mel-frequency cepstral coefficients get better results than the variables that are related to the frequency content of the analyzed instrument.

4.2 Parameterization of the Model

An iterative method was implemented to identify the best values for the size of the input data frame (features) and the size reduction of the output data set to feed the kNN model (PCA).

In Fig. 3, both of the parameters are shown with their respective value of accuracy. In the left plot, the distribution of the points is more distributed than in the right plot, where the points seem to be following a tendency line.

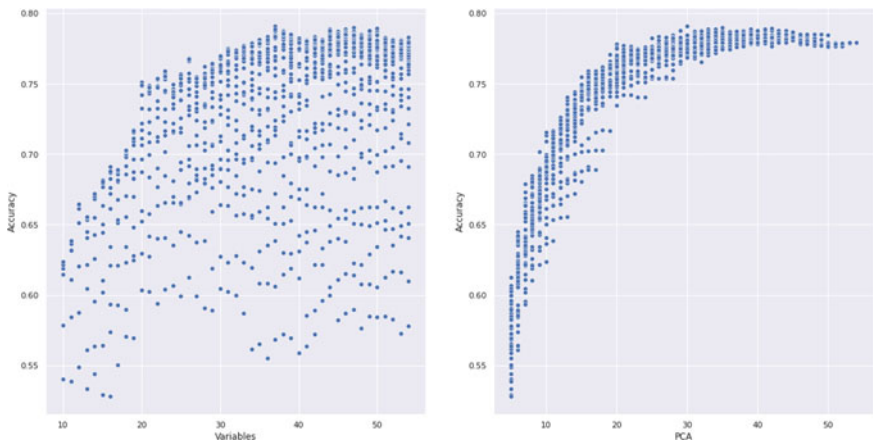

Fig. 3 Accuracy values related to input features and PCA variables

From these approaches, it can be seen that the values of the parameters at which the accuracy is maximum occur when the size of the input data frame has 37 variables, and the dimensional size of the data set, after implementing the PCA algorithm, has 30 variables in total.

4.3 Results from Applying the Optimal Parameters to the kNN Model

The scores obtained by the kNN model were as shown in Table 3. PCA did not improve the accuracy, but with the use of 45 features instead of 55, the obtained accuracy was maintained.

A comparison between real and predicted data can be seen in Fig. 4. The accuracy can be appreciated since the predicted clusters are very similar to the real ones.

By observing the confusion matrix in Fig. 5, it can be observed that 5 labels are accurate with a score of 0.9 or more; Cowbell (0.90), Double bass (0.91), Glock-

Table 3 Scores for the kNN model

Accuracy	0.7906
$F1$-score	0.7908
Precision score	0.7963
Recall score	0.7905

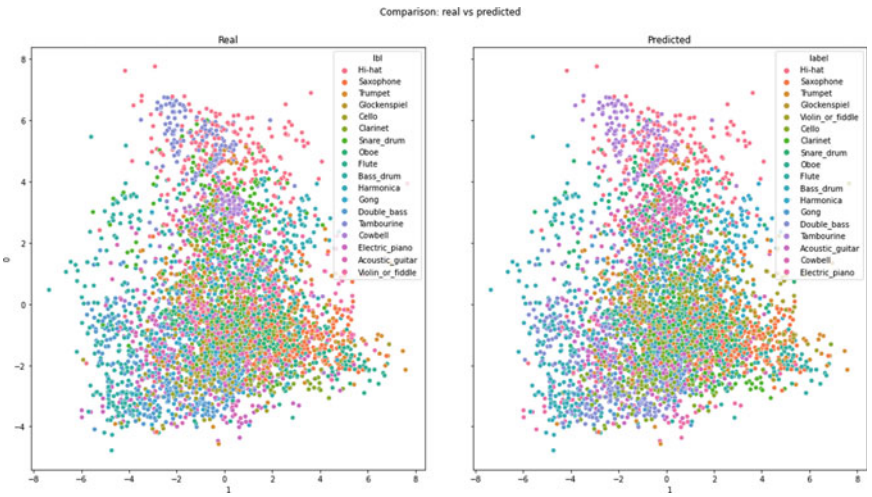

Fig. 4 Comparison between the real labels and the predicted ones for the data set

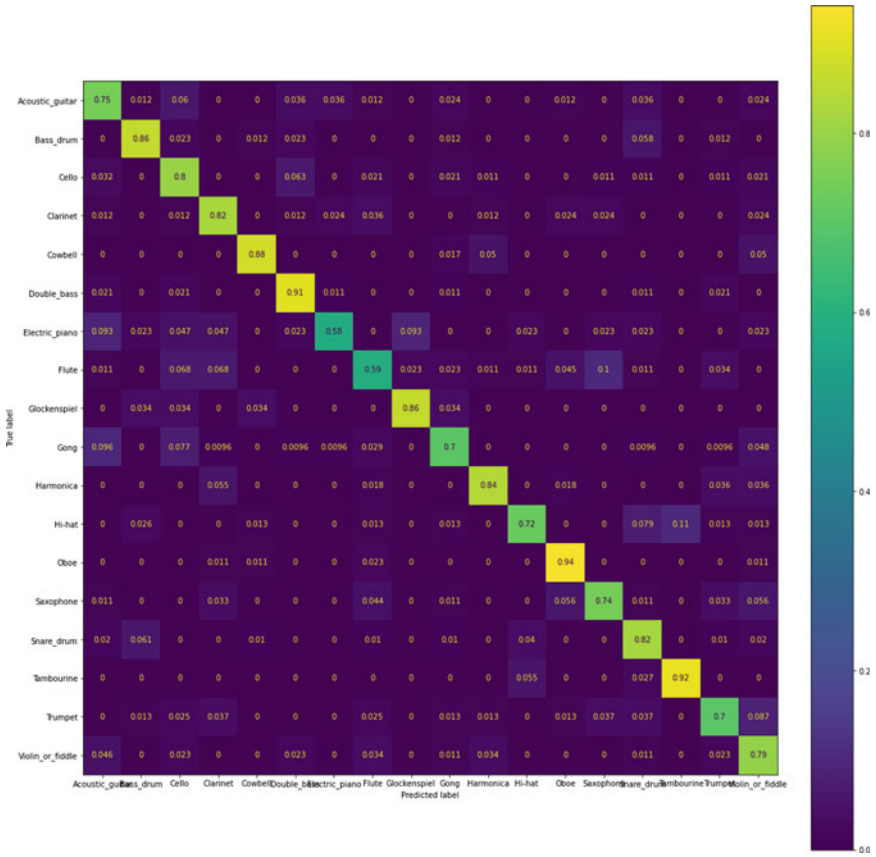

Fig. 5 Confusion matrix of kNN model

enspiel (0.90), Oboe (0.92), and Tambourine (0.93). While the least accurate labels were the electric piano (0.53) and the flute (0.56). Hence, it can be said that the overall performance of the kNN algorithm is acceptable.

5 Discussion

From Fig. 3, the number of possible solutions can be observed. However, only one combination of variables from the original database and the reduction of dimensions by implementing the PCA technique to obtain an adequate number of variables that improve the model's accuracy is optimal.

An initial hypothesis of this paper was that the selected features would be able to accurately describe all the instruments, but as it can be seen in Fig. 5, the accu-

racy range for each individual instrument ranges from 53 to 93%. This obtained information proves that the selected features do not represent the data in an accurate manner.

Another hypothesis was that the addition of the PCA technique to data treatment would increase the scores of the model. This hypothesis turns out to be correct, due to the increment of accuracy from 77% from the model without PCA treatment to approximately 79% of accuracy, when PCA is included, by reducing the initial 37 features to 30 final ones.

The model cannot achieve a score greater than 80% attributed to the generation of the data set. The features are considered not adequate to describe in the best manner the differences between the sounds produced by instruments. More on this is explained in Sect. 5.1.

5.1 Limitations of the Method

For the correct identification of the type of instrument, according to an audio signal, the ideal approach is to use an ADSR envelope [10]. It refers to measuring the time it takes for the sample wave to reach its maximum amplitude (attack), the time it takes for the amplitude to go from the maximum to the sustain level (decay), the amplitude at the sustain level (sustain), and the time it takes for the amplitude to go from the sustain level to zero (release).

Eronen et al. [6] used the full pitch ranges of 30 orchestral instruments. Due to this, they were able to obtain the features of an ADSR envelope that were not possible in this paper given our data set. Because the database is made up of instruments playing melodies rather than single notes, it was impossible for us to obtain each of these characteristics for data set generation. That is why we chose to see how possible it was to obtain a good score when ranking using other types of metrics.

The accuracy is dependent on the information obtained from the features of the data set; hence with the use of CNN to obtain the features, which are in a black box, the accuracy drastically improves [18].

5.2 Comparison with Other Works

In 2001, Brown et al. [4], identify four musical instruments (oboe, sax, clarinet, flute) in performances with the use of feature extraction as presented here, but with different features (cepstral coefficients, constant-Q coefficients, spectral centroid, etc.). Their obtained accuracy was in the range of 75 and 85%. It must be remarked that higher accuracy is expected when there are few labels to classify.

In 2000, Eronen et al. [6] used the full pitch ranges of 30 orchestral instruments. They also made use of feature extraction and, as previously mentioned, had features

that could not be taken into account here. For the paper of [6], the correct instrument was recognized in 80% of cases.

In 2018, Maliki et al. [15] continue the research of the use of learning vector quantization (LVQ) and mel-frequency cepstral coefficients (MFCC) method of extraction. They classified the sound source of the instrument with an accuracy of 94.80% of the test training test.

In 2022, Blaszke et al. [2] identified instruments present in audio samples using sets of individual convolutional neural networks (CNN) for each instrument. For this experiment, four were chosen: bass, drums, guitar, and piano. Different instruments showcased different results, and drums were easy to classify (99% accuracy), unlike guitars (86% accuracy). Their proposed solution achieved an AUC ROC of about 0.96 and an $F1$ score of about 0.93, outperforming our method.

In 2022, Prabavathy et al. [18], for 16 instruments, using the pre-trained network model GoogleNet as a feature extractor and two classifiers: support vector machine (SVM) and k-nearest neighbors (kNN). Their results obtained an accuracy of 99.37%.

6 Conclusion

This work presents the classification of 18 musical instruments. The method presented here is the use of feature extraction using the Librosa library for audio manipulation, with the information displayed being statistical waveform analysis and content analysis. This is unlike the current common methods of using a CNN to extract the main features.

After the selected features were obtained and the data cleaned, the kNN method was used to classify this new data. As it can be seen in Table 2, the scores were not optimal, the highest being with the use of all the features and an accuracy of 77.93%.

Therefore, the PCA technique is applied with the optimal parameters discovered in the previous analysis, and the final score of the kNN classification model has an accuracy of 79%.

6.1 Future Work to Do

In order to obtain higher scores, several actions should be taken. Firstly by changing or amplifying the data set containing the features extracted from the audio samples. This action should be performed with the purpose of obtaining the features of an ADSR envelope that are not covered in this paper. Besides, as mentioned in [18], the combination of a deep learning method with a classification model increases the performance of the classification model. Therefore, feature extraction and model generation should be explored, including a convolutional neural network (CNN) to observe the impact of these novelty types of data analysis.

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Sentiments Analysis on the Implementation of Online Learning in the Philippines Using Visual Analytics

Raymer P. Manaig, Paulyne S. Manaig, and Ramon L. Rodriguez

Abstract Implementing online learning in the Philippines during this COVID-19 pandemic was challenging for all Higher Education institutions and Basic Education. The study aims to analyze the sentiment of Netizens in the country during the implementation of online learning based on the tweets data. The study collected 1912 tweets using different hashtags related to online learning. Only 1750 tweets were included in the analysis because some tweets were unrelated to online learning during the preprocessing. The visual analytics approach was used to know the sentiments of the people. Results show that most netizens around the country have negative sentiments about the implementations. It further indicates the unpreparedness of education stakeholders in implementing online learning through several initiatives that have already been done in the past years. It further shows that there are no concrete strategies from the government to continue students' learning process. Institutions employ an individualized approach that leads further to the confusion of the education stakeholders that most netizens perceive negatively on implementing online learning.

Keywords Sentiment analysis · Online learning · Visual analytics

1 Introduction

Coronavirus infection 2019 (COVID-19), the exceedingly infectious irresistible illness caused by severe, intense respiratory disorder coronavirus 2 (SARS-CoV-2), has had a disastrous impact on the world's socioeconomics, with many deaths globally [4]. The pandemic triggers the need to shift the modality of the academic institution. The pandemic has changed the entire humanity. It alters our traditional way of collaborating with other people and the way we do our daily routine. The

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government immediately responded to the pandemic by implementing strict community quarantine, which hampers mobility and commercial activity. Though these steps help to prevent the spread of the virus, it has a severe negative impact on the economy. In third-world countries, including the Philippines, loss of income and job opportunities is the primary challenge. Some communities reported scarcity of the food supply, which resulted in nutrition issues. In the tourism sector, international and local flights have been restricted, tourism came to a grinding halt, and domestic lockdowns crippled the retail sector, restaurants, and hospitality industry. The economy has declined since World War II, with GDP decreasing by 9.5% in 2020.

The education sector is deeply affected as well by the COVID-19 pandemic. Face-to-face classes in the Philippines were suspended during the early months of the pandemic. Sudden changes in the learning approach have been implemented from conventional face-to-face to online learning. Unfortunately, most schools are unprepared for this setup and unable to adapt and shift to the new normal in education immediately. Furthermore, students, particularly those in remote areas, cannot find a stable internet connection. They must cross mountains or kilometers of walk to be able to go to a place with a good signal. Lastly, the cost is another burden to the students as they must buy laptop computers, subscribe to a personal internet connection, and set up a learning area at their own expense.

On the other hand, the new normal in education has opened the door to different opportunities. For the OFW, it helps them to pursue their dream of completing their studies despite being in other countries with different time zones. A flexible schedule also allows working students to balance their time between family, education, and work.

The goal of this study is to perform contextual mining of text to identify the view or sentiments of Filipino people behind online learning. Using the social platform (Twitter) data, this research will analyze the sentiment trend from the time pandemic started to the year-end of 2021. The sentiments of the netizens will be classified into positive, neutral, and negative polarities. The study's outcome can help the national government, private sector, and non-government units discover new strategies, improve crisis management, and improve the quality of services. By observing the conversations on their social media and detecting the specific key messages, specific methods or approaches can be designed for particular areas or groups. Sentiment analysis can help avoid escalating complaints by immediately identifying issues early.

2 Review of Related Literature

Social media platforms like Twitter are popular among Filipinos. Based on statista.com, around 10.5 million [8] users came from the Philippines, representing 10% of the country's entire population. Twitter has become the platform for discourse among citizens, especially if it involves national interests such as online learning.

Knowing the sentiment of the citizen in a democratic country may help in policy making which is vital.

Twitter became the avenue for students to convey their grievances and discuss hot issues concerning their feelings. Several pieces of research acknowledge that analyzing the netizens' opinions, whether positive or negative, can be a helpful input in policy making both in the private and government sectors. Isnain, A. R. et al. implemented a KNN algorithm to classify public sentiment on online learning. Only 1825 tweets were used as training data, of which 56.24% were labeled positive, and 43.76% were negative. The model experiment's training result is promising, with 84.93% accuracy, with $K = 10$ [7]. The study of Waheeb et al. [12] uses an autoencoder noise reduction and proposes a novel cross-feature fuse method that relies on the attention technique. The author adopted a deep learning-based model. On the other hand, Almalki used logistic regression in classifying sentiments of Arabic tweets in distance learning and had promising results [2].

Moreover, understanding the public emotional reaction to online learning concerns educators and policymakers, especially during COVID-19. Aldabra et al. [1] analyze Arabic tweets about distance learning in Saudi Arabia using different classifiers. Results show that most of the processed tweets have a polarity of neutral. Most negative sentiments find online learning tedious, terrible, and stressful, and positive people see this as an opportunity to explore further the benefits of online learning. On the other hand, developing policies on online education is essential. Still, it must be thoroughly examined to make it fair to all stakeholders. M. Mujahid et al. investigate the effectiveness of e-learning by analyzing the sentiments of people who experience the online modality [10]. The study uses a large dataset containing 17,155 tweets about e-learning.

There are many kinds of research done in sentiment analysis using Twitter data. Druz & Khalid conducted a systematic review on sentiment analysis using a tweets data set [5]. Then, they found that most researchers used opinion-lexicon methods to analyze the text sentiment in social media and focus on the events, healthcare, politics, and business domain. At the same time, Chen et al. [13] acknowledge the importance of social media sentiment analyzes. However, it is also essential to present the different perspectives concerning analyzing text on the social media platform.

Moreover, the paper focuses on education, where the researchers want to know the sentiments of students and parents on the online education implemented by the government. The usefulness of the Twitter platform in changing the discourse landscape is evident, especially in trying to understand its sentiment. This analysis can only be applied to another field, such as customer understanding. The sentiment analysis using social media data can also be necessary for online marketing [11], which understands the customer's sentiment.

Metadata can be used as an essential feature in the analysis. Andreadis et al. proposed a framework for collecting, analyzing, and visualizing Twitter posts in the spread of the virus in Italy. Their groups used geotags to develop the visual analytics dashboard that visualizes the result of the topic, community, and event detection methodologies [3].

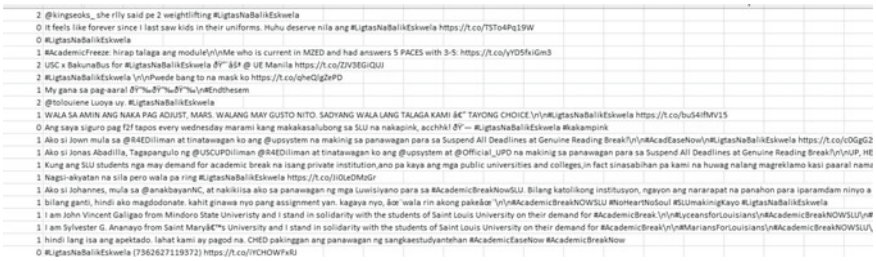

Fig. 1 Sample tweets

3 Methodology

The Twitter data were collected through the academic research license. The total number of tweets collected is 1912, of which 1753 were used for visual analytics analysis. In collecting, the following data hashtags were used: #noschoolnofees, #JusticeForStudents, #notoonlineclass, #ParentsDemandJustice, #NoSchoolNofee, #NoSchoolDuringPandemic, #NoToOnlineClass, #AcademicFreezeNOW, #AcademicFreeze, #college, #NoStudentLeftBehind, #EducationForAll, #NoMassTestingNoSchoolOpening, #StopOnlineClasses, #SafeSchoolForTeachersAndLearners, #WalangIwanan, #AcademicEaseNow, #NoToOnlineClass!, #MassPromotionNow!, #EndTheSem, #MassPromotionNow, #WalangIwanan, #LigtasNaBalikEskwela, #LigtasNaBalikPaaralan, #NoStudentLeftBehind. Figure 1 shows the sample tweets downloaded from Twitter.

The download tweets were manually cleaned to exclude tweets unrelated to online learning. With 1912 downloaded tweets after the cleaning process, only 1753 were subjects for the annotation process. Three (3) annotators ate conscious and sensibly aware of the keywords used in positive, negative, and neutral. The tweets were annotated based on three categories consisted of positive, negative, and neutral. The annotators used 2—for positive, 1—for negative, and 0–for neutral. Figure 2 shows the sample annotated tweets.

After the annotation process, Microsoft Power BI was used to get the sentiment of tweets based on locations using visual analytics. Part of the tweets data is the location metadata which mentions the location of the Twitter user in text format and automatically converts to latitude and longitude using the Power BI features.

4 Discussions and Analysis

This section presents the analysis of the tweets using visual analytics. This study was conducted to understand further netizens' sentiments regarding implementing online learning in the Philippines. In downloading the tweets, the following hashtags

Num	Class	Raymei	Paulyn	S'Ram	text
220	1	1	1	1	#AcademicBreakNow \n#AcademicFreezeNOW
221	1	1	1	1	Ang mabait na kapitbahay nag vivideoke ng tanghaling tapat, habang may online synchronous classes ka \nSaya kayo ghorl? Haha \n\nSurri na m
222	1	2	1	1	The current situation is really alarming. #AcademicEaseNow #BatStateU
223	1	1	1	1	No more checking of aims!\n#AcademicFreeze
224	1	1	1	1	what's happening right now is not okay \n\n#AcademicFreezeNOW
225	2	2	2	1	Oo nga pala #AcadEaseNow #AcademicEaseNow haha
226	1	1	1	1	Arat na mag face to face class sawa na me sa online class. Kapag nilagnat uwi na lang sa bahay chosss #LigtasNaBalikEskwela
227	2	2	2	1	Ako si Jown mula sa Maskom at nakikiisa ako sa Araw ng Paniningil sa Kriminal na Kapabayaan ni Duterte sa Edukasyon dahil walang patutunguhan ang paulit-ulit n
228	2	2	2	1	Ako si LODI mula sa UP KAL at nakikiisa ako sa Araw ng Paniningil sa Kriminal na Kapabayaan ni Duterte sa Edukasyon dahil HE'S A VERY BAD DOG! \n\n#AcadEaseNo
229	1	1	1	1	Ako si Ryan at kaisa ako sa panawagan para sa academic ease. Kinukundena ko ang kapabayaan ng gobyerno sa sektor ng edukasyon sa gitna ng pandemya!\n\nEns
230	2	2	2	1	Let us be particularly mindful of those in the direct path of this virus. #WalangIwanan https://t.co/gmTisdR2eY
231	1	1	1	1	Ayoko na . Syet umay... \n#AcademicFreeze
232	1	1	2	1	#NoStudentLeftBehind\n#UEHearYourStudents https://t.co/9omxnqPQMB
233	2	2	2	2	Nasa list na ba ang buong barkada? \n\n Ayos! #WalangIwanan https://t.co/JzroIWiTRU
234	2	2	2	1	Patuloy ang paglaban! First Day Fight with @R4EDiliman and @UP_ESC \n\n#LigtasNaBalikEskwela\n#DefendUP \n#DefendAcademicFreedom\n#NoToCampus
235	1	1	1	1	Ngayong araw, muli tayong isinasabak sa palpak na distance learning. Sa hamon ng panahon, tumitindig ang @R4EDiliman para sa ating karapatan sa ligtas, abot-ka
236	1	1	2	1	Ako si Jonas mula sa @UP_ESC, @R4EDiliman @R4EEngg at nananawagan ako sa ating administrasyon upang isulong ang hiling natin na ligtas na balik laboratoryo! N
237	2	2	2	1	-5 #LigtasNaBalikEskwela https://t.co/fHKMnB2BQp
238	1	1	1	1	#AcademicFreezeNOW #AcademicFreezeNOW #AcademicFreezeNOW #AcademicFreezeNOW #AcademicFreezeNOW
239	2	1	2	2	Kasama po sa distribution ang representatives ng Office of the Vice Governor, Provincial Treasurer's Office at Provincial Internal Audit Office. #NoStudentLeftBehin
240	1	1	1	1	Wala po akong na intindihan sa modules kbye!.\n#AcademicFreeze \n#WalaakongkaDatesaValentines \n#akoysabogna\n#salamatKBYE!
241	1	1	1	1	RETWEET KO LNG LIWAT AH HEHEHEHE BASI PAMAN YA\n#AcademicFreeze https://t.co/j8GOOIzcpv
242	2	2	2	0	Salamat po sa pag-attend ng GA!\n\n#DefendUP\n#LigtasNaBalikEskwela https://t.co/QSeTD4X7IH

Fig. 2 Sample annotated tweets

were used: #noschoolnofees, #JusticeForStudents, #notoonlineclass, #ParentsDemandJustice, #NoSchoolNofee, #NoSchoolDuringPandemic, #NoToOnlineClass, #AcademicFreezeNOW, #AcademicFreeze, #college, #NoStudentLeftBehind, #EducationForAll, #NoMassTestingNoSchoolOpening, #StopOnlineClasses, #SafeSchoolForTeachersAndLearners, #WalangIwanan, #AcademicEaseNow, #NoToOnlineClass!, #MassPromotionNow!, #EndTheSem, #MassPromotionNow, #WalangIwanan, #LigtasNaBalikEskwela, #LigtasNaBalikPaaralan, #NoStudentLeftBehind. A total of 1912 tweets were downloaded using Twitter API for academic research. However, not all tweets downloaded were included in the analysis. The tweets include metadata that helps the researchers further analyze the tweets, such as geotags and time.

Figure 3 shows the sentiments of Filipino regarding the implementation of online learning caused by the COVID-19 virus. The study utilized tweeter data as the data source. The dashboard clearly shows that netizens all over the country perceived negatively in implementation of online learning in the country. This indicates that HIEs or schools were not prepared for online learning even though digitalization was already in the country as early as 2000. This year e-learning is starting to become popular with the growing popularity of ICT in government and education [6]. Different initiatives by the government were launched to support the capability of students and teachers in the digitalization of education. Last February 2005 Department of Education launched the National Strategic Planning Initiative for ICTs in Basic Education [9]. Given all the initiatives of both government and private sectors in education transformations in the country, still, when the pandemic struck last 2020, almost all education stakeholders were in surprise. They tried to implement an individualized approach to continue the learning nationwide. With this, individualized strategies bring confusion to all education stakeholders, translated to negative sentiments of the stakeholders, as clearly shown in the dashboard.

Figure 4 shows the tweet count monthly trend based on the hashtag related to online classes in the Philippines. The trend indicates that the number of tweets started to increase by March-2021. In April-2021, the tweet count rapidly grows by more than 1000% (22 tweets from March while 245 from April). As per raw data, 60% of the

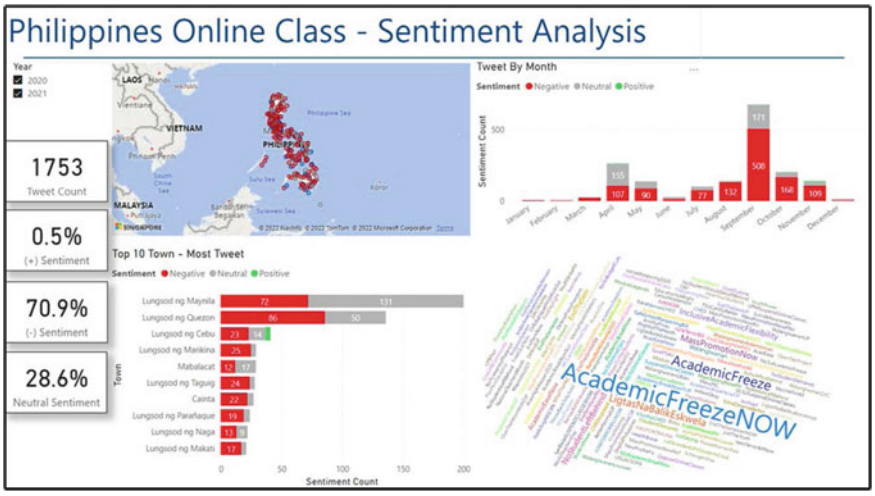

Fig. 3 Online learning sentiment dashboard

April tweets have neutral sentiments with a comment related to the mass promotion or automatic passing grades for all the students. The peak of the sentiment happened in September-2021, wherein 508 out of 679 expressed adverse reactions due to the opening of the school year 2021–2022 with an online learning setup. Based on the tweet message, students were appealing to the government to freeze the academic period feeling that the process is inefficient and not all can afford to buy gadgets for the online learning setup.

Figure 5 shows the top 10 locations in the Philippines with the highest number of tweets related to online learning. 6 out of 10 are cities from the national capital region, with Manila as the highest. A possible contributor to this trend is the number of people residents since 14.9% of the country's total population is living in NCR. On the other hand, students from remote areas could not access social media platforms due to connectivity constraints.

Looking at different hashtags used by Twitter users, it is evident that most want to end the implementation of online learning, which connotes negative sentiments. Figure 6 shows that "AcademicFreezeNOW," "AcademicFreeze," and "LigtasNaBalikEskwela" were used in airing sentiments by students. Aside from asking to halt the online classes, they also want to ensure that returning to schools should be safe by crafting schools' policies. Of 1753 tweets from 2020 to 2021, 70.9% expressed negative sentiments regarding online learning. Most of these are using the hashtag named "#AcademicFreeNow" as shown in Fig. 6.

Figure 7 shows the sentiment analysis heat map. The visual will display red for the negative, green for the positive, and gray for the negative sentiment. Most towns or cities have a red color with very minimal green and gray. There are also outliers on the heat map, which reflect blue color. These are the towns with a low number of tweets with changes in the sentiment.

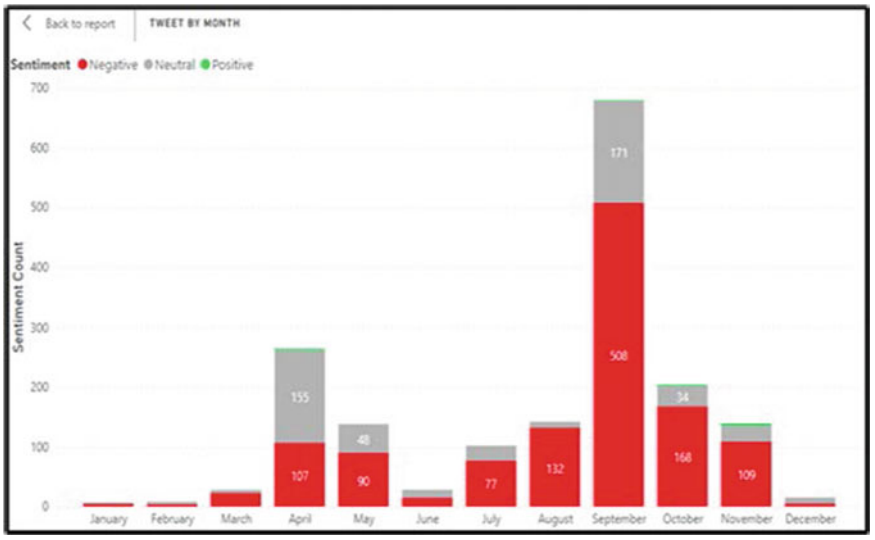

Fig. 4 Online class sentiment by month

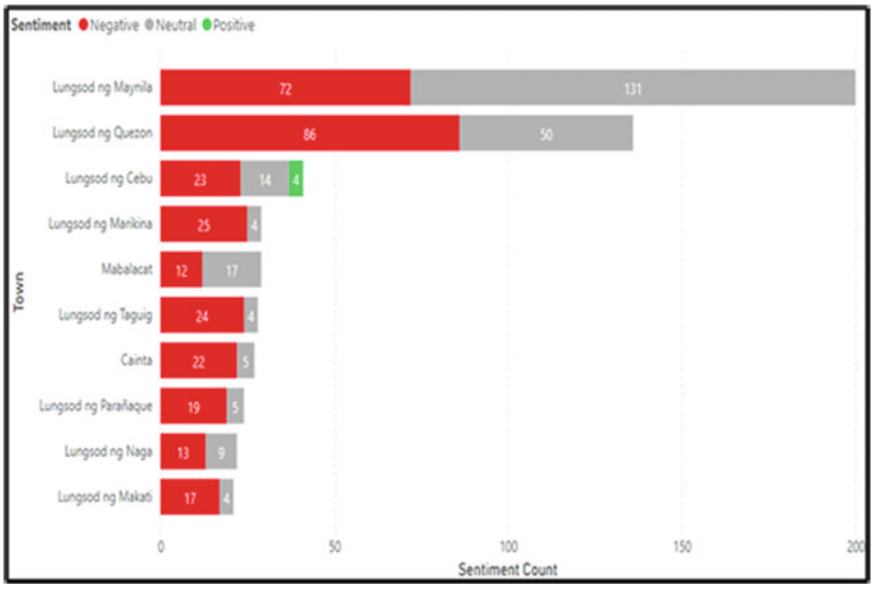

Fig. 5 Top location with the highest number of tweets related to online learning

Fig. 6 Hashtag word related to online sentiment

Fig. 7 Heatmap of sentiments around the country

5 Conclusion and Future Works

With the extremely high number of negative sentiments, the study shows that students are unhappy with the online learning setup for various reasons. The pandemic highlighted that Schools in the Philippines were not prepared for ICT-based learning despite the National Framework Plan for ICT from 2005 to 2010. The need to strengthen the ICT infrastructures all over the country is urgent simultaneously, including technology in every institution. The government can use this study to improve further or address the student challenges.

Visual analytics is only one approach that can be used in understanding the sentiments of netizens, especially in the field of education. Other researchers may explore different approaches to understand every student's flight in the country. Though the small set of tweets data was used, it was clear that netizens were not satisfied with the online or virtual learning happening in the country.

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Sentiment Analysis About the Popular Soccer Player Mbappe on Social Media and Newspapers

Oscar Yllan Garza, Angelo Jean Carlo Ovando Franco, Héctor Ceballos, and Francisco Cantú

Abstract Social networks, mainstream media, and google searches are probably the most common way Millennials and Centennials look for information, also as the World Cup being at this time big players gain or lose support from fans when there are scandals about them. Mbappe is nowadays the most expensive player in the world, but some months ago, it was discovered that he started a relationship with a Transgender Model Ines Rauz, and this project is going to analyze using modern libraries and modern techniques for sentiment analysis to analyze the three aspects that affect the opinions and believes from people. Doing it with mainstream media and users from two of the most spread languages in the world that are Spanish and English.

Keywords Sentiment analysis · Web scrapping · Trends · Social media · Text mining

1 Introduction

Soccer has reached more popularity in the last few years; more people have become fans of this sport and start following the life inside and outside of the field of the athletes that are part of this discipline. According to Topend Sports, soccer is becoming more popular and having more fans around the world every year, and this is because it has entered new markets. There are soccer players who have sponsorships with other market companies, they have become more popular, and one of these

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players is called Kylian Mbappe, which will be analyzed in this project report. The objective of this project is to analyze this popular soccer player Kylian Mbappe and analyze controversies and his growth in popularity in the last few years. We will use tools of text analysis from the main sport's online blogs and newspapers to analyze what comments are positive, negative, or neutral. We are writing about it because it has been a controversial topic nowadays, and its popularity has increased significantly, being one of the most important topics because Mbappe is the highest paid soccer player in the world. The important factors that we want to extract are to get the repetition of the name and the number of words and space that these texts talk about them and to see how the number of followers and mentions of these players in other social networks are related and compare how people who have different native language behave in social media. We want to verify if Mbappe's popularity decreased or was affected by his relationships outside of football, in this case, the current couple he is dating. Also, how the English Media and the Spanish and Latin American Media talk about these topics, and how the general users behave between different regions that is why also part of the study the analysis of comments in the popular social network Facebook, and the difference in sentiment analysis using the relative frequency of positive and negative words behaves between people of different regions.

2 Methods and Data

For doing the analysis of the media and fans sentiment analysis, we decided to use four methods in order to get the most insights possible for this project.

2.1 Text Classification

We will use different methods to determine the popularity of some soccer players mentioned in sports newspapers. One of them will be text classification, to define tags and categories to structure the text and make the analysis easier.

2.2 Text Extraction

Another technique that will be used is text extraction, to get pieces of data existing in the newspapers data, keywords that will help us to know how many times the team in which they are playing is mentioned, how many goals they score, assists per game, etc.

2.3 Word Frequency

Word frequency will also be used to measure how many times are specific words occurring or concepts using the numerical statistic.

2.4 The Specific

- Analysis in Mainstream Media Publications.
- Google News Sentiment Analysis of the Title Links from all Google Result Searches.
- Google Trends.
- Social Network Sentiment Analysis of the Comments from Football fans.

The data that we are going to use is going to come from three different types of sources:

- Sports Blogs Websites.
- Social Network Posts Comments.
- Google Trends.

From the Sports Blog Websites, we first made a Google Search and found the first 10 Relevant Online Sports News Sites that talked about Mbappe controversy. Some of them are the following ones:

- SportsBrief
- Marca
- SportBible
- Dailystar
- elFutbolero
- Futball News
- Politiko
- TheSportsGrail
- First Sportz
- Bild.

2.5 Sentiment Analysis in Mainstream Media Publications

For the first analysis, we decided to look for a list of the Top Mainstream Media Websites related to Sports or Football in an international context, so we choose 6 Websites that are known between football fans, and we decided to look using google intelligent search and keywords in order to find 6 publications from these sites.

Then, we found these 6 sites. We made use of some libraries that are useful for data analysis, Web scraping, sentiment analysis, and natural language processing.

- Newspaper library
- NLTK
- TextBlob
- NumPy
- Pandas
- Matplotlib.

With the use of these libraries, we could make Web scrap each site, then we made some data cleaning. The next step was using these libraries to use the sentiment polarity attribute from the blob class, and we could retrieve a sentiment coefficient for each site.

The criteria are the following according to the documentation:

- $-1 <$ coefficient < 0: Negative sentiment over the content
- coefficient $= 0$: Completely neutral
- $0 <$ coefficient < 1: Positive sentiment over the content.

2.6 Google News Sentiment Analysis of the Title Links from All Google Result Searches

We decided that a way to also see if the media, Websites, and google are influenced or biased about this topic so we decided to do the following approach for getting that result.

We make use of the following libraries from Python in order to do Web scraping, data collection, data cleaning, and data analysis [1].

We made the following Google Search "Mbappe Transgirlfriend" then making use of Web scraping techniques, we retrieve all results from the first 5 pages of Google News related to our search. Here, we decided to extract just the titles from each link, and then, we decided to transfer all these strings into a csv file in order to make use of pandas for doing easier analysis. When we did that after that our method gave us three values from each of the 30 results, we got that gave us a positive, neutral, and positive score, then it calculated the average from all sites and gave us some values.

2.7 Google Trends

Google has a free tool that allows for any user to see the trends of Google Searches by time period and by country for doing the analysis, we used the following constraints when looking for Mbappe.

- Fig. 3 is from October 31rst 2021 to 15th October 2022.

- In Fig. 4, we can see that we are changing the interval from September 1rst to October 31rst 2022 this with the purpose to avoid the noise that comes from the time period where Mbappe Manipulated PSG and Real Madrid to get a better contract and that increased the trend.
- We also decided to use the geographic feature emphasizing Mexico to discover which states talked more about the topic.

2.8 Social Network Sentiment Analysis of the Comments from Football Fans

For doing the following analysis, we decided that it would be convenient to use data from Facebook publications related to the Mbappe Transexual Girlfriend for doing such job, it was used the Facebook searcher with the "Mbappe girlfriend" and "Mbappe novia" the first one for the English search and the second one for the Spanish results.

We choose the three first publications with more comments in both languages, then we copy some of the comments that we found out they were negative or positive. Each of these comments were copied into a Python list format for one publication, then using lists and string properties we decided to extract each word and compare them with a list.

We decided that something that would be interesting and useful for this part of the project was that instead using just a library as before for doing the sentiment analysis, we decided to create four different lists of words with positive and negative meanings, two each language in order to create our own function of sentiment analysis using social network text mining [1].

Then, we had the twelve lists two for each publication we make use of the pandas library in order to count how many times each word from our own created lists of negative and positive meanings were in that publication then the next step for us was to create dataframes of two columns one with the total frequency (number of times that word appeared in the comment) and the relative frequency (basically, the total frequency divided by the total numbers of words in that publication) [2].

3 Results

4 Discussion

4.1 Sentiment Analysis in Mainstream Media Publications

The results from the previous sections gave us interesting results where we can observe that for our six new sites that all of the values of the coefficients were between 0.15 and −0.05. Where we can appreciate that DailyStar Sites were the

Web News Sites that had the most positive sentiment coefficient which is logical and aligns to our hypothesis the American and English Media tends to support and be pro LBGTQ Groups for the contrary, we can observe that Marca, the Spanish site, was the only one with negative value in the sentiment coefficient analysis, which is also logical because generally Spain and Latin America countries tend to have more negative feelings about that community [3].

4.2 Google News Sentiment Analysis of the Title Links from All Google Result Searches [4]

The results from the Web of all Websites that publish something about the Mbappe Transgirlfriend Scandal were as expected most of them neutral with 96.1% of them, and we found out just 2.2% for negative and 1.7% for positive sites about this scandal.

4.3 Google Trends

In this part of our work, the results of the first the last year Google trend were not conclusive and gave data not related to our Topic because Mbappe biggest peak of searches in Google Trends was not related to his scandal, and it was directly related to the Real Madrid and PSG fail Market contract.

In the second part, we can appreciate that there was a big constant trend in search when Mbappe scandal took more mediatic recognition that was during September.

The last one we can appreciate the Map was Mbappe searches which were more frequent, and we can see that Campeche and Nuevo Leon were the two states with more searches about the topic.

4.4 Social Network Sentiment Analysis of the Comments from Football Fans

The Spanish results tend to have between 0.02 and 0.083 relative frequency in the positive comments and between 0.006 and 0.045 in the negative side.

The results for the publications in the English language were the following ones, the positive ones were ranging from 0.043 to 0.67. The negative sides were between 0.028 and 0.043 [5].

We can observe that the preliminary sentiment analysis from the Figure n.0 that in the plot most of the SportsBlog news that were close to 0 having 5 positive and just one negative that shows that Mainstream media tends to be kind of neutral or

have positive trends when they talk about Transwoman news due to the political correctness.

5 Conclusion

Daily Star Sites are the Webpage which has the highest number of sentiment coefficient followed by SportsBrief, this is due they are not impartial newspapers, and they support another team different than the one Mbappe is currently playing.

In the introduction, we stated that purpose of this study was to analyze and see how media, google sites, and users interacted with each other Scandal from Mbappe dating a Transgender Woman. After the four analysis that we used we could see that our hypothesis that Media coming from English speaking countries American and British companies were between neutral to positive comments about Mbappe new love partner, and that the Spanish and Latin American tend to have more negative perception about this topic and as we saw in the discussion of results from Figs. 1 and 2. Figures 3 and 4 [5]. We saw that the impact of the scandal was significant for his reputation but not as much to be more relevant that his failed pass to Real Madrid in summer. Finally in the study that was about the social media comments and posts related to Mbappe Transgrilfriend in Spanish and English we could appreciate that generally the comments to this topic had higher value for positive and negative relative frequencies meaning that Spanish and Latin American users are more emotional and tend to express more their feelings in social media that was appreciated from Figs. 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16 (Fig. 5).

In conclusion, Spanish users as media tend to be more negative about Transexual scandals but not as much as we in the beginning believed at least for users, the values were really close from each other.

For the future what we expect to do is to analyze if Mbappe's popularity as Instagram, Facebook, and Twitter followers were affected by these scandals. We could use more modern tools such as Twitter and Software APIs and Tools for

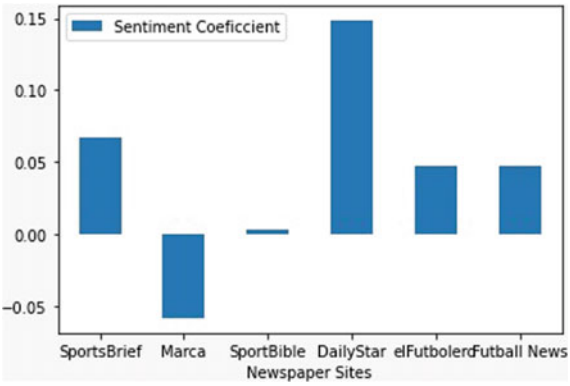

Fig. 1 Sentiment coefficient from the newspapers

```
    Negative  Neutral  Positive
20     0.000    0.783     0.217
15     0.375    0.435     0.190
19     0.306    0.590     0.103
0      0.000    1.000     0.000
1      0.000    1.000     0.000
NEGATIVE Score of the Titles:  0.021967741935483873
NEUTRAL Score of the Titles:  0.9615483870967743
POSITIVE Score of the Titles:  0.016451612903225808
```

Fig. 2 Google news sentiment analysis from all google result searches

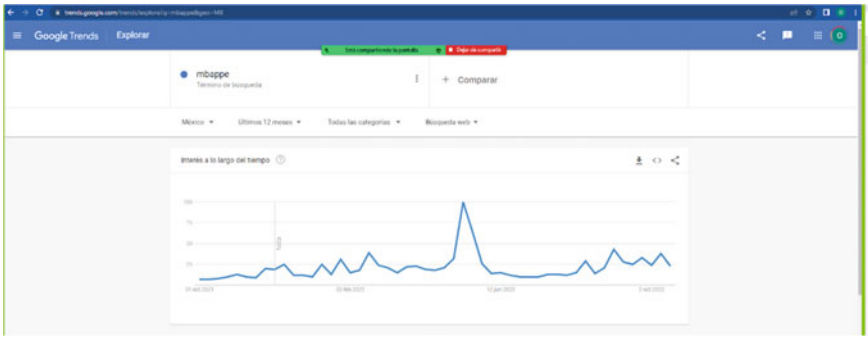

Fig. 3 Last year google trend of Mbappe searches

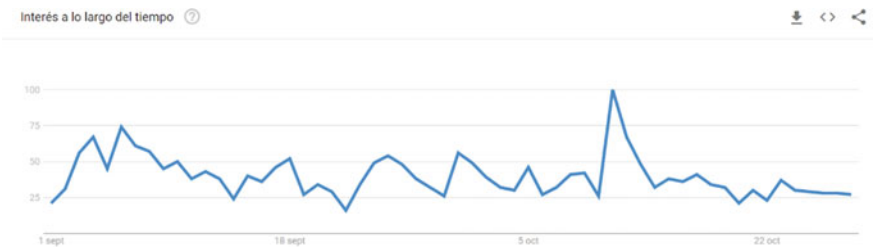

Fig. 4 Last year google trend of Mbappe searches

developers such as Facebook for Developer Graph QL and some data from Twitter to make a bigger analysis.

Fig. 5 Last year google trend of Mbappe searches

Fig. 6 Positive Spanish post 1

	Frequency	Relative Frequency
feliz	2.0	0.020202
feliz	2.0	0.020202

Fig. 7 Negative Spanish post 1

	Frequency	Relative Frequency
triste	1.0	0.005952
rabia	1.0	0.005952
vergüenza	1.0	0.005952
gay	1.0	0.005952
mal	1.0	0.005952

Fig. 8 Positive Spanish post 2

	Frequency	Relative Frequency
feliz	1.0	0.058824
alegre	1.0	0.058824
feliz	1.0	0.058824

Fig. 9 Negative Spanish post 2

	Frequency	Relative Frequency
pendejo	1.0	0.045455

Fig. 10 Positive Spanish post 3

	Frequency	Relative Frequency
grande	1.0	0.083333

Fig. 11 Negative Spanish post 3

	Frequency	Relative Frequency
zorra	1.0	0.015873
horrible	1.0	0.015873

Fig. 12 Positive English post 1

	Frequency	Relative Frequency
amazing	1.0	0.052632

Fig. 13 Negative English post 1

	Frequency	Relative Frequency
fag	1.0	0.028571

Fig. 14 Positive English post 2

	Frequency	Relative Frequency
perfect	1.0	0.043478

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A Survey on Estimation of Gender and Emotion Using Paralinguistic Features

S. Sathyavathi, H. Deksha, T. Ajay Krishnan, and M. Santhosh

Abstract Interface between humans and technology is important in a quantitative and qualitative standpoint. Gender recognition, emotion-based response, is among one of the difficult areas of research. Voice recognition serves a crucial role in spoken communication by making it easier to recognize a person's emotions as they are expressed in their voice. With the aid of voice recognition technologies, users can communicate with technology by simply speaking to it. This enables hands-free requests, reminders, and other basic tasks. As it is challenging to recognize gender by a computer, speech is a common machine interaction technique used to classify. The systematic literature survey is performed in this analysis to extract and classify innovative techniques to recognize speech or voice features from various audio datasets.

Keywords Gender recognition · Emotion recognition · Feature extraction · Classification

1 Introduction

Speech has long been seen as a fundamental tool for human communication. The process of turning an acoustic voice into text or identifying the speaker is known as speech recognition.

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It is well recognized that people's emotional states can cause some physical changes in their bodies. Movements of body, pulse, electrical impulses, blood pressure, facial expression, and auditory quality all vary depending on the emotional state. Face and voice of a person can be collected more efficiently, but it is challenging to watch how they change. This is why research on automatic emotion identification is so significant.

The non-verbal information in speech includes the speaker's age. Age estimate involves figuring out a speaker's age automatically for a specific speech utterance segment. The speaker's tone is one of the verbal cues in speaking. Emotion estimation entails determining the speaker's emotion, such as anger, sadness, happiness, or fear.

Automatic speech recognition (ASR) systems play a vital role in classifying and identifying emotions and gender. Improving ASR systems has become a key area of research due to the rising use and popularity of smart voice assistants on mobile phones and smart speakers, security systems, authentication.

A fully automated algorithm must be created to identify gender-driven emotion recognition. To accomplish this, the wav input files are converted in order to extract the necessary features and classify them using the decision-making algorithm.

2 Literature Survey

Voice is seen as a vital channel for communication since it helps individuals connect with one another. It is regarded as a significant and deeply personalized part of our identity. Due to the lack of words, paralinguistic communication carries an emotional element. It also disregards elements like background noise, speaker identification, etc. It has a taxonomy with three traits. It includes traits for the long, medium, and short terms. Their levels of intensity are entirely different. Personality trait is seen as one of these attributes that is crucial. This [1] study gives a general overview of the process, including data collection, pre-processing, chunking, feature extraction, feature and parameter selection, model learning, algorithm selection, and its difficulties to collect information from personality traits.

Glottal-to-noise excitation ratio, instability, and flicker are explored in this research [2]. Cepstral coefficients and Gaussian mixture modeling have helped to reduce diarization error rate by 24%. Different facets are present in speech data, so an audio encoder [3] is used which is used to extract relevant parameters and thus provides better accuracy. Then, data is provided to the classification model to classify emotion. Audio encoder includes Mel- frequency cepstral coefficient, harmonic noise ratio, zero crossing rate, and Teager energy operator. Support vector machine is used as a classification model. The accuracy rate obtained with stacked audio encoder is 74.07%.

Generally, emotion recognition can be done based on facial expression, text, or through speech. This paper [4] uses multimodal emotion detection where the results are analyzed for each modality (facial, text, speech) separately. At last, the average accuracy and F1-score obtained by all the three models are compared. Facial modality

produces low accuracy comparatively because the training set was small and the quality if images and videos matter. Text modality produced higher accuracy rate and F1-score when compared with both.

In this study [5], the classifier's input data is the Mel-frequency cepstral coefficient. The proposed method uses CNN model with one pair of convolutional and pooling layer. The PRAAT script application analyzes voice. The generated accuracy is 71.37%.

A framework for creating emotion classifiers and online emotion recognition [6] is suggested. Logarithmized pitch, the harmonics-to-noise ratio (HNR), signal energy, and the Mel-frequency cepstral coefficients and the frequency spectrum are all taken into account during feature extraction. Results are classified using Naive Bayes.

Feature-based approach is introduced where NLP is proposed [7]. Collection of rich audio embedding to distinguish different type of emotions in form of bag of audio words (BoAWs). NLP was inspired from BoAW. Contextual information is derived using RNN. BoAW generates a frequency matrix. The rich feature embeddings reduce the accuracy gap between the feature representation of text and audio. When this feature is used, an approximation of 20% of accuracy increase is obtained.

This paper's [8] main goal is to categorize extracted features using self-labeled algorithms based on the most reliable predictions in order to expand the initial training set. They made use of the iCST-Voting algorithm, which was trained using a group of supervised classifiers utilizing datasets that were both labeled and unlabeled. Co-training, self-training, and tri-training algorithms are employed for the trained classifiers.

In order to determine a person's gender, this study [9] compares linear discriminant analysis, K-nearest neighbor algorithm, support vector machine, random forest, classification, and regression trees. It employs scatter plots, R-plots, parallel plots, pairwise plots, dot plots, density plots, and box plots to demonstrate that support vector machine gives better results.

This study [10] extracts the underlying speech frequency trajectory and calculates statistical results. Mel-frequency cepstral coefficients are provided as input to the algorithm. The classifiers utilized were trained on an English dataset and tested on a German-based dataset that also includes child voices. They are AdaBoost, linear regression, LLAMA, logistic regression, and random forest. The accuracy obtained in cross lingual dataset is 92% and in the same language is 93.8%.

Speech samples for this article [11] were obtained by reciting Hindi vowels. For each audio file delta, delta-delta and MFCC speech features are extracted. A stacked classifier using SVM and NN was developed and predicted using Naive Bayes. If MFCC is taken into account, accuracy is 93.48% else 91.3%.

In this study [12], analog signals are sampled from the speech stream and converted to a series of digitized numbers. To obtain frequency data, the discrete Fourier transform is carried out using the decimation-in-time method. 80% of recognitions are accurate.

Gender-specific traits have been identified using an MLP deep learning system [13]. 96.74% accuracy was obtained for the provided test dataset. Using the voice, the interactive Website can determine the gender.

This analysis [14] classifies gender and emotion. Voice activity detection is utilized to pre-process the data and assess whether or not the input signals contain speech. Acoustic characteristics are extracted using mel-frequency cepstral coefficients. The required characteristics are obtained using principal component analysis. The preprocessed input signal is fed to support vector machine classifier which is trained to generate valid outputs. It demonstrates 98.88% gender recognition accuracy, and 72.02% emotion recognition accuracy is obtained.

The four traditional principles for speech-based emotion recognition are extraction of feature, filtering required selection, database access, and classification [15]. The two subsystem types employed here are the gender recognition and the emotion recognition. While emotion recognition employs two classifiers, gender recognition begins with pitch frequency approach of voice capture. One classifier is trained using both recorded male and female signals, while the second classifier is trained using just recorded female signals. Support vector machine is the classifier in use. When gender recognition is included, the overall accuracy rate of emotion recognition rises.

3 Methodology

1. Selecting the testing and training dataset
2. Dataset pre-processing
3. Feature extraction from preprocessed data
4. Feature reduction for higher accuracy
5. Acquire knowledge after training
6. Make a decision using classifier
7. Evaluation and tuning of algorithm.

4 Dataset Details

For predicting, we are employing two wave-formed datasets. By integrating the above datasets, we are planning to use the 80–20 rule in order train the dataset and improve accuracy.

4.1 Ravdess

This collection contains over 1500 audio tracks from 24 different actors. Brief audio samples of 12 male and 12 female actors exhibiting 8 different emotions, including furious, calm, disgusted, sad, neutral, terrified, happy, and amazed, are recorded. The seventh character in the name of each audio file corresponds to the varied emotions it stands for (Fig. 1).

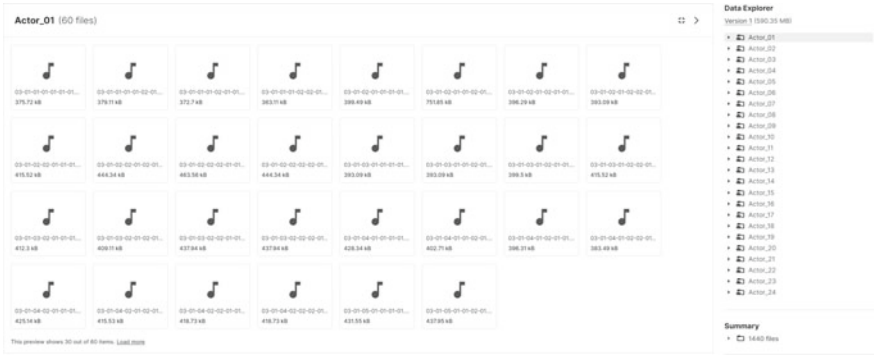

Fig. 1 Dataset for Ravdess

4.2 EMODB

The free German emotional database is named EMODB. The database was produced by the Institute of Communication Science at the Technical University of Berlin. Data was collected from 5 women and 5 male professional speakers. There are 535 utterances in the database. There are seven emotions included in the EMODB database: sadness, neutral, anxiety, happiness, anger, disgust, boredom. Data was down-sampled from 48 to 16 kHz after being recorded at 48 kHz (Fig. 2).

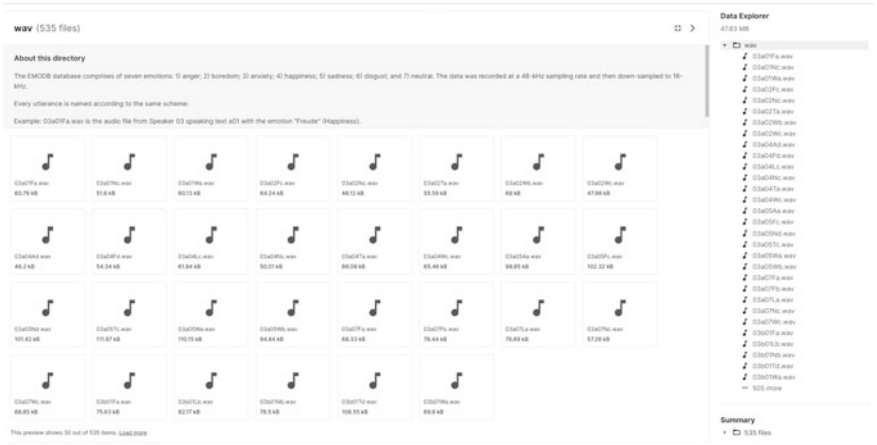

Fig. 2 Dataset for EMODB

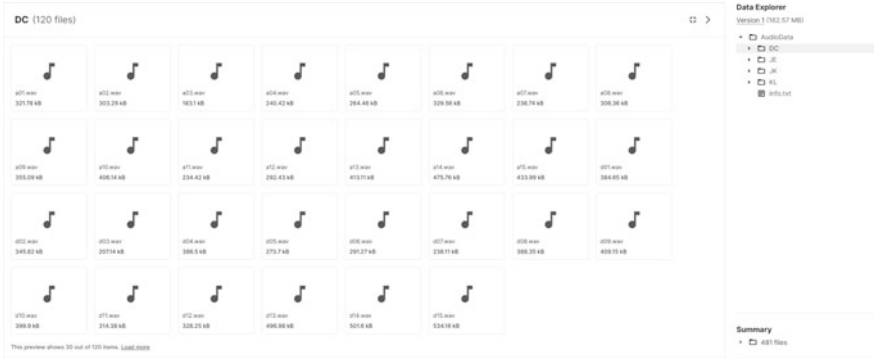

Fig. 3 Dataset for SAVEE

4.3 1.1. SAVEE

Four native English-speaking men, aged 27 to 31, who were postgraduate students and researchers at the University of Surrey, were recorded for the SAVEE database. The emotions acknowledged include disgust, anger, fear, joy, sadness, surprise, and normal. With 120 utterances per head, 480 utterances in total were collected (Fig. 3).

5 Conclusion

Applications for the gender-driven emotion recognition feature in human speech span a wide range of fields, including socially helpful robots, artificial intelligence, intelligent driving, autonomous vehicles, neurofeedback equipment, call center assistance, etc. A growing number of people are already dependent on intelligent devices in the current environment, and many of them already have a likelihood to interact with them in ways that are similar to how they interact with other people. This is the cause of the market for intelligent and sympathetic device's astonishing recent growth. Therefore, creating a classification algorithm that is efficient helps to raise the quality of the results given to the user. We have planned to devise an algorithm that improves the accuracy of estimating the user's gender and emotion.

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U-Shape Phenomenon with Gaussian Noise and Clipped Inputs

Sebastian Bock, Philipp Schwarz, and Martin G. Weiß

Abstract Object detection and recognition is a core task in machine vision. Both the position and the rotation of the objects are of interest. Common algorithms for object recognition based on neural networks use a regression formulation and are aimed at changing environments. In industrial applications, the setting is different: One would like to determine with high accuracy, the pose of known objects. We are investigating a prototype application in this field, where we identify the rotation of an object in a plane. We use common network architectures and provide an overview of how well they are suited for this purpose. In addition, we compare our results with standard image processing algorithms, paying particular attention to the accuracy with metrics relevant in the industry. Moreover, an U-shape phenomenon with disturbed data occurred during the experiments, which is partially explained analytically.

Keywords Neural networks · Pose estimation · U-shape

1 Introduction

Usually, neural networks or deep learning is used in image processing as a sort of classifier. Even when used as a regression, the use cases are often highly disturbed and accurate measurement is not possible (see [17] or [9]). Most of the time, these use cases are born out of necessity, as classical image processing fails due to the strong variation of the inputs. In this paper, we now want to review areas in which classical image processing has so far achieved acceptable results. Our aim is to use

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neural networks in an automation or industrial environment where one usually knows exactly which object is being considered. However, the location on a conveyor belt, for example, is not completely determined and has to be known with high precision so that a robot can grasp and process the object.

In industrial image processing, software packages such as Halcon [6] or In-Sight [2] are mostly used. These packages use only classical image processing algorithms. However, most tasks still require skilled engineers to implement and even these require several attempts to achieve the proper lighting conditions and a repeatable process. Application engineers usually parameterize their algorithms on location, generating high costs for companies and customers. First extension packages are on the market using neural networks like VisionPro Deep Learning [3] or Penso [14]; however, it is difficult to quantify the performance because the algorithms are not disclosed and the main application is classification.

Networks can be trained with data created by lower skilled personnel. It would even be possible to generate data automatically with the help of a robot or a turntable. The robot rotates the object, and the camera takes pictures from this orientation. The different poses are saved and used as labels. Thus, specific poses can also be trained or iterated in equidistant steps over the possible range of values. In addition, any disturbances that occur can also be retrained directly or during production. Image processing experts are mostly skeptical about neural networks due to their black box character. Therefore, in this work, we study the determination of the rotation angle of an object in the plane with the focus on the quantitative analysis of the accuracy of the calculated angle.

Furthermore, in this work, we came across a phenomenon called U-shape. Here, the minimum of the test error behaves untypically in a training set with a fixed Gaussian disturbance. We explain this phenomenon analytically and give ways to avoid it.

2 Related Work

In [7], the authors discuss the possibility of estimating the orientation of an image using Microsoft's COCO dataset [11]. This dataset contains frequently used objects in a suitable context. With the network architecture *Net-360*, they achieve an average absolute error of approximately 20°. Due to the fact that many images in the COCO data set do not have an exact orientation, this result is very good. For industrial applications, however, this would be too high an error. Xiang et al. [17] tackle the 6D pose estimation of household items in a difficult and cluttered environment. They use the average distance metric (see [9]) as the evaluation metric. This metric calculates the average of the pairwise distance of the 3D model points transformed with the label and the predicted pose. Then, the 6D pose is considered correct if the average distance is less than a given threshold value (i.e. 10% of the 3D model diameter). However, this classification is not very helpful in industry. However, in industrial applications, we usually work with tidier images and thus with smaller tolerances.

The limits for average absolute errors are usually smaller than 1°. Therefore, in this paper, we elaborate how precisely we can determine orientations of an image using neural networks.

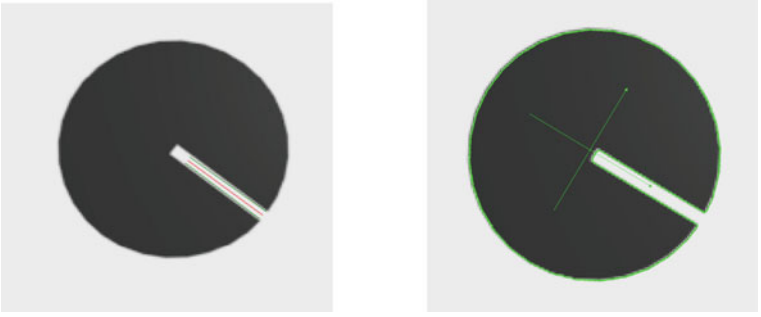
In addition, we consider the U-shape phenomenon that emerged during the experiments. Papers like [13] and [1] have already considered this effect in more detail depending on the network parameters. In contrast, our U-shape is a function of the noise variance.

3 Rotation Estimation

Dataset To prove the ability of predicting rotations of two dimensional objects, we create a simple dataset with clear contours and no disturbing stuff beside (comparable to industrial conditions). Therefore, we use a black disc on a white background. To identify the rotation, the disc got a white slot (see i.e. Fig. 1a). Each image has the size of 200 × 200 pixels. In the training set, we have 3600 images evenly distributed over 360°. Thus, we have an image available every 0.1°. In the test set, the angles are randomly selected.

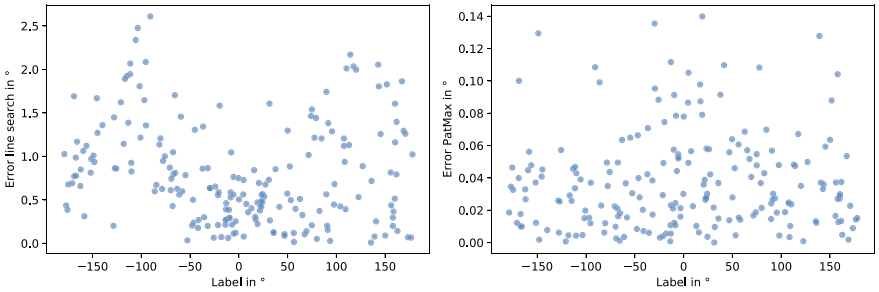
Traditional image processing We would like to compare our results not only neural networks internally but also with currently used image processing algorithms. Thus, the possible industrial benefit shall also be explored. For this purpose, we use a rudimentary method, which is especially adapted to the shape of the slitdisc (in the following called line search) and a more open pattern matching method, where only strong contrasts are necessary (in the following called PatMax™ [15]).

In the line search algorithm, we are searching for two lines around the black circle. One of these lines should have the polarity black on white and the other exactly opposite polarity. Thus, we find the notch of the disc and can calculate the angle via the middle line of these two lines. Visually, this is described in Fig. 1a. The



(a) Line search algorithm (b) PatMax algorithm

Fig. 1 Traditional image processing algorithms



(a) Error with line search and $\sigma = 0.01$ (b) Error with PatMax and $\sigma = 0.01$

Fig. 2 Error distribution in traditional image processing

Table 1 Average error in traditional image processing

	$\sigma = 0$	$\sigma = 0.01$	$\sigma = 0.05$	SnP $p = 0.005$
Line search	0.732°	0.797°	0.873°	0.739°
PatMax	0.015°	0.037°	0.488°	0.016°

two green lines are the result of the line search with the respective polarity, and the red line is the measured centre of the notch. The system was calibrated once to zero degrees and then tested.

In the PatMax algorithm, we use the pattern matching algorithm from Cognex Crop. Here, one must first train an initial contour, which is then searched for. Here, the contrast of the image is the most important factor. In Fig. 1b, for example, the found contour is drawn in green.

In our experiments, we use 200 randomly rotated slitdisc images with Gaussian noise ($\sigma \in \{0, 0.01, 0.05\}$) and Salt and Pepper (abbr. SnP) noise. In Fig. 2, we can see the error distribution as a function of the angle. Neither the PatMax nor the line search method show any systematic errors. It is noticeable that the Gaussian noise hardly influences the measurements (see Table 1). The experiments with the PatMax algorithm showed better rotation detection than the line search algorithm. Furthermore, no systematic outliers were detected. (see Fig. 2). However, the Gaussian noise increases the average error enormously from 0.015° to 0.488° (see Table 1). This can be attributed to the contrast dependence mentioned before. The SnP noise has hardly influenced both methods.

Neural network approach We also extract the rotation part from the PoseCNN [17] and test it under the name PoseCNN. We train each architecture with two different losses and four different disturbances on the training images. In addition, each variant was trained twice to minimize unwanted one-off effects. Labels were given in quaternions to prevent modulo effects. Mean squared error and the ploss [17] were used as loss. Training disturbances are 'Without noise', salt and pepper noise with $p = 0.005$ and Gaussian noise with $\sigma = 0.01$ and also random $\sigma \in [0.0, 0.05]$. We only summarize the most important findings.

Table 2 Optimization result: neural network approach

Test noise	Without noise	Salt and pepper	Gauss $\sigma = 0.01$	Gauss random σ
Best architecture $\emptyset abs$ in deg	CNN 0.210°	CNN 0.300°	CNN 0.348°	CNN 0.349°
Top 5 architectures	2× CNN 3× PoseCNN	2× CNN 1× PoseCNN 1× Mobilenet 1× VGG Mod	2× CNN 1× PoseCNN 1× Mobilenet 1× VGG Mod	2× PoseCNN 2× VGG Mod 1× CNN
Top 10 architectures	5× CNN 5× PoseCNN	3× CNN 3× PoseCNN 2× Mobilenet 1× ResNet50 1× VGG Mod	4× CNN 3× PoseCNN 2× VGG Mod 1× Mobilenet	3× CNN 4× PoseCNN 3× VGG Mod
Top 5 generalizer	3× CNN 2× PoseCNN	4× PoseCNN 1× CNN	4× PoseCNN 1 × CNN	5× PoseCNN
Top 10 losses	6× ploss 4× mse	6× mse 4× ploss	6× ploss 4× mse	6× ploss 4× mse
Worst 10 losses	10× ploss	6× ploss 4× mse	5× ploss 5× mse	6× ploss 4× mse
Worst 10 architectures	6× ResNet50 4× Mobilenet	4× ResNet50 1× VGG Mod 2× Mobilenet	6× ResNet50 3× VGG Mod 1× Mobilenet	5× VGG Mod 4× ResNet50 1× Mobilenet

1. No matter which noise was tested with, the CNN architecture achieved the lowest absolute error. The PoseCNN architecture delivered a similarly good result, which is always among the best 10 variants several times.
2. The line search method is always less accurate than the best networks. PatMax, on the other hand, is more accurate for smaller disturbances; only for large disturbances are both variants comparable.
3. Large networks such as ResNet50 or VGG Mod, on the contrary, always scored the worst.
4. With the best losses, there are no striking differences. Only when testing without noise, a weakness of the ploss can be seen.
5. Compared to traditional image processing, many networks can perform better than the line search attempt. So the networks are always preferable to this. In comparison with the PatMax, comparable networks only emerge at a very high level of noise.

Especially in the tests with a large noise, the experiments with neural networks were competitive with traditional image processing. In addition, known noise can be trained directly with neural networks, which is difficult with traditional image processing.

4 U-Shape Phenomenon

4.1 Problem Formulation

In this work as well as in the unpublished bachelor theses [10] using neural networks and [16], using SVM the following problem was studied, with similar effect. We consider a grey scale or RGB image of a slit disc (see Fig. 1a) and want to determine the angle relative to a reference position. The training images $I_1, \ldots, I_N$ with rotation $\varphi_1, \ldots, \varphi_N$ are generated from a reference image $I \in \mathbb{R}^{N_x \times N_Y}$ using rotation and additive Gaussian noise with zero mean and standard deviation σ_0. Then, a neural network or SVM was trained with these data to predict the angle φ, resulting in a function $f_{\sigma_0} : \mathbb{R}^{N_x \times N_y} \times \mathbb{R}^{N_w} \to \mathbb{R}$, $(I, W) \mapsto \varphi$ with the weights collected in $W \in \mathbb{R}^{N_w}$. The subscript σ_0 emphasizes the noise model on the data.

Then, the regression function was tested on data generated with different standard deviations. This approach corresponds to a machine learning algorithm trained on synthetic data and then tested with data from sensors with different noise. The MSE was plotted against σ, resulting in a U-shaped curve in some—not all—cases (Fig. 3).

It sounds reasonable that an algorithm trained on data with train noise σ_0 behaves well for test data with the same noise. For $\sigma \nearrow 0$, the algorithm should also behave better because test data are less noisy. Apparently, this reasoning is not correct: the MSE increases towards 0. In the extreme case $\sigma_0 = 0$, we expect an increasing behaviour of $\sigma \mapsto \mathrm{MSE}(\sigma)$.

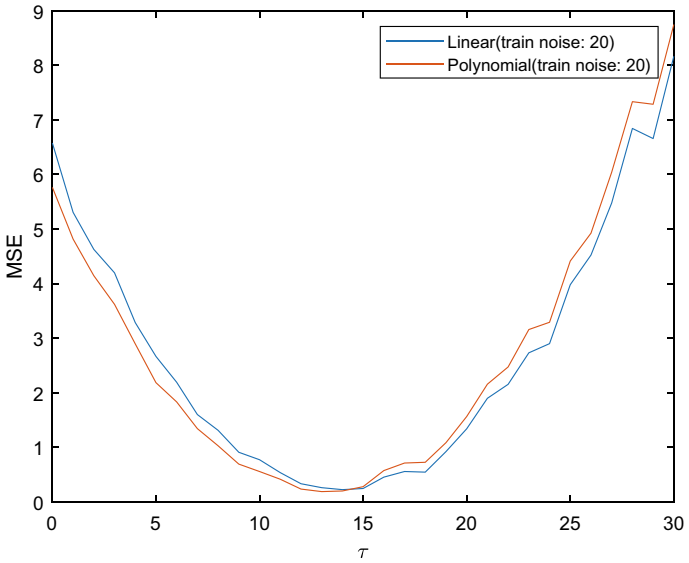


Fig. 3 SVMs with various kernels and train noise $\tau_{train} = 20$ (see [16], p. 38)

One purpose of this chapter is to explain the U-shape phenomenon which did not seem plausible to us, and to locate the minimum of the MSE curve. It turns out that the qualitative behaviour is the consequence of clipping pixel values to a finite interval like [0, 1] or [0, 255] in combination to an unbalanced number of pixel near the edge of the pixel range. This significantly destroys the Gaussian noise structure and leads to the main finding: *clipping the noise in images with an unbalanced number of a large fraction of the pixels near the edge of the pixel range is the reason for the U-shape.*

The problem is relevant, e.g. for images in astronomy, tomography, spectroscopy [5] and industrial image processing (back lighting [4]). In industrial image processing, a back light set-up is often used for measurements. Here, the component under consideration is between the illumination and the camera. This creates a very high contrast, which is ideal for measurement tasks. However, the resulting grey values are often close to the edge of the grey value scale, which can cause the problem described above.

4.2 Analysis with High Level Formulation

In this section, we analyse the U-shape using typical expressions from statistics. For this, we will use an equation from [8], which we will derive briefly and then convert to our problem. Let $X_1, \ldots, X_n$ be iid realizations of a real valued random

variable $X \in \mathbb{R}^n$, and $\hat{f} = \hat{f}(\hat{f}(X_1, \ldots, X_n))$ an estimator for the Label φ of X. So $\hat{f}(X)$ is a real valued random variable as well, we assume that the mean value $\mathrm{E}\hat{f}(X)$ exists. Think of $X \sim \mathcal{U}_{[-\frac{\sigma}{\in}, \frac{\sigma}{\in}]}$ and $\hat{f}(X) = \frac{1}{n}\sum_{i=1}^{n} X_i$. Then, we can calculate the error corresponding to the random variable φ:

$$\begin{aligned}
\mathsf{E}\varphi[(\hat{f}(X) - \varphi)^2] &= \mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)] + \mathsf{E}\varphi[\hat{f}(X)] - \varphi)^2] \\
&= \mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)])^2] \\
&\quad + 2\mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)]) \cdot (\mathsf{E}\varphi[\hat{f}(X)] - \varphi)] \\
&\quad + \mathsf{E}\varphi[(\mathsf{E}\varphi[\hat{f}(X)] - \varphi)^2]
\end{aligned}$$

In the middle term $(\mathsf{E}\varphi\hat{f}(X) - \varphi)$ is a scalar which can be moved outside the expectation. Then, the remaining factor gives $\mathsf{E}\varphi\hat{f}(X) - \mathsf{E}\varphi\hat{f}(X) = 0$, so the middle term disappears an we get

$$\begin{aligned}
\mathsf{E}\varphi[(\hat{f}(X) - \varphi)^2] &= \mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)])^2] + \mathsf{E}\varphi[(\mathsf{E}\varphi[\hat{f}(X)] - \varphi)]^2 \\
&= \mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)])^2] + \mathsf{E}\varphi[\mathsf{E}\varphi[\hat{f}(X)] - \varphi]^2 \\
&= \mathsf{E}\varphi[(\hat{f}(X) - \mathsf{E}\varphi[\hat{f}(X)])^2] + (\mathsf{E}\varphi[\hat{f}(X)] - \varphi)^2 \\
&= \mathsf{Var}\varphi[\hat{f}(X)] + \mathsf{Bias}\varphi[\hat{f}(X)]^2
\end{aligned}$$

Let us now consider the U-shape application. Therefore, we define the disturbed and clipped inputs $\tilde{X} := \Pi_{[0,1]}(X + \varepsilon) \in \mathbb{R}^n$ with $\varepsilon \in \mathbb{R}^n$, $\varepsilon \sim N(0, \sigma^2)$. Remark, that also our estimator $\hat{f}$ is trained by disturbed and clipped inputs $\tilde{X}$ with a fixed noise σ_0. This results in the error function, where the expectation is first computed over the distribution of ε and afterwards φ:

$$\begin{aligned}
\mathsf{Err}[X] &= \mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}) - f(X))^2] \\
&= \mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] + \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X))^2] \\
&= \mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})])^2] \\
&\quad + 2\mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})])(\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X}) - f(X))] \\
&\quad + \mathsf{E}\varphi[(\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X))^2] \\
&= \mathsf{Var}\varphi, \varepsilon[\hat{f}(\tilde{X})] + 2\mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})])(\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X))] \\
&\quad + \mathsf{E}\varphi[\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X)]^2 + \mathsf{Var}\varphi[\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X)] \\
&= \mathsf{Var}\varphi, \varepsilon[\hat{f}(\tilde{X})] + 2\mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}]) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})])(\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X))] \\
&\quad + \mathsf{Bias}\varphi, \varepsilon[\hat{f}(\tilde{X})]^2 + \mathsf{Var}\varphi[f(X)]
\end{aligned}$$

X is not a random variable here, so $\mathsf{Var}\varepsilon\mathsf{f}(\mathsf{X})$ is constant. Thus, the essential term for the U-shape is

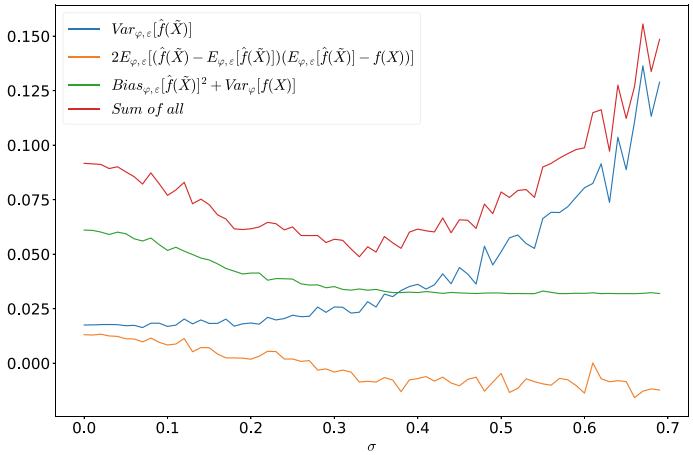


Fig. 4 Overview of the different terms of Eq. (1)

$$\begin{aligned}\mathsf{Err}[X] = \mathsf{Var}\varphi, \varepsilon[\hat{f}(\tilde{X})] + \mathsf{Bias}\varphi, \varepsilon[\hat{f}(\tilde{X})]^2 + \mathsf{Var}\varphi[f(X)] \\ + 2\mathsf{E}\varphi, \varepsilon[(\hat{f}(\tilde{X}]) - \mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})])(\mathsf{E}\varphi, \varepsilon[\hat{f}(\tilde{X})] - f(X))]\end{aligned} \tag{1}$$

$\mathsf{Var}\varphi[\hat{f}(\tilde{X})]$ is monotonically increasing with increasing test noise σ in our experiments. This curve is also fitting to the consideration that the error increases with increasing noise σ. The U-shape is created by the other two terms. Especially in the case of $\mathsf{Bias}\varphi, \varepsilon[\hat{f}(\tilde{X})]^2$, a clear U-shape with a minimum at σ_0 can be seen (see Fig. 4 for an example of the different terms). This bias, which is contained in both terms once in the square and once without, creates the U-shape. For $\sigma < \sigma_0$, the estimator tends to underestimate the system. For $\sigma > \sigma_0$, it overestimates the system. In both cases, the error increases the further away we are from the trained σ_0. Therefore, the minimum occurs at approximately σ_0. However, $\mathsf{Var}\varphi[\hat{f}(\tilde{X})]$ shifts the minimum in the error sum.

For better visualization, the individual terms were plotted in Fig. 4. These graphs emerge from an experiment with ten input neurons, a hidden layer with 124 neurons and the sum of the ten input neurons as the label. In addition, the input neurons were uniformly distributed on $[0, 0.2]$ and we train with $\sigma_0 = 0.5$.

For better visualization, the individual terms were plotted in Fig. 4. These graphs emerge from an experiment with ten input neurons, a hidden layer with 124 neurons and the sum of the ten input neurons as the label. In addition, the input neurons were uniformly distributed on $[0, 0.2]$ and we train with $\sigma_0 = 0.5$.

Also, if we look more closely at the bias, we see a U-shape. However, this is not recognizable due to the scaling in Fig. 4 and also plays a minor role in the error sum (1).

We suspect that the U-shape is a special case of the bias-variance trade-off (e.g. described in neural networks applications in [12] or in general for statistical methods

in [8]). This describes that the variance can be reduced by increasing the bias. High bias can lead to important relations between inputs and outputs not being established. Thus, the network would be more susceptible to fluctuations in the data, as important connections may not have been trained. The modified σ in combination with the clipping is probably too complex for our network trained in this way and thus lets the bias in the error calculation increase.

In summary, we can say that the clipped and unbalanced pixels cause a bias-variance trade off, which leads to a U-shape in the error function. The analysis for the U-shape in the real-world problems like the slit disc remains open. However, a U-shape did not occur in all experiments, especially not for pictures with one pixel only.

5 Conclusion and Outlook

In this work, we discovered the ability of neural networks to predict the rotation of components in quite clear production conditions. We see in Table 2 that we are always more accurate with the neural networks than the naive line search method. We only become comparable to the PatMax in the case of major disturbances ($\sigma \geq 0.05$). However, such large disturbances also occur in industrial environments, and as we have seen in this paper, neural networks are then comparable or more accurate than traditional image processing. In these applications, neural networks offer the advantage that they can also be operated by less trained personnel. Network architectures can be created once, as even simple architectures achieve best performance (i.e. CNN in Table 2). Moreover, no expertise in image processing is necessary to remove disturbances in the image. Neural networks are able to deal well with these, especially trained, disturbances. This can save a company a lot of money and resources.

Furthermore, we have discovered the U-shape phenomenon in an application with a constant network setting and a changing test set complexity. We were able to show analytically that this occurs due to *clipping* at the edge of the pixel scale and the bias-variance trade-off during the training with less complex train images.

In the future, neural networks should predict all 6 degrees of freedom with extremely high accuracy, so that all industrial applications can be realized.

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An Electronic DIGI White Cane for the Visually-Impaired Personnel

Abhishek Koti, Akhil Khare, and Pallavi Khare

Abstract Humans take in information about our surroundings via our five senses of sight, hearing, smell, taste, and touch, with vision accounting for roughly 75% of our total information intake. A variety of technologies are designed to help and support blind and visually-impaired (BVI) residents on indoor and outdoor journeys. However, these technologies have not fully addressed the technological requirements and user demands. The majority of these unaddressed features are being addressed individually in other research disciplines, such as computation offloading, distributed sensing, or indoor location, to investigate spatial-related cognitive and perceptual processes in BVI persons. The proposed system's framework involves the study of the frequently referred to term "cognitive mapping" for better assisting the movement of blind or visually-impaired individuals. To conduct research on smart gadgets for the blind and visually-impaired and suggest a suitable strategy. Blind visually-impaired individuals require specialised systems such as the Braille System for reading and writing. They also find it difficult to use the latest technology like mobile phones and computers unless certain adjustments are made to help them. The development of intelligent devices will significantly improve their standard of living. Many smart gadgets have been created that use optical character recognition and text-to-speech to convert written or printed text into audio signals. All such gadgets have many disadvantages.

Keywords DIGI white cane · Cost-effective assistive technologies for blind people · Object recognition via feature detection · Speech synthesis

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1 Introduction

Researchers investigated how the prevalence and primary causes of juvenile vision impairment change over time and across countries. The WHO Prevention of Blindness Programme and the International Centre for Eye Health have developed a standardised strategy and reporting form to track the factors that cause visual impairment in children. The strategy was implemented in low-income as well as middle-income nations [1].

Cerebral visual impairment (CVI) is loss of vision-related abilities resulting from injury or dysfunction of the brain's visual networks and computing centres (especially the ones behind the lateral geniculate bodies) [2]. This condition is sometimes aggravated through concurrent abnormalities of eye movements control. Visual impairments range from severe cognitive visual dysfunction to normal or almost normal visual acuity. It is critical to understand that CVI and ocular visual impairment (OVI) can occur concurrently [3]. For children suffering from cerebral palsy, CVI considerably increases the probability of subsequent visual impairment. Blindness in childhood could be caused by conditions like ocular congenital malformations (microphthalmia/anophthalmia), cataracts/lens-associated corneal opacities (together with vitamin A deficiency), optic atrophy, retinal dystrophy, amblyopia due to higher refractive error, glaucoma, and abnormalities of higher visual pathways. Childhood blindness is a prevalent cause in India [4, 5].

4.1 million people in America who are blind or have low or poor vision are helped by new technology and methods being developed by the National Eye Institute (NEI), a division of the National Institutes of Health. The developments are meant to make it easier for persons with vision loss to carry out daily duties, such as navigating office buildings and crossing streets. Many of the developments make use of computer vision, a technique that allows machines to observe and translate a wide variety of images, entities, and behaviours in their surroundings [6]. Low vision refers to the inability to perform routine tasks without the use of glasses, contact lenses, medication, or surgery. According to Cheri Wiggs, Ph.D., the NEI's programme director for low vision and blindness rehabilitation, it can affect a number of everyday activities such as cooking and reading. Depending on the type and extent of visual loss, different tools are required to continue participating in daily activities. For instance, glaucoma results in peripheral vision loss, which can make driving or walking challenging. On the other hand, age-related macular degeneration impairs central vision, making it challenging to perform tasks like reading. As a result, innovations being developed with NEI funding are meant to alleviate the effects of low vision and blindness.

2 Challenge and Constraints

Various technologies exist that help to guide and support BVI residents on indoor/outdoor journeys. They have not, however, totally addressed the technological requirements and demands. The majority of these unmet requirements are now being addressed individually through several academic domains, spanning from distributed sensing, indoor location, or computation offloading to the study of locational cognitive and perceptual processes in the BVI persons.

The following are the major challenges:

1. "The existence, position, and, ideally, type of impediments directly ahead of the traveller." This is connected towards assisting with avoiding obstacles.
2. "The placement and description of elements near the travel route," like bushes, railings, benches, and gateways.
3. Data that assists users in "maintaining an even trajectory, particularly existence of some sort of aim point in the distance," such as nearby traffic and vehicle noises.
4. Information about the "route or plane on which the person is travelling," like gradient, texture, and the impending steps.
5. "Common point and landmark identification and position" include the previously viewed landmarks, notably within- (Point 2).
6. The data which helps the passenger to construct a mental map, picture, or schema for the intended path to be followed. This topic entails the investigation of what is usually referred to as "cognitive mapping" in visually-impaired persons.

3 DIGI White Cane: An Electronic Assistant for the Visually-Impaired Personnel

3.1 Objectives of the Project (Brief and to the Point)

1. To improve compensatory skills in the blind as alternative modes of communication.
2. To develop assistive technology usability for blind.
3. To enhance social life of blind detecting and reporting gestures, actions, body language, facial expressions of other side interacting person.
4. To instil the ability to live independently by providing warnings for personal care, clothes care and management, eating and food preparation, household upkeep, and time and money management. To help educate blind to obtain and maintain a career to help learn about jobs and work-related skills.
5. To improve sensory efficiency by reporting various feedbacks on vision from the environment.

3.2 Preliminary Investigations Done by Organisation (if Any)

1. Sensory Translation Rules: Research was conducted on an intermediate level of visual interpretation known as optical character recognition.
2. Information Selection: In the blind assessments of touch, haptic perception, echolocation, and audio perception were reviewed.
3. Device Operation: A study was conducted on the strengths and limitations of assistive technology under a variety of environmental settings that necessitated the integration of several technologies.
4. Form and Function: Aesthetic influence on the user was investigated using contemporary assistive technologies.

3.3 S&T Component in the Project

See Fig. 1.

3.4 Linking with NGOs/Resource Persons/S&T Instts./ Industry/ R&D Organisation for Technical Back-Up

1. Ph.D. Research centre Affiliated to Osmania University.
2. Resource Person: Dr. Ramadevi Yellasiri (Life Member CSI & ISTE), Professor, CBIT, Gandipet, Hyderabad.
3. NGO: Associated with Youth Red Cross through College Chapter.
4. Industry: Associated with CISCO through College Chapter.

3.5 Other Organisations Working in This Area

1. Sambhav is a new initiative launched by the Government of India to offer information on the assistance and assistive gadgets provided to people with disabilities under the National Trust Act.
2. Surabhi Srivastava of IIT Bombay and co-founder Shyam Shah created the "Braille Me" tablet for the visually handicapped.
3. Suraj Singh Senjam of the Community Ophthalmology Department, Dr. Rajendra Prasad Centre for Ophthalmic Sciences, AIIMS in Delhi, India, addresses assistive technology for student populations with vision difficulties.
4. Sightsavers, a worldwide development organisation that has been working in India since 1966 to reduce preventable blindness and to guarantee that individuals who are irrevocably blind have appropriate support to live independent and dignified lives.

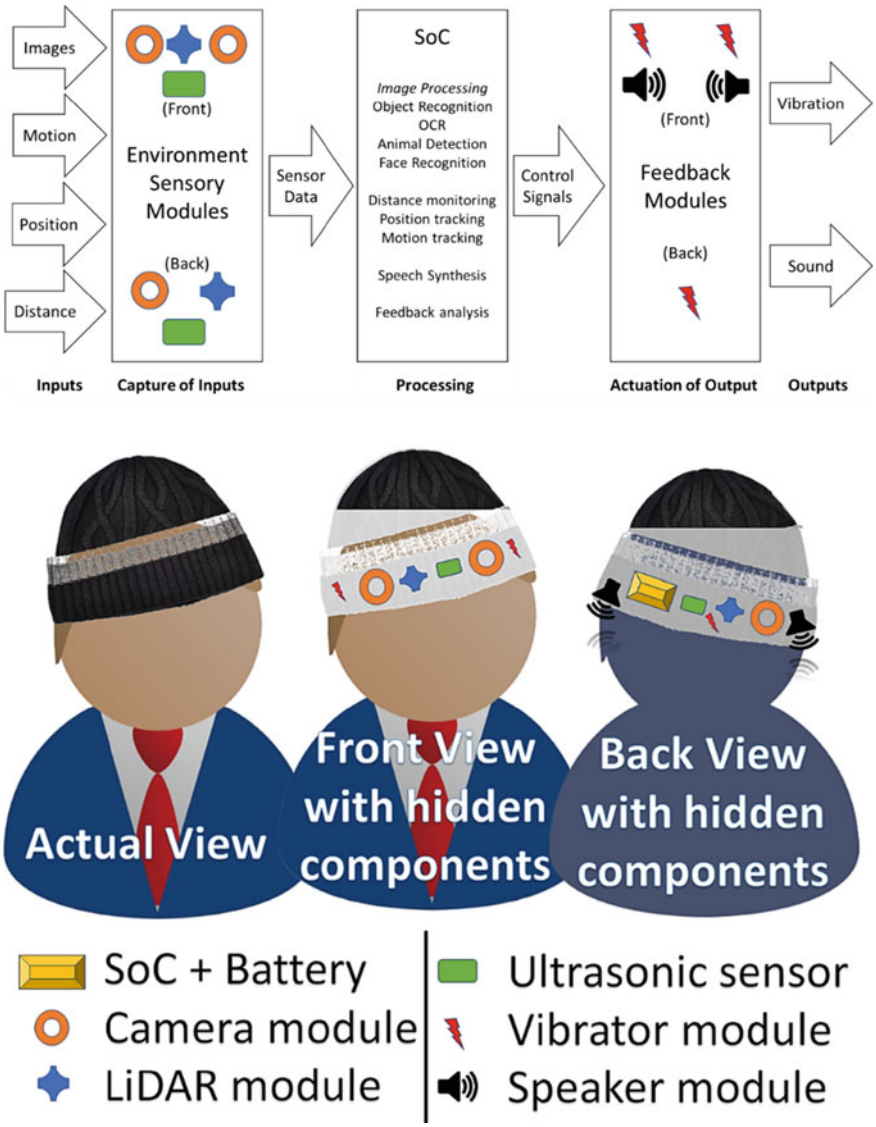

Fig. 1 Block diagram of the proposed system followed by graphical representation of the expected final product

5. Clear View + Speech, created by the Dutch company Optelec, will be distributed throughout the country by BarrierBreak Technologies, an Indian accessibility and assistive technology company.

4 Methodology Detailing Stepwise Activities and Sub-activities

1st Step: Electronic Travel Aids (ETAs)

These aids are the devices, which gather information about their environment and relay it back to user via sonar, sensor cameras, or laser scanner modules. ETAs serve the following purposes:

(a) Recognising obstacles from the ground to the head that surround the user's body
(b) Giving the user instructions regarding the moving surface, which consists of gaps or textures
(c) Finding goods in the vicinity of the barriers
(d) Providing the distance between the individual and the barrier, as well as any required guidance information
(e) Recommending remarkable sightings and providing identification instructions
(f) Providing data to assist self-orientation and the creation of a mental picture of a person's surrounding environment.

2nd Step: Electronic orientation aids (EOAs) are gadgets offering guidance to travellers in unacquainted areas. The following are the roles of EOAs:

(a) Describing the route in order for selecting the best path;
(b) Tracing the path to roughly compute the user's location;
(c) Giving the user motion directions and path signals to guide them and grow their understanding of the environment.

3rd Step: Position Locator Devices (PLD)

(a) GPS technology modules, for example, are used to pinpoint the specific location of its carrier.

4th Step: Text Recognition and Reading Software

(a) Use synthetic voice to read aloud the material shown on a computer screen.
(b) Making the tool compatible with the majority of applications and features for PC operating systems.
(c) To locate add-on for Linux-powered PCs, which normally run a built-in screen-reading function. For some Linux distributions, screen-reading applications such as JAWS and Orca are examples.

5th Step: Magnification Software

(a) Functions similarly to sliding a high-powered magnifying glass over a page. They have the ability to magnify all objects in front of them for identification.
(b) Some people with limited eyesight may benefit from bigger text sizes and increased contrast.

Making the aforementioned characteristics suitable for many low-vision individuals, since extra magnification software is required.

Step 6: Dictation Software

(a) Make use of standard or customised accessories that could be utilised by persons who are blind or have limited eyesight.
(b) Before purchasing any dictation software, examine its compatibility with the screen reader of choice.

Step 7: Optical Character Recognition (OCR) Systems

(a) Entails transforming the image into text characters and sound for blind recognition.

If a pre-scanned electronic picture is already accessible (for example, a PDF file), OCR systems may turn it into text without scanning a hard copy.

Use of synthesised voice processing algorithms for best performance (c).

5 List of Major and Significant Challenges

1. The occurrence, positioning, and desired nature of barriers right directly ahead of the traveller. This pertains to support in overcoming adversity.
2. Knowledge about the "terrain or track" upon which the individual is heading, like irregularity, elevation, and forthcoming ledges, amongst others.
3. "The positioning and characteristics of items along the travelling route," such as stairwells, barricades, or shrubs.
4. "Point detection and identity," which includes previously seen sites, specifically in metropolitan locations.
5. Input that aids individuals in "keeping a regular route, particularly the presence of certain type of focussing point in the vicinity," such as vehicle disturbances in the location.
6. Input which "enables a person to develop a visual image or scheme for the anticipated route to be taken." This is also known as "cognitive mapping" in BVI people.

6 Relevant Examples

1. The Indian government has launched a new project called "Sambhav" with the goal of educating persons with disabilities about the aids and assistive technology that are provided to them in accordance with the National Trust Act.
2. At IIT Bombay, Surabhi Srivastava and co-founder Shyam Shah created the "Braille Me" tablet, which costs around Rs. 20,000, a tenth of what its rivals across the world charge.
3. Dr. Rajendra Prasad Centre for Ophthalmic Sciences, (All India Institute of Medical Sciences (AIIMS), New Delhi, India,- Suraj Singh Senjam, from Department of Community Ophthalmology, Assistive technology for visually-impaired students.

4. Global development organisation called Sightsavers has been working in India since 1966 to eradicate avoidable blindness and make sure that people who are permanently blind have the help they need to live independent and respectable lives.
5. BarrierBreak Technologies, an Indian accessibility and assistive technology company, will promote Optelec's Clear View + Speech product throughout the nation. Optelec is a Dutch company.

7 Applications and Utilities

1. Blind people can move confidently without another individual's assistance
2. Recognition of known faces, strangers (alerts), and animals
3. Detection of obstacles and objects along with perceptive distance
4. Currency identification
5. Identification of road signs
6. Periodic battery status alerts
7. Easy to wear/mount carry without assistance
8. Solar support for recharge.

8 Conclusion

We provide a DIGI white cane that tackles some of these issues. As the product is used, the system seeks to provide cost-effective assistive technology for the blind and give a higher degree of freedom in their daily activities in order to enhance their standard of living. The system's architecture uses actuator modules to generate a vibration and auditory alert upon obstacle detection, allowing visually-impaired persons to be digitally assisted in real-world settings. The structure of the system also provides distance-to-object data through auditory warnings that are computationally triggered by LiDAR and Sonar modules. To assist vision-impaired people in their everyday activities, the system also enables human, animal, and object recognition via feature detection, text detection by optical code recognition, and speech synthesis via speakers. By carrying out the project, we are assisting the impoverished and blind/visually-impaired communities in increasing their self-confidence in their daily routines through technology help that adds more safety parameters to their lives.

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Maize Plant Conditions Prediction Using IoT Systems and Machine Learning Techniques for Precision Agriculture

F. Nzanywayingoma, M. Nyirinkindi, B. Karikumutima, and G. Bisetsa Jururyishya

Abstract Maize is the major source of income in Africa, especially in Rwanda. However, there are many diseases which affect its growth as well as lowering its production. Using technologies like Artificial Intelligence (AI), the Internet of Things avoids the manual tasks which may come up with errors and help farmers to get automation of farms and the control of farm resources such as soil parameters, pests, and insects. This work highlights the IoT systems and Machine Learning Techniques applications in precision agriculture. The proposed solution uses NPK sensors to sense the soil quality/chemical properties, temperature, moisture, humidity, and EfficientNet deep learning model was used to predict maize plant healthiness. The output results shows that the model provides the best performance and can achieved 95% accuracy, and it can be seen that our model has reduced the loss from 79% to the 17%.

Keywords IoT sensors · Machine learning · EfficientNet · Maize plant conditions prediction · Precision agriculture

1 Introduction

Maize is a very important cereal plant in Africa and it is the dominant source of food produced in both industries and small scale agriculture. Most of the family farms in rural areas cultivate maize crop which makes it one of the top stable foods in east Africa. In Rwanda, crop productivity supplies about 69% of national sum up of agricultural outcomes with maize contributing more than 50% [1]. For now, there are variables that can clarify the prevalence of maize in Rwanda relative to other crops which incorporate maize appropriateness to the Rwandan climate and type of soil; however maize plants are affected by some diseases which causes less productivity. Plant leaves classifications has been already carried out with aid of morphological

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feature like width, height and parameter of the plant leaves as well as color histograms used by traditional form of machine learning image classifiers including K-Nearest Neighbors (KNN) and Probabilistic Neural Network (PNN) of deep learning.

Current advanced processing technologies like graphic processing units (GPUs) enabled the possibility of using emerging best performance technologies to process data sets. To extract plant leaves characteristics, the EfficientNet framework of CNN can be used. The dataset of our research is made up of maize plants collected in Rwanda, these maize plants leaves were identified and classified into several groups. We believe that by using EfficientNet, farmers will be able to get predicted plant leaves healthiness status and take care of the plant accordingly and effectively.

In this research, IoT based system was developed and used for sensing soil parameters and capturing maize plant image leaves and we used convolutional neural networks (CNN) framework known as EfficientNet to identify maize crops health status by classifying maize plant leaves into categories of infected, rust, and health and predict the maize plant healthiness with highest accuracy outputs, then help farmers to precisely take care of plants in order to prevent plant diseases and increase yields harvests. Therefore, the next section of our study includes review of related literature, Research methodology, Data analysis process, Justification of the research, Results and discussions, Conclusion and Acknowledgement.

2 Literature Review

Maize crop growth is primarily influenced by the soil's macronutrients. Soil being the broad representation of several environmental factors such as rainfall, moisture, humidity, temperature, etc. [2–4] Different types of diseases such as Common Rust, Ray Leaf Spot, and Blight affect both the quality and quantity of the production. As a result, it is very important to detect these diseases to mitigate the harm.

The use of CNN models and other ML techniques were investigated by researchers: The work done by Maitah et al. [5] presents a thorough assessment of a country level maize yield prediction using ML model and an extensive set of weather data in Czechia. O. M. Adisa et al. [6] has also conducted research using Artificial Neural Networks to predict maize yield in South Africa.

With the use of CNN, deep learning development boosted up from CNN layers to pooling layers as well as full connection, and it is made up with simple networks VGG-16, AlexNet, and LeNet [7]. By extending the depth on the network and enlarging the network channel for getting the best network, promoting image data resolution gives best characteristics. They not only increase the recognized network accuracy but also the cost of calculating parameters explosion is highest.

According to [8] the research done on the classification and recognition of the maize plant leaves disease images, proposed a technique based on fine tuning model based on EfficientNet of transfer learning which raises up the network accuracy and speed in recognizing diseases from small datasets by doing data cleaning and get

best image data, and pass pre trained through EfficientNet on ImageNet of the model for disease prediction.

The research done by [9] proposed adjusted and improved DenseNet-based maize leaf disease recognition model where the dataset was subjected to data enhancement techniques like rotation, translation, and scaling for the purpose of increasing leveling disease recognition's accuracy. As stated by [8] variety deep-learning algorithms have been implemented for maize plant diseases recognition and the research proposed the transfer learning network based on EfficientNet, the study shows that the transfer learning algorithm based networks are faster in recognition and on a high level in accuracy compared to the networks without transfer learning, since EfficientNet uses transfer learning and has fewer network parameters than Inception, and DenseNet, its performance can be considerably enhanced.

According to [10] conducted a study investigating potato plants Early Blight disease up to its growing stages. Various deep learning models have been applied including EfficientNet, GoogLeNet, and VGGNet, the study results demonstrated that EfficientNet had highest accuracy in real time image detection and plant disease recognition and classification. Various CNN models are being used for detecting and identifying different disease of fruits [11] although CNN is computationally complicated and resource intensive, especially when used on devices with limited resources. Duong et al. [12] created an expert system using machine learning and image processing to identify and classify fruits from captured fruits images. To recognize fruits in a real-time context with limited computational resources, the authors used two classifiers, EfficientNet [13] and MixNet. Using transfer learning and randomization techniques, performance is assessed using an actual plant leaves images dataset. The authors support the use of pre-trained weights in transfer learning for plant disease recognition and classification. An approach based on EfficientNet presented in [8] applied to recognize and categorize maize plant leaf diseases The AI Challenger dataset and a few web photos of maize disease are used to extract a minimal dataset sample. Images are cleaned and screened first to prepare a sample dataset, which is then enhanced with scaling, translation, and rotation transformations. Based on the EfficientNet model, transfer learning is applied to increase the accuracy and plant diseases recognition speed. The work of Rehman, A. et al. [14] reviewed different diseases/infections detection using enhanced CNN models such as AlexNet, LeNet, ResNet, Inception, VGG-16 [7], MixNet families, GoogleNet, etc. Hati and singh, 2021, [15] have used ResNet 20 (V2) in Species Recognition (SR) and Identification of Healthy and Infected Leaves (IHIL). Their work emphasized the contribution of residual network (ResNet) in plant leaves health condition monitoring.

Others for example different applications [12, 16–18] have used EfficientNet deep learning model to classify plant leaf disease in cucumber, Cassava, and Rice Germ Integrity. Our proposed model is considered the best among the CNN models and trains the pre-processed leaf images and extracts multi-dimensional depth, width, and resolution features. Its performance depends on the type of the input data with a more complex network which intends to provide a better prediction outcome.

3 Methodology

3.1 Resources, Materials and Tools

Research data was primarily collected from the site using soil integrated sensors, soil parameter sensors, and Raspberry pi Camera, then analyzed by using Machine Learning Algorithm. Soil integrated sensors were used to measure soil nutrients level (Nitrogen, Phosphorus and Potassium), detecting soil pH and measuring soil moisture. The modbus module (MAX485 TTL to RS-485 interface module) used in connecting soil integrated sensor (NPK and PH sensor) to microcontroller. Its type is named MAX485 Modbus. The BME280 sensor was used to measure humidity and temperature on the field. The Raspberry Pi 4B was used for processing data captured from Raspberry Pi Camera, it has a powerful processor, 8 GB of RAM, Gigabit Ethernet port, 2 Micro HDMI ports, USB-C Power supply and a Pair of USB2 and USB3 ports. The microcontroller used for connecting soil integrated sensors is Arduino ATMEGA 2560 R3.

The system architecture in Fig. 1 has the mentioned components that work together. They function as an end devices system and must be connected to a local area network to transfer data. The Fig. 2 shows the hardware system architecture and measurements of soil parameters using soil sensors connected to Arduino ATMEGA 2560 R3.

3.2 Data Collection Process

To follow up with the plantation growth and state, we visited the field during the plantation period up to the harvest time. The used data was collected during the silking and milking stage of growth. The used maize crop type is RHM1407 [19]. The data collected includes NPK concentration, temperature, humidity, altitude, and the plant leaves images. We used the NPK sensors and BME 280 sensor. We sampled some different spots on the field that represent the entire characteristics/ conditions observed on plants.

The Table 1 shows the values of the soil NPK values.

3.3 Data Analysis Process

We have collected the images data to analyse the maize leaves healthiness. To get the plant images we used our designed IoT tool to capture focused images, which were uploaded immediately to our centralized server. The captured images are of the size of 1600 $\times$ 1200 (Approximately 1 MB) around 72 dpi (Pixel Density), 24 bit (bit density).

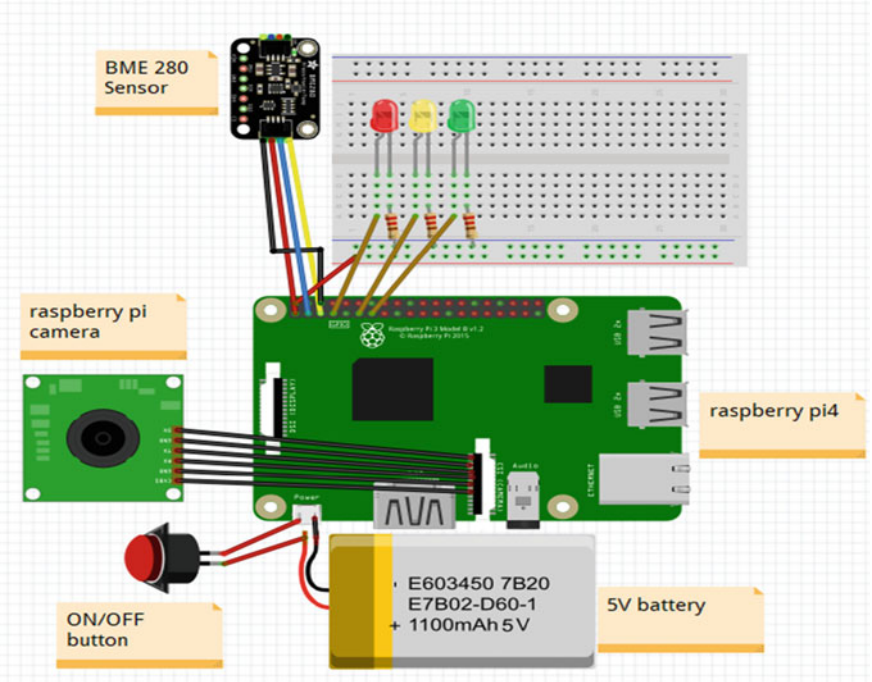

Fig. 1 System architecture designed using fritzing

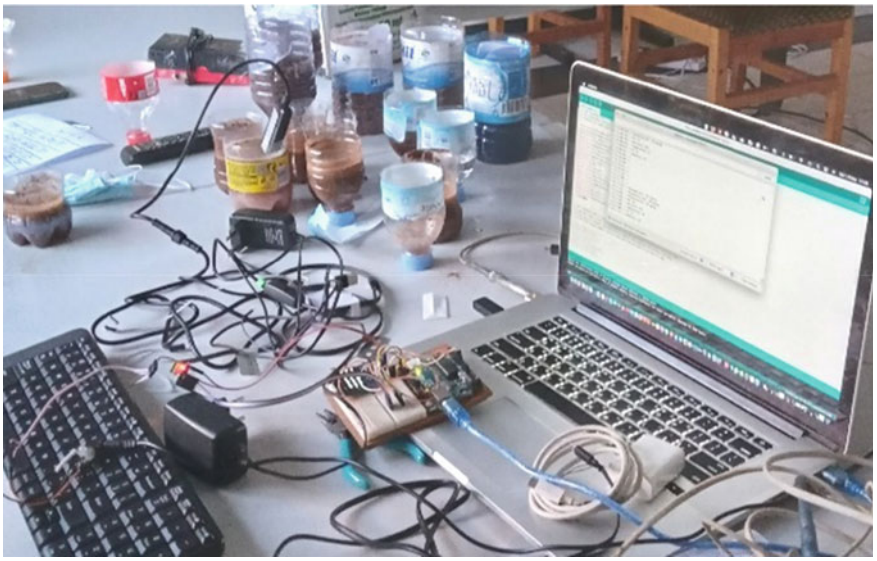

Fig. 2 Measuring soil parameters using Arduino ATMEGA 2560 R3

Table 1 The soil nutrients values

Field location	N	P	K
Top left	110	39	55
Top right	66	22	31
Middle	58	20	29
Bottom right	61	22	30
Bottom right	66	23	33

The analysis process involves examining a dataset and drawing conclusions based on it. Images analyzed belong to 4 categories namely: healthy, Common Rust, Ray Leaf Spot, and Blight (Fig. 3).

We analyzed the status of leaves collected on the field using the EfficientNet approach. This is a convolutional neural network architecture and scaling method that uses all depth/width/resolution dimensions using a composite coefficient. Better accuracy is achieved using big size and high resolution of the image. Based on [13] during image processing we can use resources in the following ways to maximize the accuracy using EfficientNet. Suppose that we want to use 2N times more computational resources, then simply we have to increase the network depth by αN, width by βN, and image size by γN, here α, β, γ are used as constant coefficients determined by a small grid search on the original or starting small model, in a condition that each

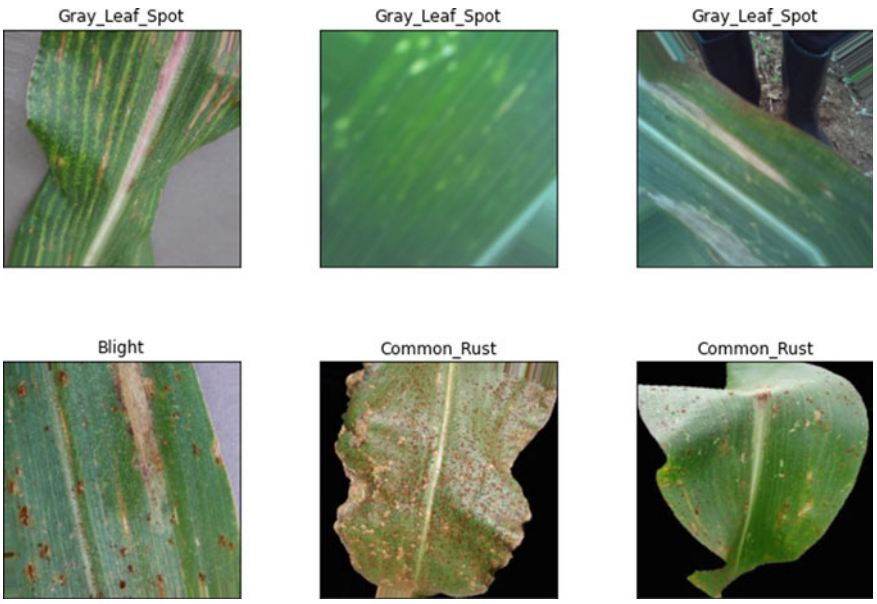

Fig. 3 Sample of health and unhealth maize leaves

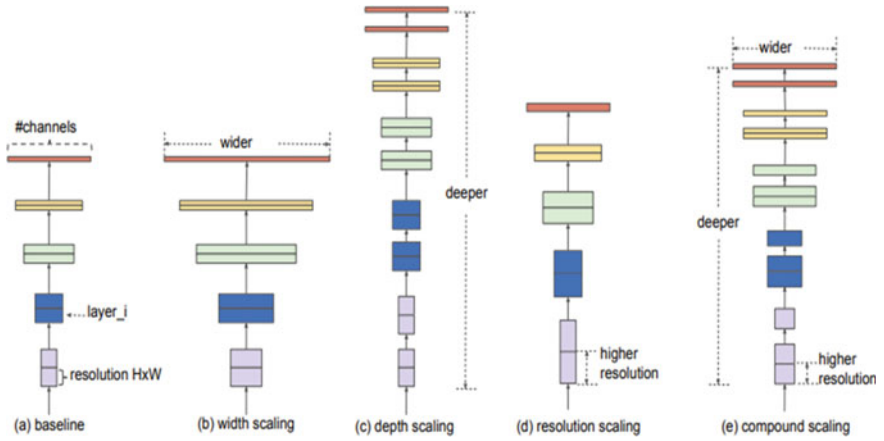

Fig. 4 EfficientNet network scaling process

of constant must be superior or equal to 1. EfficientNet uses a compound coefficient ϕ to uniformly scales network width, depth, and backbone in a very principled way.

The Fig. 4 shows an example of the EfficientNet process. From the left of this scaling model, we have an example of a baseline network. Next we have a convolutional model which scales only the width, the third shows the convolution which scales in depth, the fourth shows the one scaling in a network and lastly is the compound scaling method which scales all the parameters at the same time.

4 Results and Discussion

4.1 Data Modeling Approach

Data modeling approach is starting from the data collection, data pre-processing, model training, model evaluation, and model retrain.

a. **Data preparation**

The process involves cleaning the dataset by removing some images which didn't fit the criteria due to the angle of capture. In this EDA (Exploratory Data Analysis) step we go in depth to each picture and analyse its status in order to classify it in one

of the 4 categories of identified signs of health or infection depending on the type of infection presented on maize leaf.

b. **Data Pre-processing**

In this step we made a verification about outliers possibilities and then we did the data cleaning in order to remain with a ready to process dataset.

c. **Data splitting**

Our dataset is divided into 4 different folders based on the category of infection. We have precisely 765 figures in the Blight folder, 1673 in Common_Rust folder, 928 in Gey_Leaf_Spot, and 1323 in Healthy folders as depicted in the following figure (Fig. 5).

We randomly pick pictures that we will use as a training set; where the model learns from, then a test set where the evaluation of final model performance is done, finally the validation set used as Model hyperparameters in the proportion of 0.6, 0.2, and 0.2.

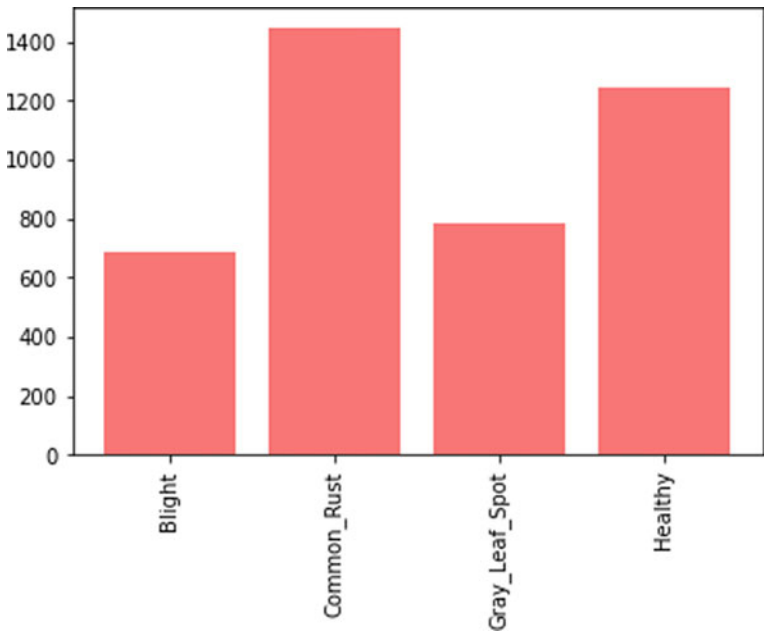

Fig. 5 Data splitting process

4.2 Train a Model

a. **Choice of algorithm**

Our machine learning accuracy depends on the clear visibility of the images. The bigger visibility means more chance to have good accuracy, based on research, using EfficientNet is a good choice compared to other algorithms of its category as it gives the ability to scale up all parameters at the same time.

b. **Results of data analysis**

The results of data analysis are presented in the figures below which shows the model accuracy, validation loss and confusion matrix in terms of the percentages.

The accuracy indicates the rate of correctly classified samples out of all samples. The Fig. 6 shows the results of accuracy and validation loss which change at each epoch. It shows the increase of the accuracy from 77 to 95%. This means that the proposed model is able to accurately classify the maize leaf images.

The Fig. 7 shows the loss which is decreasing as the epochs increase. It shows that the model is learning progressively since the epochs increase. Since the loss is the important parameter to major the effectiveness of the solution. It can be seen that our model has reduced the loss from 79 to 17%.

As shown in the confusion matrix Fig. 8 below, the results show values in True Positive, meaning that the prediction results belong exactly to the category which is found. A True negative when the predicted result is in the category that actually it doesn't belong to. A False Positive in case the results of prediction classified the

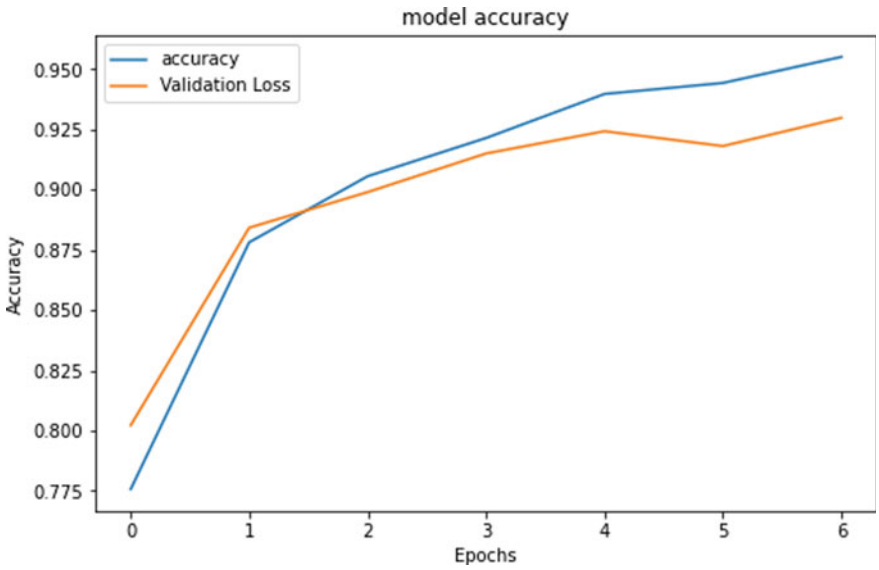

Fig. 6 Accuracy and validation data

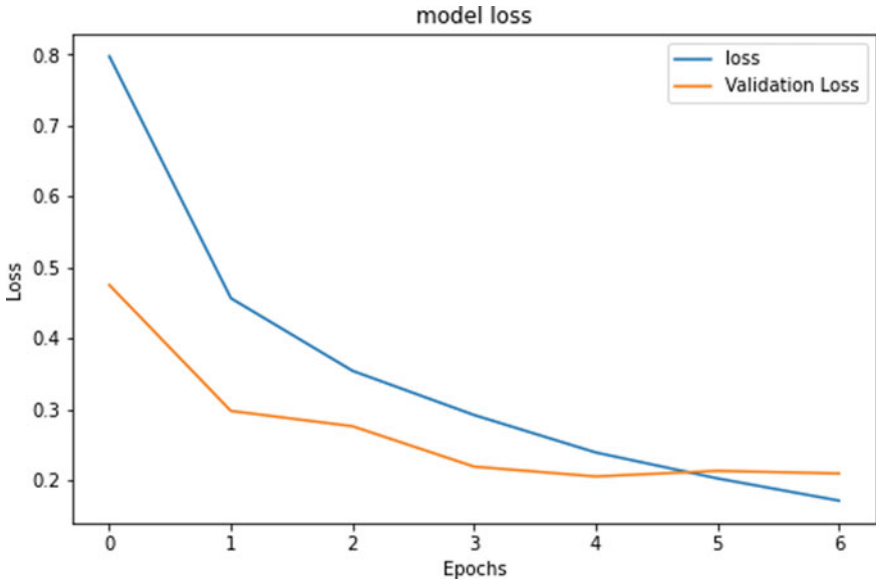

Fig. 7 Model loss and validation loss

image in the category which really it doesn't belong to, and a False Negative when the result of prediction is not classifying the image in the category but actually it does belong to it.

The Fig. 8 shows the confusion matrix as the performance of a classification algorithm. The corresponding percentages and the number of images present the detected confusing healthy and unhealthy images. This shows that a certain number of images were confusing the model during the training at certain percentages. That confusion is caused by the background of the images. It can be seen that the best classification accuracy is 96.09% with 221 confusing images and the worst performance is 91.92% which has a large number of confusing images (535).

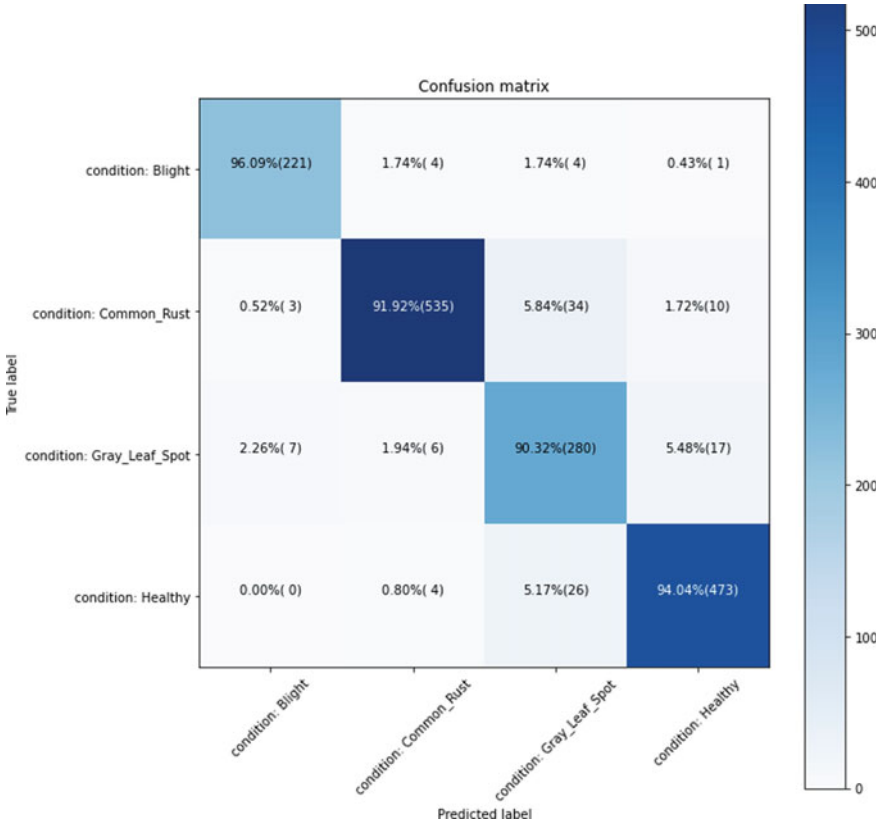

Fig. 8 Confusion matrix

5 Conclusion

CNN models have become popular and more important in image processing, especially in plant disease classification. In our study, we have used EfficientNet deep learning architecture to classify 4689 maize leaf images. The images were composed of the original images collected from the maize farm. Based on the outcome results, the efficient model can be applied in real-time monitoring. This is going to be our future research direction.

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Extracting Temporal Association Rules Over Datacubes

Carlos Molina and Belén Prados-Suárez

Abstract Association rules are one of the most used data mining techniques. The first proposals have considered relations over time in different ways, resulting in the so-called *temporal association rules (TAR)*. Although there are some proposals to extract association rules in OLAP systems, to the best of our knowledge, there is no method proposed to extract temporal association rules over multidimensional models in these kinds of systems. In this paper, we study the adaptation of TAR to multidimensional structures, identifying the dimension that establishes the number of transactions and how to find time relative correlations between the other dimensions. A new method called *COGtARE* is presented as an extension of a previous approach proposed to reduce the complexity of the resulting set of association rules. The method is tested in application to financial data of companies.

Keywords Temporal Association Rules (TAR) · OLAP · Multidimensional model · Complexity

1 Introduction

Association rules are one of the most commonly used methods for decision making. Since the first proposal by Agrawal et al. [1], several extensions of the concept have been proposed. Tung et al. [2] extended the association rules approach considering time relationships between records—what they call *inter-transaction association rules*. The authors proposed an algorithm to extract relations as follows:

when A appears, then B appears T later

where A and B are a set of items, and T is a measure of time (e.g., 3 *days*, 1 *month*, etc.). Lu et al. [3] extended the model from one-dimensional inter-transaction (time)

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to N-dimensional inter-transaction association rules (e.g., time and distance) with application to stock movement prediction.

The time concept in association rules has been studied from several perspectives, where authors have distinguished between "sequential rules" [4], "cyclic association rules" [5], "calendar association rules" [6], "interval temporal association rules" [7], etc. An exhaustive review and classification can be found in [8].

Association rules have been adapted to other systems that differ from the transactional one. An example are OLAP systems where the data are organized using multidimensional structures called datacubes [9]. One common characteristic of these datacubes is that there is always a dimension to represent time, since OLAPs are used for strategic analysis in organizations. Typical analyses are those to search for trends and see the evolution of data over time.

To the best of our knowledge, although there are proposals for association rules over datacubes (e.g., [10]), none include time in their methods.

In this paper, we propose a new method to extract temporal association rules from fuzzy datacubes adapted to these analysis-oriented systems.

There is no standard for OLAP structures, so we first need to present the multidimensional model, and we will use to represent the data (Sect. 2). As starting point, we will describe an association rules method according to the complexity defined for this structure [11] aimed at getting understandable association rule sets (Sect. 4.1). The next section presents the datacube applied to companies' financial data to test the proposed method. The last section is dedicated for the conclusion and future lines of research.

2 Multidimensional Schema

In this section, we present a datacube applied to company financial data to test and illustrate the method. A more detailed description of the underlying model can be found in [12]. Figure 1 shows the multidimensional model to use as example.

In this example, we have financial information on companies. The *Enterprise* dimension includes values of the companies that do not change over time (e.g., name, import/export, etc.). In our studies, we want to know how the relationships between the other variables evolve over time for each company, so this dimension will establish the number of records we have (for each company, we will have times series for the rest of the variables, and we want to identify temporal relationships common to all the companies). We will refer to these kinds of dimensions whose values do not change over time as *fixed dimensions* (D_F), which will allow us to identify each of the entities over time.

As we have mentioned before, in most datacubes, there is dimension that represents time, which is used for evolution analysis to see trends in the rest of the variables or dimensions. In this example, the time dimension is *year*. This dimension establishes the financial period in which we have values for the rest of the variables.

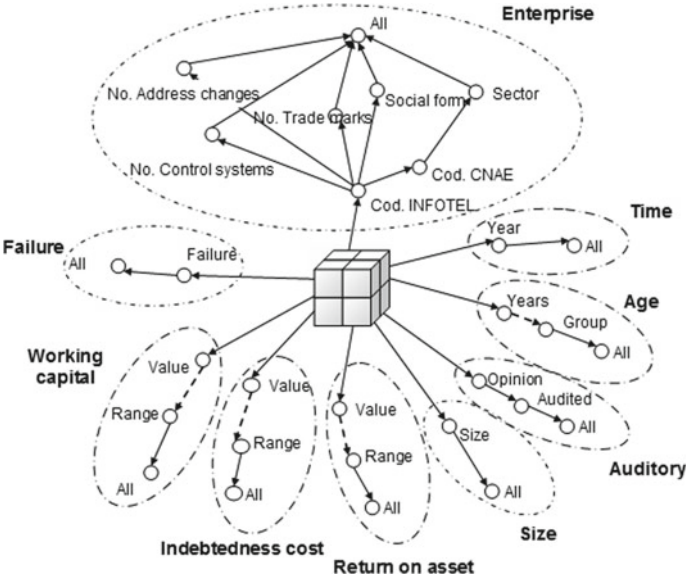

Fig. 1 Multidimensional model for financial data of companies

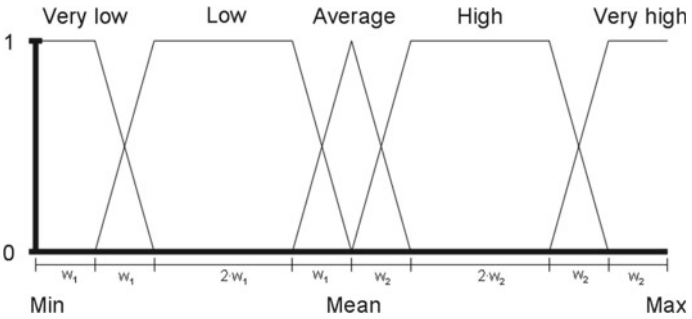

Fig. 2 Fuzzy *Range* level in numerical dimensions (*return on asset, indebtedness cost* and *working capital*)

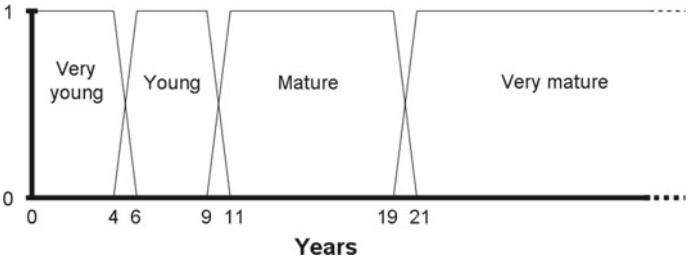

Fig. 3 Fuzzy *group* level in *age dimension*

The rest of the dimensions have values that change over time for each company, and we want to find relationships related to time between them. We call these *variable dimensions* (D_V). In our examples, we have the following *variable dimensions*:

- *Return on asset*, *Indebtedness cost*, *Working capital*: It represents three of the usual measure over financial state of the companies. They are numerical, and over each one, we define fuzzy groups as shown in Fig. 2.
- *Failure*: It only has two values: *yes* (if the company is considered *default* and has financial problems) and *no*.
- *Age*: This dimension represents the age of the company in a that concrete year (value of dimension *Year*). Over the numerical values, we have defined fuzzy groups as shown in Fig. 3.
- *Size*: It is a simple dimension with three values in the base level: *small*, *medium*, and *big* and stands for the size of the company considering the number of employees.

3 Temporal Association Rules Over Fuzzy Datacubes

Over the previous multidimensional model, we present the process of finding TARs. For example, we can search rules as follows:

AR_T = *For Companies of* Building sector, *when* Working capital *is* low, *then after* 3 *years the* Indebtedness cost *is* high.

where we have items from the *fixed dimensions* (Sector = Building) which do not change over time, items from the*variable dimensions* (Working capital and Indebtedness cost) and a time relation (*T=3 years*) between them.

The last element we need is a way to measure the representativeness and strength of the relationship. For the former, we use the normal measure in association rules: the *support* (in this example the number of companies that satisfy the rule) and the *certainty factor (CF)* [13]. We do not use *confidence* measure because it presents problems when there are very frequent items (see [14] for further details).

3.1 Definition

Now, we have all the elements to define the *Temporal Association Rules* over datacubes.

Definition 1 *The temporal association rules AR_T are*

$$AR_T = (a \cdot b \rightarrow b', t, Support = \alpha, CF = \delta) \tag{1}$$

where:

- $\forall i \in a / i \in D_F$, I_a *are items belonging to the* Fixed Dimensions
- $\forall i \in b / i \in D_V$ *and* $\forall i' \in b' / i' \in D_V$, i *and* i' *are items from the* Variable Dimensions.
- t *is a time measure.*
- $Support = \alpha$ *is the representativeness of the rule, where* $\alpha \in [0, 1]$.
- $CF = \delta$ *is the strength of the relationship, where* $\delta \in [-1, 1]$.

which means that for a concrete value of time dimension I_T *where* $a \cdot b$ *appears,* $a \cdot b'$ *appears in the moment* $I_T + t$.

In the previous example *a = {Building sector},* b = {Working capital=low}, b' = {Indebtedness cost=high} *and* t = 3 years.

This definition follows the same concepts as inter-transaction proposal [3] but adapted to multidimensional model.

4 Algorithm

Once we have formally defined the temporal association rules, we present the algorithm to extract them from datacubes. We adapted a previous method that extracts nodal association rules reducing the complexity of the results. The method uses the hierarchies of the dimensions in the datacubes to reduce the number of rules, presenting concepts that are more understandable by users.

4.1 COGARE

The method extracts rules and diminishes complexity by using the more abstract concepts defined in the hierarchy over each dimension. Figure 4 shows the flow chart for the method. The general schema is similar to Apriori algorithm [1], but it uses the hierarchies to reduce the complexity.

It applies a bottom-up approach, in to phases. The first is in the itemset generation. In that case, when an itemset is not frequent, the method uses the hierarchy to generalized the concepts and get more representative items: Instead of using a concrete value for a dimension (e.g., *Working capital* is $1M$), it uses values more abstract in the hierarchy that group this (*Working capital* is $High$). These kind of concepts are easier to understand by the user. The other phase is after generating the rules. In that case, the process is similar (it generalizes the items in the rules) controlling the loss of quality. A more details explanation can be found in [11].

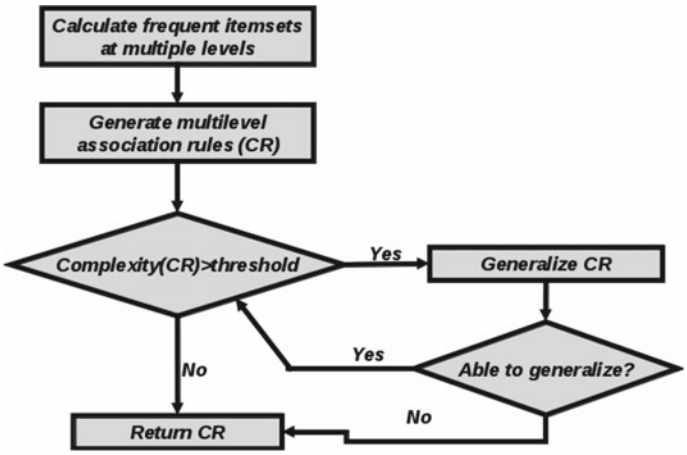

Fig. 4 COGARE algorithm

4.2 COGtARE: COmplexity Guided Temporal Association Rule Extraction

In this section, we present the changes made to the COGARE method to extract temporal association rules. As we have mentioned, the concept of support is different. Now, we have to calculate the number of *entities* (different values—records—in the *fixed dimensions*). This can be done querying the datacube applying slice (selecting only the *fixed dimensions*) and applying the values in *variable dimensions* as restrictions. Algorithm 1 shows the complete process for any itemset.

Algorithm 1 Support Calculation

Inputs: $I = a \cdot b$: itemset; DC: datacube; Max_{Supp}: max support
D_a = set of dimension of the items in a (*fixed dimensions* in itemset I)
DC' = query over DC splicing to dimension in D_a and conditions b
return $|DC'|/Max_{Supp}$ (number of records of DC' divided by Max_{Supp})

Once we have the frequent itemsets, next step is the rule generation process. In our approach, we have combined two itemsets, one for antecedent and the other for consequent items. But not all itemsets can be combined—they have to be compatible in the sense that both represent the same entity. In our case, the same entity means the itemsets share the same values for the *fixed dimensions*:

Definition 2 *In $I = a \cdot b$ and $I = a' \cdot b'$ we have two itemsets where*

- $\forall i \in a / i \in D_F$ *and* $\forall i' \in a' / i' \in D_F$
- $\forall i \in b / i \in D_V$ *and* $\forall i' \in b' / i' \in D_V$

then I and I' are compatible if $a = a'$.

Algorithm 2 applies this definition and establishes the step to generate all the temporal association rules (TRS) once we have all the frequent itemsets (FI).

The last aspect is how we calculate the time relation (t) part of the rules. To represent it, we consider the period between the two closest records that satisfy the restrictions (b and b' in the rule) for all the entities that meet the rule. With all these values, the user has a 95% confidence interval.

Algorithm 2 Rule generation

Inputs: FI: Frequent itemsets; $threshold_{CF}$ threshold for quality
$TRS = \emptyset$
for all I in FI **do**
  for all I' in FI **do**
    $I = a \cdot b$
    $I' = a' \cdot b'$
    if $a = a'$ **then**
      AR_T=$(a \cdot b \rightarrow b', t)$
      if $CF(AR_T) >= threshold_{CF}$ **then**
        Calculate t (search for confidence interval t that satisfies AR_T)
        $TRS = TRS \bigcup \{AR_T\}$
      end if
      AR'_T=$(a \cdot b' \rightarrow b, t)$
      if $CF(AR'_T) >= threshold_{CF}$ **then**
        Calculate t (search for confidence interval t that satisfies AR'_T)
        $TRS = TRS \bigcup \{AR'_T\}$
      end if
    end if
  end for
end for
return TRS

To calculate the quality of the rules (CF), we need to change the method too. For a rule $a \cdot b \rightarrow b'$, we need to know for each different entity e if $a \cdot b$ appers, and if later $a \cdot b'$ appers too for the same e. The algorithm to calculate it over the datacubes is shown in Algorithm 3.

The rest of the steps in Fig. 4 do not change, so we have all the elements to extract temporal association rules over the datacubes. In next section, we test the method over the running examples datacube over financial data of companies and show some interesting extracted rules.

Algorithm 3 Rule quality calculation

Inputs: $TAR = a \cdot b \rightarrow b'$: Temporal Association Rule; DC: datacube
  $record = 0$
  $pos = neg = 0$
  for all $e \in Entinties$ **do**
    DC_1 = Query DC using as restrictions e and $a \cdot b$
    if DC_1 has values **then**
      $record = record + 1$
      $date_1$ = get value from time dimension in DC_1
      DC_2 = Qery DC using as rstriction e, $a \cdot b'$ and value in time dimension $> date_1$
      if DC_2 has values **then**
        $date_2$ = get value from time dimension in DC_2
        $pos = pos + 1$
        $diff_{time} = diff_{time} + (date_2 - date_1)$
        Update *Confidence interval* with value $(date_2 - date_1)$
      else
        $neg = neg + 1$
      end if
    end if
  end for
  $cons_{TAR} = pos/record$
  $sup_{con} = (pos + neg)/|e|$

$$CF = \begin{cases} \frac{Cons - sup_{con}}{1 - sup_{con}} & \text{if } cons_{TAR} > sup_{con} \\ \frac{Cons - sup_{con}}{sup_{con}} & \text{if } cons_{TAR} < sup_{con} \\ 0 & \text{in other case} \end{cases}$$

  return $diff_{time}/pos$ (average time distance distance); *Confidence interval*, and CF

Table 1 Parameters

$\text{threshold}_{\text{Sup}}$	$\text{threshold}_{\text{CF}}$
0.001	0.5
0.01	0.25
0.05	0.25

5 Experiments

Once we have presented the method, in this section, we test its behavior considering different parameters. The tested configurations are shown in Table 1. The main results of the executions are shown in next section.

Table 2 Results of the experiments

$\text{threshold}_{\text{Sup}}$	$\text{thredshold}_{\text{CF}}$	FI	$\lvert AR_T \rvert$
0.01	0.25	649	643
0.05	0.25	238	113
0.1	0.25	124	26

Table 3 Examples of rules obtained

Rules	*Support*	CF	t in years (avg and interval)
{Company is Young}·{Working Capital is Low, Indebtedness cost is Very low}→*{Return on asset is Very low}*	0.093	0.33	1 [1–1]
{Company is Young }·{Return on asset is Low}→*{Company Failures }*	0.114	0.455	1.09 [0.764–1.414]
∅·{Working capital is Normal, Return on asset is Normal, Intendedness cost is Very Low}→ *{ Company does not Failure}*	0.031	0.25	1.25 [0.39–2.10]
{Company is Old}·{Working capital is Low, Indebtedness cost is Very low}→*{Company does not Failure}*	0.093	0.47	1.14 [0.78–1.5]
{Company is Old}·{Return on asset is Low}→*{Working capital is Normal}*	0.158	0.44	2.1 [1.56–2.56]
{Company is Young}·{Working capital is Normal, Return on asset is Low}→*{Working capital is Low, Company Failures}*	0.082	0.43	3.1 [2.74–3.47]

5.1 Results

In Table 2, we show the main results. We indicate the number of frequent itemsets (column FI), and the number of rules ($\lvert AR_T \rvert$). Table 3 shows some examples of extracted rules.

We can see that the number of rules is lower that the number of frequent itemsets, and this is because the method generalizes the rules to reduce the complexity of the resulting rule set. This process is independent of the support threshold. The method converges to get more abstract and general rules and reduce their number, so that the final result is more understandable for the user.

The rules in Table 3 use abstract concept instead of concrete values or intervals given by other methods, so they are easily interpretable.

6 Conclusions

In summary, we have introduced the time relationships in the extraction of association rules over multidimensional structures in OLAP systems. We have the different roles that dimension in datacube may play, where we have the ones that identify the entities and which do not change over time (*fixed dimensions*), the dimensions that do change over time, which is where we can find the temporal correlations (*variable dimensions*), and the dimensions that measure the passage of time (*Time dimension*). We have proposed a method to deal with these categories and properly calculate the support of the itemsets and the quality of temporal association rules.

The next step is to apply the method in more challenging domains (like health-related data) where data and relations are more complex for the multidimensional model to handle correctly. The extracted relationships may be very interesting and useful not only in management decisions but in regular medical praxis.

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The Efficiency of Software Methodologies Used in Artificial Intelligence-Based Biomedical Projects

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Abstract Safety critical software usage areas are increasing day by day, and biomedical software applications are one of them which is a promising and ever-evolving branch. This study is designed to investigate the efficiency of software methodologies used in artificial intelligence-based biomedical projects. To identify issues and controversies regarding the agile development of safety critical software and key features, this research compares and identifies which methodology, waterfall or agile, is more effective for safety critical systems. A literature has been reviewed with a research design of find, evaluate, extract, and comprehend the findings of the studies. Research findings show that there are central points of interest and recommendations which is extracted from literature and then combined into conceptual model in order to understand the key difficulties of agile software development in safety critical systems. The software development methodologies such as Scrum and Extreme Programming, that are agile strategies adopt an iterative and incremental approach, are deemed appropriate in the development of biomedical software projects.

Keywords Software methodologies · Biomedical project · Agile · Scrum · XP

1 Introduction

Software engineering is an engineering field based on developing complex software systems using various methods and tools under certain principles. The development process is a set of processes called software life cycle, and it is an ongoing process within the constraints or possibilities of the adoption of a software project development methodology [1]. The suitability of software development methodologies can be determined by factors such as project requirements, where stakeholders are and their

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competencies, and size of the development team. The waterfall model, which takes a straight forward and sequential approach, can be used in small-scale projects with well-understood requirements. However, it is not suitable for large projects where there is a risk of changes in requirements. With the help of the methods that adopt the agile approach, it is possible to catch the changes at every stage of the development of the project. For this reason, it is suitable for risky and change-oriented projects [2]. Scrum and Extreme Programming (XP) are software development methodologies that apply agile principles.

Biomedical project products can be an X-ray device or a device to be used in diagnosis and treatment branches that interact with the patient one-to-one. Therefore, the criticality level of the methodology to be chosen in the development of these projects is higher than the software development methodology applied. Stakeholders of biomedical software projects are software engineers, doctors, and scientists. At this point, it is important to associate the stakeholders with the development methodology. Many researchers and scientists think that software development in scientific projects has some limitations. In addition to being a good software developer in scientific projects, it can be expected to have different competencies in the relevant fields [3–6].

In this study, software development methodologies in biomedical projects were studied. Answers were sought for the research questions.

2 Related Work

In the study of Kane et al. [2], the research was conducted on six different organizations, these organizations are classified in terms of their work areas, applications and users, team sizes, and the software development methods they use are listed. Agile approaches have been applied in projects belonging to each organization, and their effects on software development lifecycle processes have been evaluated. As a result, it was stated that agile approaches are suitable for biomedical software projects.

On the other hand, Sanders [7] evaluated how the software lifecycle processes (design, coding, testing, etc.) and other issues addressed during the project development phase are handled in a scientific software development process.

The use of agile approaches is discussed in the study of Pitt-Francis et al. [1], a computational biology project conducted at Oxford University in which many scientists are involved. The authors stated that it was suitable for use in scientific studies because it adopted the XP method, which is a principle of agility, to keep up with the change in the development of the project.

In the review of Sletholt et al. [3], researchers examined the article of the scientific project on the use of agile approaches and the methods adopting it and summarized their findings. Six search queries were determined, and the studies that came out of these query results were evaluated and eliminated. Nine articles were presented with the evaluations of the agile approach models they used. In the synthesis part of the study, it has been determined that agile approaches may be appropriate in

the development of scientific software projects due to their positive aspects such as requirements analysis, flexibility in development and testing stages, and customer internal.

In another study, Lee et al. [8] discussed how Scrum, which is an agile approach model, can be adopted in biomedical project management, based on the fact that the project results in an error when students cannot create high-level designs that will be applied correctly in a solid model such as waterfall during project development. Waterfall and Scrum models were compared, and then the previous study and project work after adopting Scrum model were evaluated. Considering the feedback received from the students and outputs of the students' work by adopting the Scrum framework, the authors concluded that use of Scrum is highly beneficial.

In the study of Baxter et al. [4], which is almost an answer to the question of how efficient and quality software is, rather than directly evaluating methodologies, the authors discussed why software products are necessary and how these applications can be applied efficiently and effectively in scientific software development. They gathered the best solutions they suggested such as up-front design and gave the projects where the implementation was successful.

The researcher Aldwairi [5] believes that agile approaches can be applied to the development of computational biomedical projects. It was stated that the most suitable method for the development process of biomedical software projects, which he described as large and complex, is the methods that adopt agile approaches. Evaluating the challenges between software engineering and computational biomedical projects, the author then outlined how agile approaches can solve these problems. He exemplified the applications of different projects, focusing on the analysis, design, implementation, and testing phases.

Kelly [9] touched on the gap of software engineering applications and scientific calculations. It was emphasized how software engineering should be connected by a bridge in scientific computing applications in sectors such as health and security. It was stated that software engineers should choose the appropriate methodology for a successful result in projects, and, as the main idea, by referring to various studies, software engineering applications are not far from scientific computing applications.

In a study of Cates et al. [6], study, which stated that the agile approach was adopted, the software processes of the project were explained and evaluated. The use of the agile approach is exemplified in the study, in which each stage of the software lifecycle is supported by sample projects developed.

Rottier and Rodrigues [10] present how Scrum plans and mapped Scrum to DCP. This document is supported by the Software Requirement Specification (SRS), which describes it for all non-user use purposes. It demonstrates how these user stories can be achieved as a technique that gives easy access to their stories, while also allowing to learn about using each technology.

In the study of Miller et al. [11], the research shows that XP is best seen as a general approach. The authors stated that, adaptation is important, and XP creators may not see this. Their XP inspired approach is more sequential than XP, in keeping with the pre-existing system.

On the other hand, Qiao et al. [12] use test-driven development (TDD), which was demonstrated as a viable approach to reduce defects of product. Generating "executable feature document" allows client to detect design parameters before the code generation with the help of the developer.

The research of Hajou et al. [13] is about how the agility methodologies conflict with generally accepted methods, and also the resulting literature covers a wide range of related agility methodologies pharmaceutical industry.

Dwight and Barnes [14] research shows how active and changing requirements, frequently driven by empirical data-driven models, benefit projects using an agility method.

In another study [15], waterfall and Scrum models begin the statements that are refined according to specs of system. And as a result, their methodologies can be adopted in biomedical project management, such as Scrum, which is an agile approach model.

The researchers Najdawi and Shaheen [16] were discussing which method is better for the projects of AI and innovation. The similarities between agile and Scrum methodologies, their effects on the projects, and their superiority over each other were examined. Project management methodologies, expected contributions, ongoing research, and further work are detailed. Finally, it is argued that it may be possible to choose a more appropriate method with some logical questions.

In an article [17] based on designing a fault-tolerant decision-making system in biomedical applications, design process is based on systems engineering methodologies. This article discusses the state of fault-tolerant biomedical systems. The design feature which provides fault tolerance is described in three stages depending on the agreement, requirement, and specification stages. The study explains the necessity of such designs by emphasizing the importance of fault tolerance in the advancing and increasingly dependent human organism on biomedical systems and the need to work even with minimal errors.

In an article written by Fabelo et al. [18], they have studied hyperspectral imaging application of that helps to identify brain tumors of brain surgeries within the scope of the European HELICoid project. The methodology used to create a dataset is generally assisted by spectral features of HSI to distinguish between tissue types. In addition, the repeatability experiments used provide an opportunity to measure the effectiveness of the data.

In an article [19] based on DICOM compliance, it is aimed to develop an up-to-date software that meets medical criteria. DICOM compliance is of great importance for medical radiography scanners; therefore, in order to ensure this compatibility, appropriate methodology based on software requirements analysis, risk assessment, and test management tasks is developed in the study. The methodology diagnoses whether the software complies with medical standards by looking at the software's DICOM compliance.

In a study of Lin and Fan [20], a hybrid methodology depending on a waterfall-like lifecycle combination is used to set up documents and the agile method to eliminate the risks in the project. Using a subjective methodology template, it is intended to strike a balance with agility and discipline to better trace documents in the study

and demand FDA requirements. In the study, a plan-oriented software process like CMMI was also mentioned, and waterfall and agile approaches were compared, their pros and cons were examined, and as a result, it was decided to create a hybrid model that combines them rather than just an approach like CMMI or agile.

As a last study [21], it is based on the integration of artificial intelligence functionality into digital health systems that describes different approaches to examine cutting-edge technologies and managing global pandemics. The study builds a methodology for future waves of COVID-19 and also makes a qualitative case study with information from the COVID-19 pandemic with this constructed model. Control of any future disease can be made possible by integrating artificial intelligence into digital health systems, in the six-step way used here for the methodology to be successful. With this conceptual methodology, it also aims to design more compact and effective algorithms, diagnose losses from diseases, measure possible risks, and do better by learning from the results in the future.

3 Research Methodology

In this research, literature has been reviewed to address research questions.

RQ1. What are the software development methodologies used in the development of biomedical projects? This question to be answered in terms of being a preliminary information for other narrowed questions and an overview of the research scope of the article. The answers aimed to be reached are to determine which software development methodologies are used in the development process of biomedical health software made in the last 16 years and to provide information about these methodologies.

RQ2. Which methodologies are recommended (appropriate) in the literature during the development process of biomedical projects? Software lifecycle stages basically involve the same processes for every project. However, according to the chosen methodology, there are some changes in the operation of these stages, project roles, and prioritization of the stages. Based on this question, the intended research outputs are to reach a conclusion about which methodologies and why are appropriate for the development lifecycle of biomedical projects that include many different stakeholders (doctors, hospital management, software engineers, electrical engineers, etc.), and various hardware and software products. It is thought that examining and evaluating the suggestions of respected scientists who have done research on this subject about which methodology they consider appropriate in their studies and why will be an important output in terms of shedding light on the research question for future studies.

RQ3. What methodology can be useful in developing biomedical projects? In this question, depending on the outputs of our second research question (methodologies found suitable in the development phase of biomedical software projects), with the

support of our own academic background and theoretical knowledge, the answer to which specific software development methodology is useful for biomedical projects has been investigated. At this point, the advantages of the chosen methodology in the relevant context were evaluated.

RQ4. What criteria are used when selecting a development methodology for biomedical computing projects? When starting a project, careful and good analysis and planning from the very beginning minimizes the problems that may occur later. Choosing the software development methodology according to the scope of the project from the beginning is one of the important planning stages in software engineering. The requirements and constraints of the product to be produced in each sector vary during the development phase. The purpose of processing this research question is to evaluate what the requirements and constraints of biomedical projects are and what criteria are taken into account for the selection of methodology.

To answer research questions, an evaluation has been done on the basis of the subject, and articles were collected from three databases. The collection and selection process of these articles are explained in detail in the following section.

3.1 Article Selection

Selection of articles, which is the initial stage of this study, was carried out by collecting the articles from three databases and refining these articles by applying some selection criteria. Articles were collected from the databases of Web of Science, IEEE, and Google Scholar with the search string of "Biomedical projects AND software methodologies" for the last 16 years. Some of the studies that are not related to the subject but overlapping with the words contained in the string, such as biomedical, software, and methodology, were also obtained at that point. Forty-five articles obtained at the beginning were refined by manual examination of titles, conference, and journal titles, removing those deemed irrelevant, and were reduced to thirty articles. Nine of them were found to be out of scope of this research and were eliminated. As a result, it was decided to evaluate twenty-one studies.

4 Analysis of Results

In this part of the study, the relevant articles, that is, twenty-one were reviewed and evaluated, and the research questions were answered.

RQ1. What are the software development methodologies used in the development of biomedical projects?

The selection of the software development methodology is made by criteria such as the scope of the project, the project resources, who the stakeholders are, and what their

needs are. Biomedical projects require working with many different stakeholders. Developers come from academic disciplines, commercial, and governmental organizations [2]. At this point, choosing a methodology that enables the involvement of each stakeholder in the project may be an important criterion. It has been seen in the studies that the size and requirements of the projects also played an important role in the methodology selection [5]. This is a methodology selection criterion that highlights the suitability of methodologies that support change for biomedical projects.

Kane et al. [2] have examined six biomedical computing projects, and it was observed that companies consisting of small teams adopted the Rational Unified Process model before adopting agile approaches or that specialized methods similar to the agile approach were used within the company, and XP and Scrum methodologies adopting agile approaches were included in company projects, and positive responses were mentioned. In computational biology projects that are directly related to the patient, such as Pitt-Francis et al. [1], the "customer" relationship is very important. The realization of these projects is so important that it can change the lives of many people. Therefore, the choice of development methodology is extra critical. It should be able to adapt to all kinds of new technologies and offer the best results instantly. In such requirement and tool priority projects, the use of the XP method has been followed. XP is seen as a good "general society" choice for software production, diverse, that a subset of the concept can be adapted for its core purpose by specific error prevention [11]. As a result, the researches and the outputs of software engineering knowledge showed that agile approach methodologies such as XP and Scrum, which put change management and stakeholder interaction at the core, used in biomedical software projects.

RQ2. Which methodologies are recommended (appropriate) in the literature during the development process of biomedical projects?

By narrowing down the answer to our first research question and make an evaluation according to the studies, methodologies that adopt the agile approach have been seen by many scientists as suitable for biomedical projects [2]. Biomedical projects require iterative and incremental management because of their complexity, constant change of requirements, and financial cost. Continuous feedback, as another benefit of agile approaches, is another prominent point in the studies examined [14]. Involving various stakeholders such as medical doctors, biologists, software engineers, and even patients depending on the scope of the project is also very important for a good understanding and implementation of the requirements. To sum up, since with its practices such as pair programming, test-driven development, tight iterations XP yields productivity boosts [1, 5, 7], daily and at the end of each iteration, review events, and prioritization approach, Scrum methodologies are the recommended methodologies that come to the fore in the development of biomedical projects.

RQ3. What methodology can be useful in developing biomedical projects?

It has been determined that methodologies adopting the agile approach are appropriate in the development of biomedical projects. At this point, it would not be the

right approach to strongly suggest the appropriateness of a single methodology for biomedical projects. Considering the scope of the project, the delivery time, and the resources offered, one of the models that adopt the agile approach (such as XP, Scrum, Lean Development, Kanban) can be selected. However, XP can be recommended as an appropriate methodology due to the cost and structure of biomedical projects that require change of management and roles with different backgrounds. With the advantages of XP principles, frequent and fast feedback affects progress of a project. XP does not require high-budget starter packs. Therefore, processing of priority requirements with low cost at the initial level of already costly biomedical projects makes the project resource management efficient. The teach-to-learn principle brings together stakeholders with different academic backgrounds and supports continuous learning within the scope of the project. For example, a programmer should learn the structure of a tooth canal from the relevant scientist during image processing operations, so that programmer can understand a correct application. Continuous improvement can be achieved with the advantage of retrospective practice. Thus, the repetition of problems that may occur is prevented that is important to minimize errors in projects in the biomedical/health field. For such reasons, XP can be suggested as a methodology that can be used in the development of biomedical projects [2].

RQ4. What criteria used when selecting a development methodology for biomedical computing projects?

Biomedical projects have more serious constraints and requirements than other software projects. It is one of the projects that must be managed efficiently because it has various stakeholders, needs to respond to change frequently and quickly, is long-term projects, and requires costly work. These constraints and requirements have been influential in the selection of models that adopt the agile approach in the selection of methodology in the planning phase of biomedical projects.

During the specification phase, sometimes producing a formal model can be concluded with some problems. In these systems, although system performance is as expected, three ANNs can give an error. Because only two of them can take the input data, the system can stop, freeze, or cannot give a decision because of insufficient or limited data. However, instead of this, reducing three ANNs to two or resetting the systems can solve the problems. Furthermore, screening modalities (e.g., mammography) can also have some restrictions on the detection of some diseases such as breast cancer. For instance, these systems may be limited in young women with dense breast tissue because of the lower resolution. Here, high specificity and sensitivity are required; therefore, some other screening techniques can be useful for early diagnosis of breast cancer based on the patient history and physiology. In addition, systems engineering design methodology needs certain requirements in fault-tolerant decision-making systems. For example, systems must be fault tolerant, based on machine learning, cost-effective; fault tolerance must not change processing speed and must not affect classification performance [17]. This research shows that it is useful and common method that can be used in XP software methodologies. At the same time, we see that success rate of projects developed with inspiration from

XP is high [11]. Also it is a benefit of active and changing requirements of agile methodology [14].

Hyperspectral imaging (HSI) is known as completely harmless, non-contact, and label-free technique for imaging brain tumors. However, this also has some limitations. In one limitation, HSI can capture tumor images only when tumors are on the surface or in a deeper layer that is easy to capture. Also, HS push-broom camera used in the study requires spatial scanning in order to acquire the images. Changes that occur in the patient's brain during surgery (bleeding or surgical serum) can affect the spatial consistency of the image. For this reason, snapshot cameras are used, but the number of spectral bands affecting resolution is lower than push-broom cameras. The second limitation concerns the number of patients. The limited number of patients make it difficult to collect data and build a base. In addition, since the biological characteristics, tissue types, and tumor types of the patients may differ from each other, more research and data collection are required with each wavelength HS camera. For example, studies based on the combination of SAM algorithm and the pathological analysis were preferred in order to better diagnose the differences and generate more detailed data. Moreover, since the push-broom camera used in HSI captures only one spatial dimension, a scanning platform is needed to obtain its second spatial dimension in HS cube. In neuropathology evaluation, standard H&E stain and other necessary additional staining are required to make the histopathological diagnosis for the resected tissue that is fixed with formalin [18].

In Radanliev et al. [21], authors mention that it is necessary to use artificial intelligence more efficiently by increasing algorithms on deep learning to have better performance than hackers in Disease X events and in other healthcare services. However, problem here is that artificial intelligence algorithms are not suitable for working on IOT, drone, and some edge devices used in the healthcare field, and they have very low memory. To solve this, faster and more efficient processing is needed. Another problem is that more memory is needed to use artificial intelligence on these edge devices. It may be possible to solve this problem algorithmically; e.g., more compact and efficient algorithms should be developed to better distribute the AI algorithm on edge devices. This may be possible by building a set of new algorithms on top of each algorithm. And with this methodology, there is a need for some experimental developments to measure risks in diseases. In pharmaceutical industry, agility methodologies conflict with generally accepted methods [13]. On the other hand, there are some experiments that use test-driven development, and the key reason to use an approach of TDD to MATLAB is that it is possible to use same tests validate final code, that is, non-MATLAB, running on a properly translated biomedical device [12].

5 Conclusion

In this research, the methodologies used in the development of biomedical software projects, which are more complex than projects in many different sectors, contain different constraints and requirements, involve stakeholders from different academic fields, can be labeled as critical, and are examined. The analysis is done by searching with the search string from three databases to answer the research questions.

In the software development parts of the projects covered in the studies, used development methodologies were explained. Information about the scope and application of the methodologies was given, and how the methodology was integrated in line with the requirements of the processed project was given. It has been obtained that biomedical projects are long-term projects with ever-changing requirements. Since biomedical computing projects require many resources, they can be considered as costly projects. These costs must be managed well; otherwise, project may not even be completed due to lack of resources. These projects, which involve many different stakeholders such as doctors, scientists, biologists, and software/electrical engineers, require a continuous transparent project management. Other point is that problem is understood correctly, and solutions are applicable by everyone, which impose additional responsibilities and capabilities on software developers other than their own competencies. Considering all constraints and requirements, agile approach in software development process in biomedical projects has been found appropriate in literature. With the advantage of always embracing change adopted by agile approaches, the ever-changing requirements of biomedical projects can be managed efficiently. With the short and incremental working principle of agile, changes can be implemented with the help of feedback received at every stage of the project, and product quality is maintained with continuous automatic integration tests. By prioritizing of requirements, resources are protected, and availability of products delivered in short versions is ensured. As a conclusion, Scrum and XP are appropriate to be used in the management of biomedical software projects.

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Multi-source Data Fusion for Climate Variation Study—Case Study: Algeria

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Abstract Further to the recent technological advances in physics and computer science researches, the implementation and deployment of solar energy plants become more and more efficient to face the exhaustion of energy sources fossils. The feasibility and studies of solar energy projects are performing by the processing of solar irradiation parameter. However, the solar irradiation data sources are in most cases unavailable in hostile or inaccessible areas making a new paradigm of solar data availability in proximity to the point of interest. Meanwhile, the researchers had developed models for the solar irradiation estimation based on different meteorological parameters like: sunshine, temperature, and cloud-cover. These terrestrial meteorological data sources represent a real mine of multi-modal and correlated data that could be fused in order to build locally a global climatic database. In this paper, we introduce a low-level data fusion approach based on multi-source and multi-modal meteorological parameters followed by a classification and mapping process of climate clusters with the objective of facilitating the identification of regions with high variation potential in Algeria.

Keywords Data fusion · Linked-data · Classification · Decision making · Solar potential · Climate variation

1 Introduction

The solar radiation remains an emerging renewable energy source field enabled by the recent advances in solar energy systems (photovoltaic system and thermic system), that led to design performant solar-based power plants as an example the "concentrating solar power system CSP" which is characterized by important capacities of

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power production, environment saving, and sustainability. To accomplish scientist tasks such as prediction of solar potential, climatic change study, and geographical zone classification, researches need to explore and fuse data from heterogonous source disposed at the level of meteorological stations in order to overcome the lack of measurement data for some specific climatic parameters used in the prediction models.

Since the acquisition of measurement equipment and the employment of qualified technical skills are very costly for the solar radiation measurement, the alternative solution should be inevitably focused on the exploration of other available parameters like meteorological variables and satellite images in the location of interest.

In this paper, we investigated data availability problem in the context of the solar field and conception of a global solar information system which must be open to scientist community for statistical analysis and cartography in the solar research filed and in other hand for professionals to evaluate the return on investment of any prospected solar plant project. We introduced the linked data principals to standardize representation and access to meteorological data sources through Uniform Resource Identifiers (URIs) in one hand and, on the other hand, to set links between different sources of meteorological data. These links connect all sources into a unique global meteorological data source explored by a single solar information system in the data fusion and classification process for solar data estimation.

Thirteen Algerian weather stations with their monthly insolation data collected over 30 years (1980–2010) were selected in this work for simulation. After data fusion, classification, and mapping process, six main balanced classes were obtained, dividing Algeria into six climatic regions with different solar potentials.

In this work, we will try to respond to the next questions:

- Does the presented system have the ability to locate and access data sources with high data availability potential for a specific study area?
- Does this system allow classification of geographical areas into climatic clusters and define the most stable areas with high solar potential?
- Can a solar potential map be generated based on fused meteorological parameters?

The article will be structured on the following basis: Sect. 2 discusses various approaches to related work. Section 3 presents the developed approach with details of some relevant phases. Section 4 illustrates a case study that demonstrates the implementation of this approach. Section 5 concerns the results of the fusion and classification processes as well as the mapping of the solar potential generated by the presented system. Finally, remarks and orientations for future work will be quoted.

2 Related Works

Data fusion, as a widespread and useful multidisciplinary, merges data from numerous sources to enhance the performance and potential values of the original data and to generate a high-quality of the data. Fusion techniques provide a variety of

purposes, from detection, recognition, identification, and classification of objects, to tracking of objects, change detection, and decision making. They have been applied in the domains of space and ground observation [1], network control [2], medical image processing [3], artificial intelligence [4], defense security, etc.

Climate data fusion is one of the widely used techniques for studying weather phenomena. It attempts to combine the collected data with different meteorological parameters from sensing station and satellite sensor data sources to generate fused date source which contain more comprehensive data than either source.

In recent work [5–7], the authors have reported a promising trend in the application of a decision-making model to study climate variation. For example, there are many studies on the use of decision-making approaches for climate change and sustainability. In some works, [8, 9], approaches based on decisional models are proposed for the study of climate change in some Algerian regions that have targeted particular climatic aspect using a single source and type of data. In this paper, the proposed approach involves multi-source data of different types (insolation, temperature, wind, humidity, etc.). We can cite below some national research projects in the development of a solar information system.

2.1 Project #1: Development of a Solar Information System Based on Multisource Data [National Research Program CR0162/10/03]

Project Affiliation: Center for the Development of Renewable Energies (CDRE) of Algeria—Renewable Energies Unit in the Sahara URER-MS Adrar.

Project Purpose: The objective of this project is the transformation of satellite images using meteorological data into a digital usable and exploitable "Solar Deposit".

2.2 Project #2: Realization of an Algerian Atlas of the Solar Field from Satellite Imagery and Geographic Information Systems

Project Affiliation: Algerian Space Agency and the Algerian Ministry of Energy.

Project Purpose: This project, engaged with the Ministry of Energy, includes two main objectives: (1) the realization of an Algerian atlas of the solar deposit; (2) the identification of sites with high solar potential for the implementation of solar power plants.

3 Data Fusion

Data fusion makes it possible to consolidate multi-source data to produce complete and efficient databases. These data can be used in the taken decision. The US Army's Joint Directors of Laboratories (JDL) data fusion group have proposed the following definition of data fusion [10]: "*A process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete a timely assessment of situations and threats, and their significance*".

3.1 Levels of Data Fusion

The fusion algorithm may be implemented across three points in the decision-making cycle [11]:

Low-level fusing. It is the combination of raw data (readings, signals, etc.) collected from multiple sources into a single fused matrix (more informative and summarized).

Mid-level fusing. It is the recovery of different data source characteristics (averages, data type, image texture, etc.) in order to combine them into feature relationship matrices used in data processing rather than the original matrix of individual data sources. It is useful when the number of data sources is large, and it is difficult to process each data source separately.

High-level fusing. It is the combination of decision results. Decision-level fusing includes statistical and voting methods, also some fuzzy logic techniques.

In this work, the low-level fusion is the chosen model that concerns the fusion of climate data sources collected from meteorological stations.

3.2 Multi-source Data Fusion Model

In this subsection, we summarize the three core steps of the data fusion processing: modeling, combination, and decision.

Modeling. Fused data are defined according to the experts' knowledge and the characteristics of the original data. If we consider a data fusing problem from m sources S_j, then for every single source S_j we have a decision d_i on observation x defined by $M_j^i(x)$. The decision d_i corresponds to the class C_i where x belongs. Thus, the modeling stage involves the definition of $M_j{}^i$ matrix as a distribution, cost function, equation… etc.

$$\begin{array}{c} \\ S_1 \\ \vdots \\ \vdots \\ S_j \\ \vdots \\ S_m \end{array} \begin{array}{c} \begin{array}{ccc} d_1 \ldots & \ldots\ldots d_i \ldots\ldots & \ldots d_n \end{array} \\ \begin{bmatrix} M_1^1(x) & M_1^i(x) & M_1^n(x) \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ M_j^1(x) & M_j^i(x) & M_j^n(x) \\ \vdots & \vdots & \vdots \\ M_m^1(x) & M_m^i(x) & M_m^n(x) \end{bmatrix} \end{array} \tag{1}$$

The indicator function is given by:

$$M_j^i(x) = \begin{cases} 1 \text{ if } \quad S_j(x) = i, \\ 0 \text{ else,} \end{cases} \tag{2}$$

$S_j(x) = i$: the source S_j choices the decision d_i, and the observation x belongs to C_i.

Combination. As a main step of the fusion, it consists of combining the original data through a combination function chosen on the basis of the data modeling. The combination function can be defined simply by: intersection, union operations, or the weighted sum of indicator functions (Eq. 3).

$$M_E^k(x) = \sum_{j=1}^{m} \alpha_{jk} M_j^k(x), \tag{3}$$

where $\sum_{j=1}^{m} \sum_{k=1}^{n} \alpha_{jk} = 1$.

Decision. In this last step, we have to minimize or maximize the combination function. However, the final decision about observation x is made from combining the data from $M_j{}^i$ to make the "best" decision d_k. The decision formula E is given by:

$$E(x) = \begin{cases} k \qquad \text{if } M_E^k(x) = \max\limits_i M_E^i(x) \geq cm + b(x) \\ n + 1 \text{ else,} \end{cases} \tag{4}$$

c: constant; $b(x)$: function of $M_E^k(x)$.

4 Contribution

Our contribution in this paper is an improvement of an information system developed for solar data management in an earlier work [11], designed to study climate variations in Algeria. The solar information system (SIS) is built on five modules, and each module concerns specific methods and process policies.

The processing of the SIS system starts with the step of linking the data sources and defining the connections between the different data sources. Then we have the collection and archiving of data in single climatic database driven by the ETL data engine (data extraction, transformation, and loading). After that, we have the step of building the solar data by applying the appropriate estimation models according to the collected data type. The last step is the classification and mapping of the obtained solar data.

4.1 Data Link Definition

The data collection begins by linking the SIS system to all available data sources via a secure and structured link. Every new data source link is paired with a fusion method that describes the process of fusion with some other data sources.

To exploit data from heterogeneous data sources, a dedicated linking method must process each available type of data. However, data hosted behind a personal or corporate firewall should be considered and labeled as public or private sources. Subsequently, it was useful to consolidate all linking and authentication policies into a central catalog [12] and to identify fusion connections between sources.

Derived from the Web Linked Data basics [13], the linking method is a core of standard rules for sharing and linking structured data on the Internet. To formalize the data link rules, we have used a JSON file format with its attributes (Table 1).

After checking and confirmation by specialists, the new connection link is added to the central links catalog. If the proprieties of the data source changed (reset of the

Table 1 Attributes of the data linking rule

Attribute values	Definition	Examples
ClimData_X	Name of the climatic parameter	*Temperature*, *insolation*
DataSource_X	Initial source name of data	*Temp_DB*, *Inso_DB*
Type_X	Data format (stored in the initial source)	*CSV*, *TXT*, *JSON*, *SQL*
Address_X	Data source connection link	*URL*, *ODBC*, *LDAP*, *FTP*
Auth_X	User authentification parameters/license	*User/PW*, *License code*
DataSource_Y	Linked/fused data source name	*Weather station*
Method_Y	Fusion method	*Function*
Fus_DB	Fused data storage destination	*ClimateTable*

authentication parameters, expiration of the license period or change of data source environment…), the whole process of linking rules generation has to be redone.

4.2 Data Extraction-Transformation-Loading

The ETL data process explores the central data links catalog for extracting data from sources, then transforming it into the specified format, and finally loading it to the central climatic database. We have three sub-processes: (1) **extraction and** collection of original data from sources based on the central data links catalog; (2) transformation of the collected data according to the fusion methods (low-level fusion); (3) loading of data in the central climate database.

4.3 Building Solar Data

The solar data are estimated using the parameters of the collected climate data (temperature, wind, insolation… etc.). Various models of solar data estimation are introduced in researches [14, 15]. The most commonly used models are grouped into four categories:

- Models based on insolation (Angström 1924).
- Models based on temperature.
- Models based on climatic data.
- Hybrid models based on geographical and climatic data.

4.4 Data Classification

To study the dynamic evolution and variability of the solar irradiation parameter, scientists and researchers mostly need to classify geographical regions into clusters [16] and generate solar maps. Two classification approaches are deployed, and we have the supervised type and the non-supervised. The supervised classification is preceded by a learning stage in order to set rules of classification and clusters specifications, then the objects are assigned into adequate cluster based on the discovered rules.

The unsupervised classification is not preceded by a learning step. It is used when the objects are not labeled or when their membership to a class is not known. The target is to classify these objects based on a similarity criterion between objects and kernels of each class (cluster).

Here, the geographical areas should be classified to climatic classes, and the objects of study are represented by the weather stations. The retained classification

type is the non-supervised method using the hierarchical ascending classification algorithm [17].

The HAC algorithm is based on classes fusion and the setting of a hierarchal clusters (indexed hierarchies) where each class is a result of combination of two sub-level classes using a distance metric (Manhattan, Euclidean) or a similarity index (Jacard, linear correlation coefficient, Sorensen). The classification result is presented by the dendrogram.

In the beginning, each object represents a cluster. The HAC algorithm will classify objects using an iterative loop. At each loop, a new cluster is created by the fusion of two closest clusters obtained previously. The selection criterion of the two closest clusters depends on the used algorithm. The Ward's method is the most used one, and it aggregates the two clusters that reduce least the inter-class inertia.

4.5 Solar Data Mapping

The solar classification results are used to build solar potential maps to facilitate visual analysis for researchers on a temporal basis (daily, monthly, or annual). Also, a global potential and variation maps concerning the repartition of geographical areas into climatic solar clusters are generated based on the chosen climatic parameters.

5 Application

Algeria is considered as a region with a high solar potential (5 billion GWh/year) where the duration of sunshine in the Saharan regions and the high plains can reach 3500 h/year. This important solar deposit will enable to initiate several investment projects for the exploitation of this type of renewable resources and the production of solar energy. However, the Algerian government aims to generate 400 MW of electricity using photovoltaic panels across several regions in the country.

To estimate this solar potential, we have simulated our current approach using two climatic parameters (daily insolation duration and daily average temperature) available in thirty meteorological stations, dispersed over the Algerian territory. This real database covers the period from 1980 to 2010. We have chosen as a classification parameter the global solar irradiation ratio which is given by:

$$\frac{G}{G_0} = a + b \cdot \left(\frac{SS}{SS_0}\right) + c \cdot T_{\text{avg}} \tag{5}$$

where:

- G/G_0 indicates the global solar irradiation factor.
- T_{avg} represents the temperature average.

Fig. 1 First rule of "insolation"

```
{
    "LinkID" : "L001",
    "LinkData" : "Insolation",
    "STOREDin" : "InsoDB.csv",
    "HAVEtype" : "CSV",
    "LOCATEDin" : "//localhost/d$/inso",
    "ACCESSas" : "OPEN",
    "FUSION" : {
        "Exist" : true,
        "FUSIONlist":[
            {
            "FusSource" : "Temperature",
            "FusMethod" : "H/H0(SS,Tavg)",
            "FusTarget" : "SolarTab"
            }
        ]
    }
}
```

– a, b, and c indicate the empirical constants.
– SS/SS_0 represents the insolation fraction defined by the ratio of SS (measured insolation duration*)* by SS_0 (*theoretical insolation duration in clear sky*),

$$SS_0(j) = \left(\frac{2}{15}\right)\text{arc}(\cos) \cdot [-\tan(lat)\tan[23.45\sin(0.98(j+284))]] \quad (6)$$

where j is the day number of measurement and lat is the latitude station.

5.1 Data Source Links Generation

The insolation and temperature measurements are collected from the weather stations in CSV format and consolidated in a central server located at the Algerian meteorological data center. For each weather station, we have a specific and separate CSV file for one parameter (insolation or temperature), hereby the rules for linking the data defined for each parameter at the central level (Figs. 1 and 2).

5.2 Data ETL

To collect the sunshine and temperature data measured in the thirty weather stations, an ETL tool is developed in Python to extract and transform the data from the original CSV files, and by exploring the linking rules, then to load these data into the solar information system database.

Fig. 2 Second rule of "temperature"

```
{
    "LinkID" : "L002",
    "LinkData" : "Temperature",
    "STOREDin" : "TempDB.csv",
    "HAVEtype" : "CSV",
    "LOCATEDin" : "//localhost/d$/temp",
    "ACCESSas" : "OPEN",
    "FUSION" : {
        "Exist" : true,
        "FUSIONlist":[
            {
            "FusSource" : "Insolation",
            "FusMethod" : "H/H0(SS,Tavg)",
            "FusTarget" : "SolarTab"
            }
        ]
    }
}
```

5.3 Solar Data Building

The estimation of the *G/G0* factor (global solar irradiance) is performed on two bases: on a monthly basis and on a global basis. The standard deviation ratio is calculated to refine the solar variation by station.

6 Results and Discussion

6.1 Data Classification

The classification chart of thirteen weather stations is divided at the dissimilarity = 10 k. Therefore, six clusters are resulted representing six climatic regions (Table 2 and Fig. 3).

Table 2 Weather station classification result based on the solar irradiation data [1980–2010]

Clusters	Stations
Class_01	Djanet, Ain Amenas, Tamanrasset
Class_02	In Sahel, Adrar, Beni Abbes, Bechar, Timimoun
Class_03	El Oued, El golea, Ghardaia, Biskra, Touggourt
Class_04	El bayedh, Djelfa, Elkhaiter, Saida
Class_05	Bejaia, Alger, Annaba, Skikda, Setif, B-b-Arreridj, Batna, Msila, Chlef
Class_06	Oran, Benisaf, Tlemcen, Mostaganem

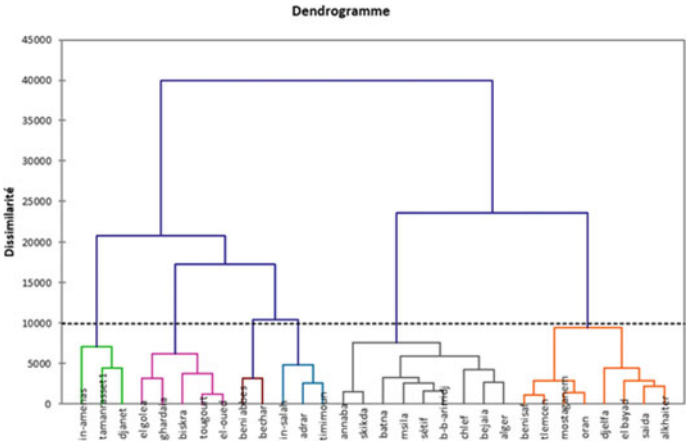
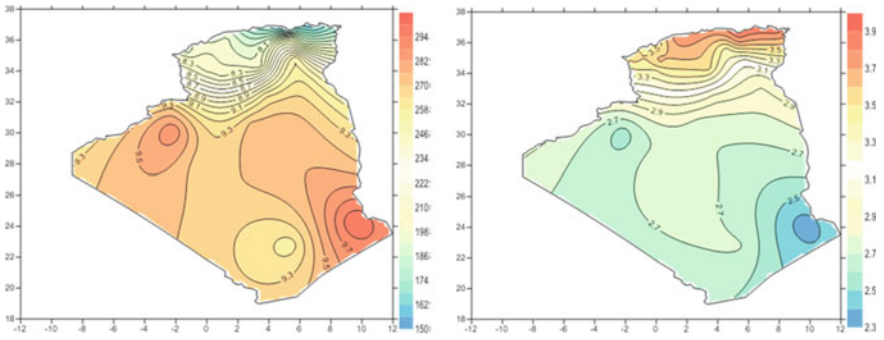


Fig. 3 Dendrogram of parameter "solar irradiation"

6.2 Solar Mapping

Based on the classification results, maps of the solar potential and variability of Algeria were produced using the Surfer® software. A valid distribution of the solar parameter was obtained, since a logical and explicit distribution of clusters with stations having a very close climate was observed (Fig. 4).



a. Solar Potential b. Solar Variability

Fig. 4 Algeria solar mapping results [1980–2010]

7 Conclusion

In this paper, a data fusion approach has been introduced to enable the study of climate variations via the solar irradiance parameter which is estimated based on exploration models of various meteorological parameters extracted from different data sources and consolidated into a solar information system. The fusion method is applied at the data collection level, i.e., by choosing the low-level fusion approach.

This low-level fusion case is supported by the generation of data source linking rules to facilitate the access to data in secure and trusted way. Meanwhile, the central catalog of links must be continuously updated by checking existing data sources connections and exploiting new ones.

Previously, users wasted effort and time in structuration and adaptation of the collected data. With this system, data are automatically extracted, fused, and ready to explore.

This new version of the solar information system with the data fusion process is applied for the study of climate variation for Algerian regions based on the solar irradiation parameter. The results of its application provided logical climate clusters compared to the previous results of the application of the solar information system without data fusion. The quality of the fused climate data is almost improved by reducing gaps, uncertainties, and inaccuracies.

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KALAKA-3 Database Language Classifier Through Convolutional Recurrent Neural Network

Jorge O. Ordoez-Ordoez, Luis F. Guerrero-Vsquez, Paul A. Chasi-Pesantez, David P. Barros-Piedra, and Edwin J. Coronel-González

Abstract During the last few years, the field of automatic speech recognition (ASR) has been growing exponentially, due to the diverse applications and solutions it offers. For this reason, this paper presents a multiclass language classifier based on recurrent convolutional neural networks, whose objective is to classify the audios of the KALAKA-3 database, according to their language. To meet this objective, the mel frequency cepstral coefficients (MFCCs) were extracted from each of the audios in the database, with which the training process is carried out. A recurrent convolutional neural network (CRNN) was created for this process, resulting in an accuracy of 98% using the testing data, and 40% using the Eval data. This work sets a precedent for improving real-time translators, since in the future it would be possible to listen to a few seconds of a conversation, identify it, and automatically perform a translation process, which would be very useful in various applications.

Keywords Artificial intelligence · Neural networks · CRNN · Database · KALAKA-3

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1 Introduction

Automatic speech recognition (ASR) is a discipline of artificial intelligence that aims to recognize by computational means characteristics of speech [1]. The possibility of using automatic systems capable of decoding the human voice has countless applications, among which stand out those of defining phonemes, which is the spoken language, analyzing feelings, knowing who the speaker is, that is, allowing a better interface between human beings and computers [2]. Currently, this discipline is used in a variety of tasks, such as translation of spoken language [3], multilingual speech recognition [4], spoken document retrieval [5], among others.

However, to perform all these tasks, it is necessary to have a database with which to train the neural network. Thus, the database to be used for this work is KALAKA-3 [1]. This database is specifically designed for the development and evaluation of spoken language recognition systems and was created by Rodriguez-Fuentes et al. [6]. It consists of two parts, one for the training process, and one for the evaluation and testing process. The training audios were extracted from television broadcasts, while the audios of the evaluation and testing section were extracted from YouTube videos.

Thus, we present the implementation of a language classifier for the real database KALAKA-3, using recurrent convolutional neural networks. To meet this objective, first, the mel frequency cepstral coefficients (MFCC) of the audios in the database will be obtained, and after that, we will proceed with the creation of the model, and finally, the training of the network will be carried out.

From each of the audios in the database, MFCCs, which are coefficients for speech representation based on human auditory perception, are extracted. That is, they are a representation of the short-term power spectrum of a sound, based on the logarithm of the cosine transform of a bank of triangular filters proportional to the mel scale.

On the other hand, a multiclass classifier is created that allows us to identify the languages, using the MFCCs provided in the previous stage. It is said multiclass because the classifier will separate by means of hyperplanes the number of classes, which in this case will be the number of languages to be classified. This classifier can be modeled in different ways; in this work, it is done through the combination of convolutional neural networks (CNN) and recurrent neural networks (RNN).

It should be noted that the database is divided into training, evaluation, and test sets. Thus, the training set was used for the training and the test set for the classifier test, obtaining as a result a value of accuracy higher than 90% in the training set, and greater than 40% in the test set.

This recurrent convolutional network model was chosen after testing its effectiveness using data from the DEV portfolio and comparing it with other combinations of neural network models, such as multilayer neural networks, deep convolutional neural networks, and deep recurrent networks.

This article is divided as follows. Section 2, presents the methodology used and the problems presented, as well as the manner in which they were solved. In Section 3, the results obtained are presented. Finally, in Sect. 4, the conclusions of this work are shown.

2 Related Works

Currently, there are several works that are related to automatic speech recognition, since this technique, nowadays, is applicable to different experiences that allow a more real human–machine interaction. Thus, in [7], conduct a state-of-the-art study describing the technologies and applications used for multilingual conversational systems.

For its part, in [3], perform a translation of the spoken language. For this purpose, they apply techniques of acoustic model combination, bootstrapping, and adaptation, achieving excellent results and improving with their research the translation systems of several languages, being these some of the first works related to this subject.

In [8], research on language models using deep contextual representations. In [9], encodes words using a stack of transformer encoders, this research uses two self-monitored targets for pre-training. However, in [10] reduce the size of the BERT-type models by parameter partitioning and factorization.

For longer sequences, in [11], learns long-term contextual dependencies through recursion and positional coding, providing a perfect fit for large-scale modelsPlease check the clarity of the sentence 'For longer sequences, in [11], learns long-term …'.. Another research of this type is the one found in [12], where it uses a deep learning neural network to generate and read text and is currently the largest transformer of natural language processing. (NLP), that can accurately and efficiently reproduce the speech and argumentation of human beings.

Another area of research within this topic is devoted to the understanding of spoken language (SLU); in this process, it is about understanding the semantic meanings of human discourses. To perform this task, a set of subtasks such as gap filling, user intent classification, and speech event detection must be accomplished. For example, in [13], employ knowledge transfer to learn the invariant characteristics between some text types.

The aforementioned works are the ones that stand out the most in this research topic, currently, they are among the most used technologies to perform spoken language recognition. However, none of these face the reality as we do in our work, because what we try to do is a language identifier, taking a real database. With our approach, we achieve excellent results. This means that we can decipher what language is being spoken in a given conversation.

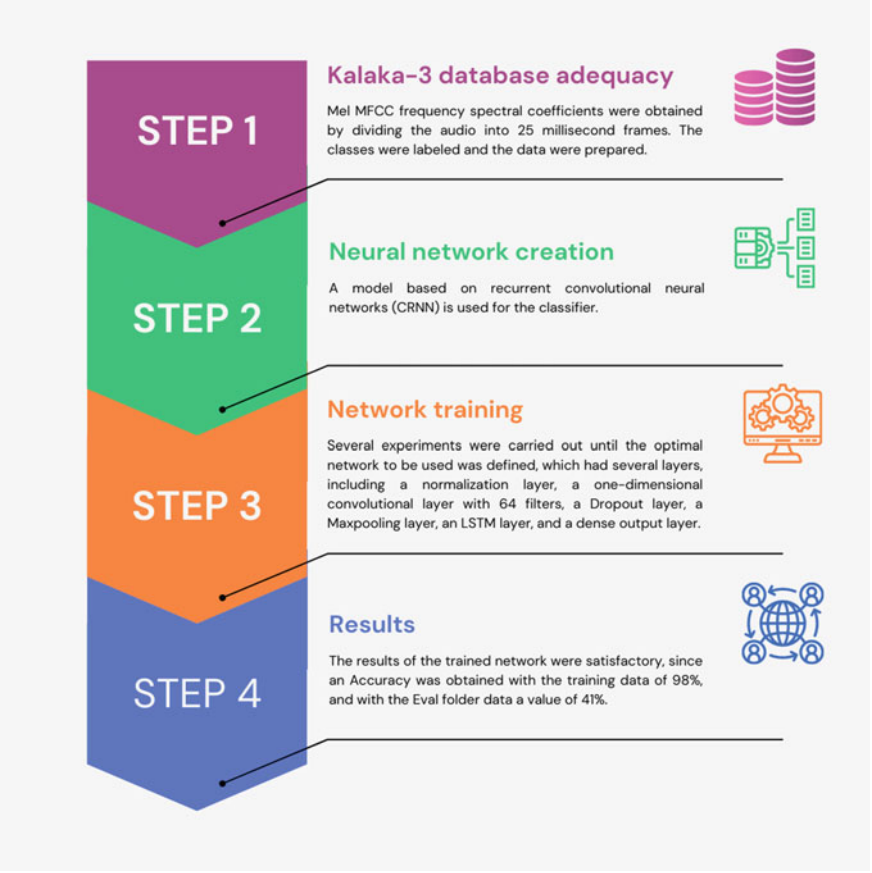

Fig. 1 Process for the language classifier of the KALAKA-3 database

3 Methodology

This section details the methodology used to obtain a multiclass classifier from the KALAKA-3 database. The first thing that was done was to obtain the frequency spectral coefficients mel MFCCs from the audio files, then the data preparation, and the creation of the model. Finally, the training of the network was performed. Each of the stages is shown in Fig. 1.

In the first instance, the MFCCs were obtained by dividing each of the existing audios into frames of 25 milliseconds (ms) with an overlap of 10 ms. That is, each of the audio files was divided into small portions of that size to perform the analysis. The overlapping process is performed to avoid loss of information. Then we proceeded to perform a Hamming window, i.e., to multiply each of these frames by a Hamming window, in order to obtain the greatest amount of energy in the center of the audio

frame. Once the Hamming window was applied, we proceeded to obtain the modulus of the fast Fourier transform, to that value we applied a triangular filter bank which was built using the mel scale as a reference. Finally, the discrete cosine transform was applied, and the first thirteen coefficients of this transform were transformed to the natural logarithm; the rest of the coefficients were discarded. It should be noted that when this method was used, the amount of storage and processing needed was considerable, since each file had to be saved and then move on to the next step. Then it was observed that this method was not feasible due to the amount of time it would take, so a new test was performed, where instead of generating each of the files, they were stored in a matrix for each audio, and at the end, only that matrix was stored. This process significantly reduced the execution time but not the amount of processing required.

In order to verify that the MFCCs obtained are correct, they were compared with those obtained by the HTK software [14]. This utility is an integrated set of software tools for constructing and manipulating continuous densities based on hidden Markov processes (HMMs). After performing the respective comparison, it was observed that the values were different in the first instance. For this reason, it was decided to follow the process used by the HTK software to find the MFCCs. For this purpose, the freely available source code of the program was followed, and the processes that were carried out in different ways were corrected, until the results were almost identical to those of the HTK. Among the processes that were found to be different were the size of the division into frames, the application of the triangular filter bank, the definition of the logarithm of the mel scale, and the definition of the logarithm of the mel scale. Finally, the MFCCs were obtained from the database, which were almost identical to those delivered by the HTK software, maintaining the same value with a precision of two decimal places.

KALAKA-3 database is divided into training, Eval and Dev folders. The MFCCs were obtained from the existing audios in all these folders. However, for the training of the network, only the data from the training folder were used, since they are labeled with their respective class. Two methods were used to prepare the data. The first method consisted of dividing each of the files into groups of equal frames, after which each group was labeled appropriately. The second method took each file considering only the first 5000 vectors of MFCCs and discarded the rest; in the case that there were not enough, a filling with zeros was performed.

Having defined the methods to be used, we proceed to establish that a model based on recurrent convolutional neural networks will be used (CRNN) for the classifier. All the convolutional layers used were of the type CONV1D,. In addition to the vectors that are normally used for signal processing, our vectors were compacted into matrices of dimension mx13, where m is the number of frames considered for training, and 13 are the frequency cepstral coefficients in mel. By arranging them in this way, the matrix works as if they were multiple signals to be convolved separately.

In order to arrive at the final model, several experiments were carried out, as follows.

- The first experiment was performed using a convolutional network of 2 layers, 1 dropout, 1 maxpooling, 1 flatten, and 1 dense; with this model, 59.16% of accuracy was achieved. This experiment was trained with 100×13 arrays where the MFCC files were divided into groups of 100. The experiment was abandoned because it took too long, approximately 14,800 s per epoch.
- For the second experiment, the same model was used, decreasing the number of units per layer, and the size of the input matrices was increased to 625×13; with this change, the result of 72% of accuracy with the Eval folder was obtained.
- In the third experiment, a different model was tested, which consisted of 5 convolutional layers, 2 dropout layers, 1 maxpooling layer, and the learning rate and decay of the Adam optimization function were modified to 0.00001 and 1e−6, respectively. With this model, an accuracy of 32% was obtained. The training time per epoch was approximately 5400 s.
- For the fourth experiment, the model was again divided into 625×13 matrices, and the number of convolutional layers and their size was increased, leaving the model as follows: 4 convolutional layers of 5×5, 1 dropout of 0.1, 1 maxpooling of 2×2, 1 flaten, and 1 dense. The optimizer was changed to rmsprop, and with this model, 86% of accuracy was achieved in the neural network.
- For the fifth experiment, a recurrent model was used with a dense input layer, three hidden layers, two of them dense, one recurrent and one dense output layer. We proceeded to increase the sample sequence from 625 to 2000, changed the optimizer from Adam to rmspropt with a learning rate of 0.0001 and a decay of $1 \times 10^{-}6$. This model, after 4 epochs of training, showed a loss of NAN, so it was discarded.
- For the sixth experiment, we proceeded to perform the training using directly the samples from the WAV files, without using the MFCCs, taking 100,000 samples at a time and using a 3-layer convolutional network. A training accuracy of better than 80% and an evaluation accuracy of better than 34% were obtained.
- Finally, we chose to combine the recurrent networks with the convolutional network obtaining a model with the following layout, 1 normalization layer, 1 convolutional layer with a dimension of 64 filters, 1 dropout layer of 25%, 1 maxpooling layer, 1 LSTM layer, and 1 dense output layer. The Adam optimizer was used again, resulting in a training accuracy of 98% and an evaluation accuracy of 41%.

In this way, the methodology used was presented, and how several variations were carried out in order to obtain classifications with an accuracy higher than 40%.

4 Results

By extracting the MFCCs from the KALAKA-3 database with a program that follows the source code used by the HTK software, results with a similarity of two decimal places were obtained, as shown in Fig. 2.

```
MFCC obtenidos mediante el software HTK
------------------------------------------ Samples: 100->102 -------------------------------------------
100:     0.573  -3.924  -1.851  -2.802  -0.164  -1.802  -1.270   0.061  -0.161  -0.052  -1.611   0.162  85.222
101:     1.461  -3.792  -1.896  -3.377  -0.437  -2.060  -1.745  -0.322   0.045   0.026  -1.614   0.103  84.702
102:     2.599  -2.135  -0.876  -2.708   0.186  -1.506  -1.684  -0.186   0.294  -0.206  -1.707  -0.166  81.258
------------------------------------------------- END --------------------------------------------------

MFCC obtenidos mediante el software de nuestra autoria.

------------------------------------------------------------------ Samples: 100->102 -------------------------------------------------------------------
100: 0.586197 -3.9214785 -1.8458629 -2.804251 -0.1624930 -1.7947574 -1.2750516  0.05873610 -0.16391477 -0.04942530 -1.6138884  0.13945024 85.223862
101: 1.473697 -3.7870855 -1.8921245 -3.384839 -0.4373159 -2.0502677 -1.7490541 -0.32806376  0.03693949  0.02659088 -1.6183136  0.08387991 84.703278
102: 2.606548 -2.1277332 -0.8661530 -2.706193  0.1878163 -1.4952933 -1.6879025 -0.19114734  0.29142666 -0.19761518 -1.7105836 -0.18294518 81.255455
------------------------------------------------------------------- END --------------------------------------------------------------------
```

Fig. 2 Similarity between the MFCCs obtained by HTK and by the software created

```
import os
import sys
import random
import numpy as np
from keras.models import Sequential,load_model
from keras.layers import Dense,Flatten,MaxPooling1D,Dropout,Conv1D,LSTM, BatchNormalization
from keras.callbacks import ModelCheckpoint, CSVLogger
from keras.optimizers import rmsprop

def mkmodel():
    model = Sequential()
    model.add( BatchNormalization( input_shape=(SAMPLES_PER_BLOCK,13)  ) )
    model.add(Conv1D(64, kernel_size=5, activation='relu',padding='valid' ))
    model.add(Dropout(0.25))
    model.add( MaxPooling1D(4) )
    model.add( LSTM(70) )
    model.add (Dense(6, activation='sigmoid') )

    model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])
    print(model.summary())
    return model

model = mkmodel()
```

Fig. 3 Recurrent convolutional neural network model created for the classifier

By treating the matrix of MFCC coefficients obtained from each of the audios as a multicomponent signal, it was possible to take advantage of the potential of recurrent convolutional neural networks. In Fig. 3, the model created in Python to perform the training of the network is observed.

With the model shown, we proceeded to perform the training phase of the network; this phase was very delayed because the amount of audios contained in the database used is quite large and therefore required machines with high processing capacity. For all the work involving multilayer and convolutional neural networks, an AMD R9 280X card was used to speed up the process, which considerably helped performance during training. However, once we tried to use recurrent neural networks, the Keras backend used does not support this type of networks, so it was necessary to perform the training using only CPUs. At the end of the training phase, the accuracy with the training data was 98%, and with the data from the Eval folder, it was 41%.

5 Conclusions

In this work, a multiclass language classifier was implemented for the KALAKA-3 database using recurrent convolutional neural networks. The input data for the training of the network were the MFCCs obtained from each of the audios in the database.

A recurrent convolutional neural network was used since, after testing multiple alternatives, the highest level of accuracy was achieved using this type of model. It is possible that the improvement in performance is due to the combination of the features of the convolutional layer and the recurrent layer, allowing the convolutional layer to obtain more features from the signals, and the recurrent layer to better process time-sequential data such as an audio signal, or in this case their MFCCs which are a form of spectrogram and can be interpreted as multiple one-dimensional signals correlated to each other.

It is important to use parallel processing in future tests to see if the training provides better results. However, with the values obtained, it can be defined that the expected language classifier was achieved. With our proposal, we conclude that we significantly improve the processes to make a real-time translator, since we could automatically know what language is being spoken, just by listening to a minimum amount of audios. This will make life easier for meeting translations, travel, tourism, and other activities.

Future work is expected to use the classifier to apply it to an online language translator, i.e., when listening to an audio file, it can determine what language it is and thus be able to translate it into the required language.

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Energy-Aware Contention-Addressing Algorithm in WLAN Wake-Up-Based Radio Network Uplink

Suleiman Zubair, Bala Alhaji Salihu, Michael David, Abdulkadir Abdulbaki Olayinka, Michael Tunde Dare, and Wali Momoh Zubair

Abstract The increased relevance of WLAN in upcoming wireless technology has made the efficient design of WLAN medium access control an open issue of concern especially in terms of energy. Energy efficiency primarily focuses on carrier sensing, false wake-ups, collision, and number of contention rounds. Research has proposed the use of low-power wake-up radio to perform carrier sensing operation which has the potential of making WLAN to have more energy and time for data transfer. However, the reduction of false wake-up and collision is still areas that consume node energy if not properly designed especially when contending stations are much. This work proposes an IEEE 802.11 wake-up radio algorithm for uplink that employs a hybrid contention-addressing to enhance energy in WLANs. Unlike other methods, the algorithm makes use of a distributed contention strategy to determine which station can wake up for data communication. Contention rounds are used to determine and queue up a set of stations chosen to transmit data. The algorithm greatly reduces false wake-ups which arise from delay between sleep and wake-up, by broadcasting the ACK frame after modulating the frame with a wake-up message (WuM), piggybacking the address of the next station to transmit. Simulation results show that the HCA–CSAM/CA algorithm is able to reduce energy overhead by 97%, which translates to 60 h increase in battery lifetime and 68.3% reduction in latency as compared with ESOC.

Keywords Wake-up radio · Medium access control · Network uplink · IEEE 802.11

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1 Introduction

Typically, the contention-based IEEE 802.11 algorithm grants channel access to the lone station that wins contention, while others that failed all wait for another session of contention before they can attempt data transfer [1–3]. The downfall of this strategy (especially in large networks) is longer waiting periods and possible loss of buffered data. In addition, extended latency period between "sleep" of a station in a previous transmission and the "wake-up" of the next station (STA) has also been identified as an issue [2].

This work focuses on contention-based IEEE 802.11-enabled wake-up radio (WuR) algorithm. Using both addressing and contention techniques, there is the need of an algorithm which is effective in mitigating energy consumption of a wake-up radio-based IEEE 802.11 WLAN. The proposed algorithm enhances energy efficiency of the WLAN stations and as well increases the wireless LAN battery lifetime. This in turn reduces data latency while ensuring that bandwidth is not reduced and increases the number of connected devices. Obtained results from the developed hybrid contention-addressing (HCA-CSMA/CA) protocol were compared with that of WuR-ESOC [2].

After this introduction, a detailed literature review of relevant issues on the design is presented in Sect. 2. Methodology adopted in the design of the algorithm is presented in Sect. 3. In Sect. 4, results are discussed, and the article is concluded in Sect. 5.

2 Literature Review

In order to save energy, duty cycling technique depicted in Fig. 1 was developed [4, 5] allowing WLAN modules that only wake up for data communication; otherwise, it remains in the sleep mode [4].

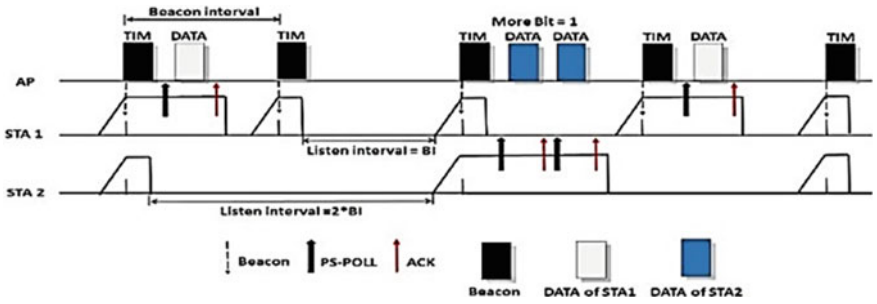


Fig. 1 Legacy power save mode (PSM)

Traditional duty cycling which is used for power saving in stations is composed of four (4) components which include: power save mode (PSM), Target Wake Time (TWT) mode, Transmission Opportunity Power Save Mode (TXOP PSM), Power Save Multi-poll (PSMP) mechanism, and the Automatic Power Save Delivery (APSD) [4, 6].

With IoT in focus, to increase energy efficiency of devices, the wake-up frontend developed by the task group on IEEE 802.11ba standard was designed as a low-power radio. This takes off the burden of uninterrupted channel sensing from the WLAN module, which translates to energy saving. Our detailed review on this topic can be found in [7].

In a bid to eliminate hardware modification in the module, a WuR system was proposed [8] to enable any IEEE 802.11-enabled device to act as a WuR transmitter via the subcarrier On–Off-keying (OOK) modulation scheme. As shown in Fig. 2, this causes a high-frequency 2.4 GHz WLAN signal to emulate the low-frequency 15 kHz wake-up signal. Another work [3] used idea of varying frame lengths of WLAN signals to transmit wake-up IDs.

In order to decrease collision probability in contention-based protocols, the contention window method is used for scheduling channel access. Improved network throughput has been recorded via dynamic adjustment of contention window [9, 10]. In [3], energy efficiency was enhanced by adjusting contention window using the WuR. Duty time for every packet was reduced by this. In the work, channel contention is initiated through inter-frame space measurement.

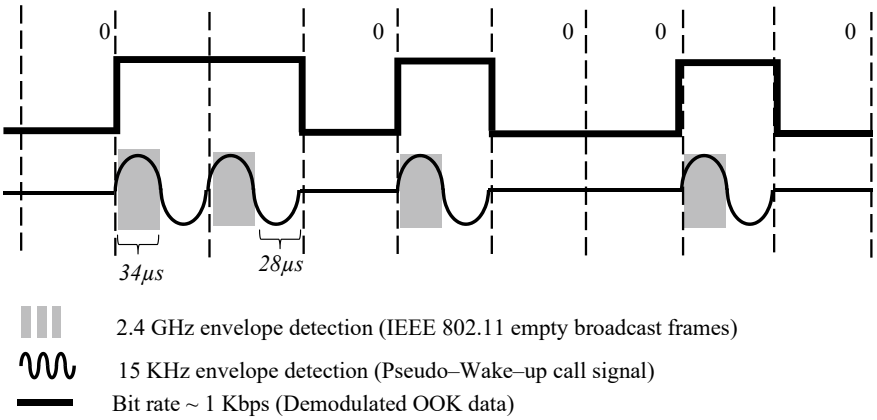


Fig. 2 On–Off-keying scheme (modulation)

3 The Hybrid Contention-Addressing Algorithm

The **Hybrid Contention-Addressing Algorithm for Energy Efficiency in WLAN Waku-Up-Based Radio Network Uplink (HCA-CSMA/CA)** which allows WLAN users to reduce power consumption is proposed. **HCA-CSMA/CA** maximizes power management by making use of the low-powered WuR for both carrier sense and control. Contention window (CW) is maintained constant, while the WLAN transceiver is used only for data communication. The algorithm is made up of the contention and addressing stages as shown in Fig. 3.

3.1 The HCA-CSMA/CA Procedure

1. At the initialization stage, the size of the contention window is set to a value of CW = w by the AP. For this work, CW values of 5, 10, 20, 50, 100, 200, 500, 370, 800, and 100 STAs were considered.
2. For every uplink session, the AP is only allowed to obtain a number of stations w from the stations in the cluster N. In order to obtain these w stations, backoff values (BO) are randomly selected by WLAN modules of STAs. Also set their WuR counter values to BO = i values which are one of the contention windows (where *i* is between 0 and w). This is illustrated in Fig. 4. The WLAN module is only woken up by WuR when its count becomes zero. After then, the data transmission takes place.
3. Since AP is modeled to accommodate a maximum of w STAs per session, only the w of N STAs is allowed to set their BO values to a value between 1 and w. During this period, the backoff counters of the unselected STAs remain idle.
4. When channel is sensed idle for DIFS value (TDIFS = 36 μs or 4TSLOT. where TSLOT = 9 μs), the contending STAs start decreasing their counters from BO = *i* to zero.
5. All selected w STAs are expected to perform two actions; first, counter decrement and secondly, wake-up. As depicted in Fig. 5, this action synchronizes their successive transmission of their RTS packets. Meanwhile, AP listens to STAs within SIFS before the next action is initiated.

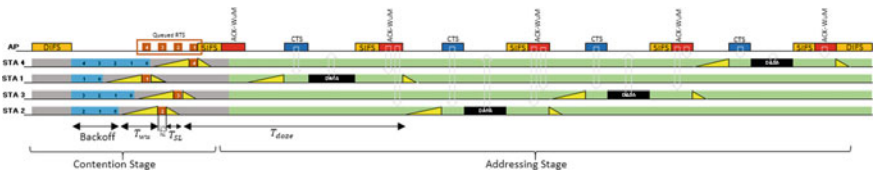


Fig. 3 Proposed HCA-CSMA/CA algorithm

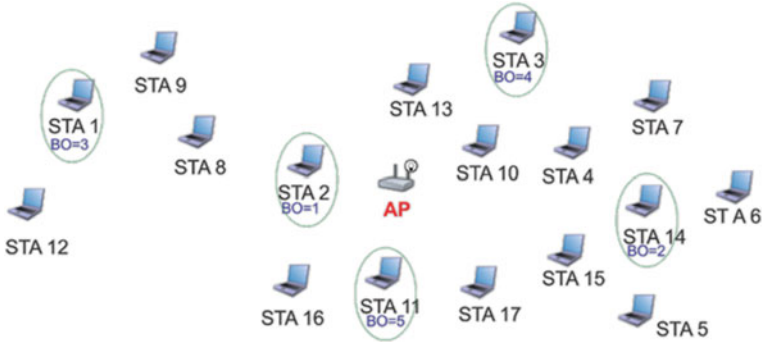


Fig. 4 Basic service area (BSA)

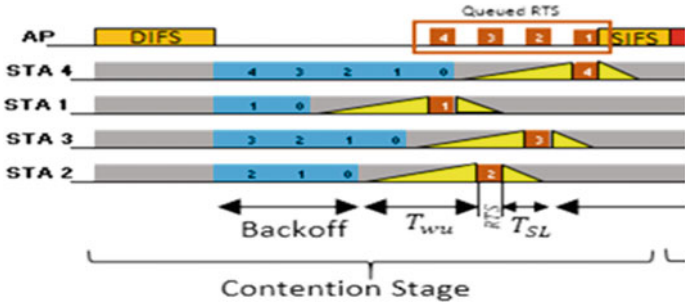


Fig. 5 Illustration of uplink transmissions at contention stage

6. Stations forfeit the opportunity to transmit RTS in an active session after it experiences collision during the active session. It can only try transmission after a fresh contention and selection session.
7. In order to prevent degradation of throughput because of excessive contention window when the network is idle [11, 12], contention windows are only modifiable before the initiation of the session of fetch. This will however be in accordance with the prevailing network condition and traffic.
8. After queuing the successfully received RTS packets, AP uses the collected addresses from the RTSs sent by STAs to sequentially address a CTS packets to the STAs.
9. As depicted in Fig. 6, addressing stage commences. After AP confirms zero channel activity within SIFS, AP addresses a WuM to STA number 1 on the queue. This is possible because of the previously harvested addresses it had from RTS packets sent in the contention stage. AP then observers a wait time of T_{wu} before sending CTS.
10. STA1 wakes up its WLAN module with duration T_{wu} of receiving WuM. It receives the CTS and then afterward transmits its data packet.

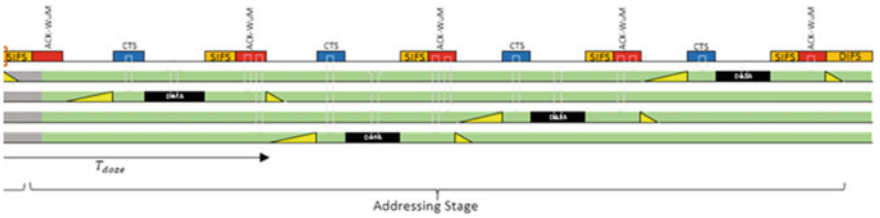


Fig. 6 Illustrating the addressing phase for four stations

11. An acknowledgment wake-up message (ACK-WuM) frame is broadcasted once AP senses the channel idle for a complete SIFS after successfully receiving STA1's packet. This signifies a successful transmission of the packet. The address of the active station is also stated in this broadcast.
12. This ACK also serves as a WuM for the next station on queue (STA2). This is possible, because ACK-WuM frame is OOK modulated with WuM.
13. This ACK-WuM OOK modulated technique creates a sleep/wake-up overlap between two succeeding stations (in this case, STA1 and STA2). This is a major factor that reduces overall network latency when added up.
14. The ACK-WuM frame a STA sends to indicate successful data transfer is also used to initiate data transfer permission for the next STA on the queue. This process continues until all previously fetched STAs complete packet sending. The next contention cycle is initiated for another w set of selected STAs. The HCA-CSMA/CA flowchart is depicted in Fig. 7.

3.2 Simulation Setup Analysis

Using MATLAB simulation platform, the energy expended by HCA-CSMA/CA is studied for both contention and addressing phases. The WLAN modules possess wake-up latency (T_{wu}), and WLAN radio cannot communicate during this period, but however consumes power. The considered WLAN for this work consists an AP, N stations. Contention window was set varying values of CW = w. Considering the work in [13], it takes about 139 μs to switch from 1/4th clock rate to full clock rate and about 200 μs to generate a stable carrier frequency. Hence in this work, latency for wake-up is computed as $T_{wu} = N_{wu} \cdot T_{wu}$, and this equals to 200 μs. This is derived by considering number of slots required for a complete WLAN module wake-up as $N_{wu} = 22$ while considering a slot duration as $T_{\text{slot}} = 9\ \mu s$.

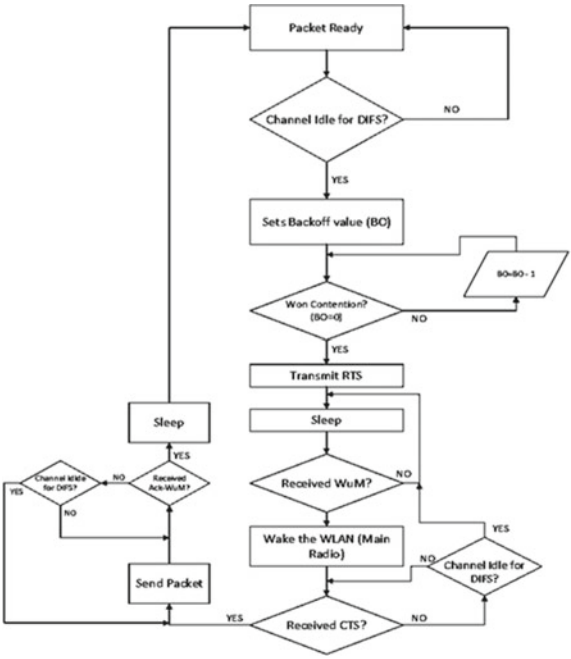


Fig. 7 HCA-CSMA/CA algorithm flowchart

4 Discussion of Results

The results were compared with CSMA/ESOC. The results were generated by from the parameters in simulation setup into the developed model. Performance of HCA-CSMA/CA was aimed to evaluate energy consumption, channel efficiency, and lifetime. The results for CSMA/ESOC were studied and compared with the results of HCA-CSMA/CA.

4.1 Energy Consumption and Lifetime

Total energy consumed by the STA's frontend (which comprises the main radio and WuR) is plotted in Fig. 8 against the contention window for both algorithms. When compared with ESOC, HCA offers a 97% reduction in maximum energy cost. The energy utilization increases with the increase in contention window. More significantly, unnecessary period spent before stations send packets which is a characteristic of ESOC and similar protocols is responsible for the increase in energy cost. In the process, WuR does channel sensing which costs energy. At contention phase, energy cost consumed for RTS packet transmission and doze accounts for 30% of the overall energy consumed at the main radio. This is 23% of the total energy consumed by a STA on data packet transmission. About 77% of the total energy consumed is spent

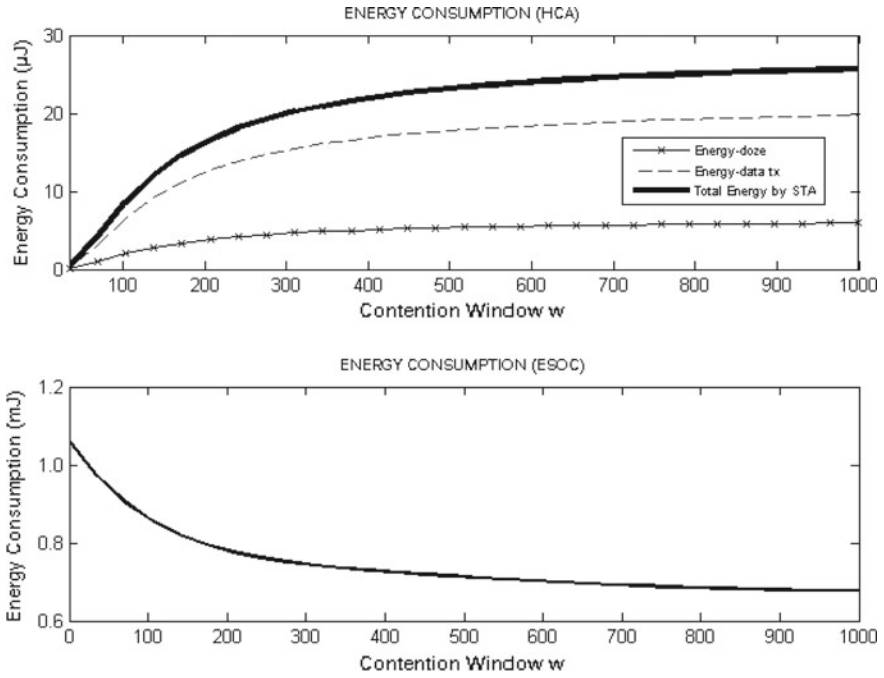


Fig. 8 Total energy consumption by STA

by stations for packet transmission. Thus, the minimal use of energy shows that energy is prudently utilized.

The improvement exhibited by HCA-CSMA/CA on energy consumption over traditional techniques is primarily due to the fact that false wake-up probability has been greatly reduced and the fact that STAs spend more time awaiting the reception of WuM packet.

The time duration over which a 3.8 V, 4000 mWh rated battery is expected to fully discharge, also referred to as the "lifetime", is plotted against the power consumption in Fig. 9(ii). As deduced from Fig. 9(i) and (ii), a maximum power consumption of 190.9 mW for a contention window of 1000 will result in a battery life of 79.62 h (3.3175 days). At lower contention window of 102, the battery life is extended to 206.9 h (8.62 days) due to the reduced power consumption resulting from lower STA fetch size which translates to reduction in energy for processing their transmission. The lowest battery lifetime of the HCA exceeds the peak for the ESOC by approximately 60 h (2.5 days) due to the reduced probability of false wake-up and longer time spent in sleep mode by the WLAN module.

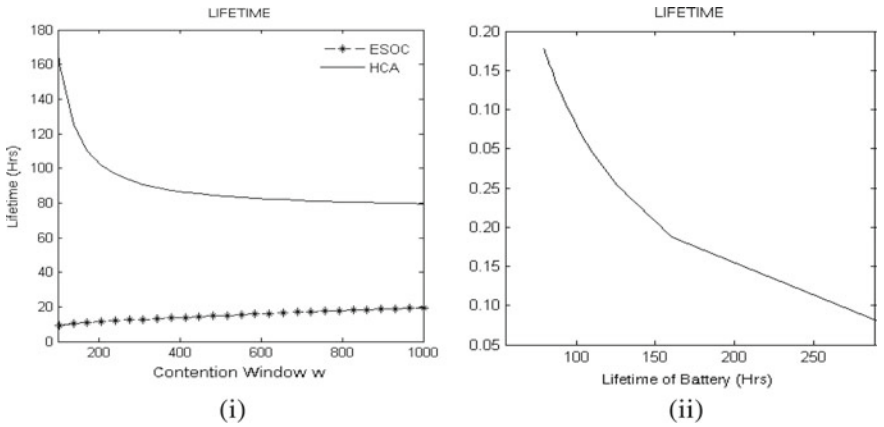
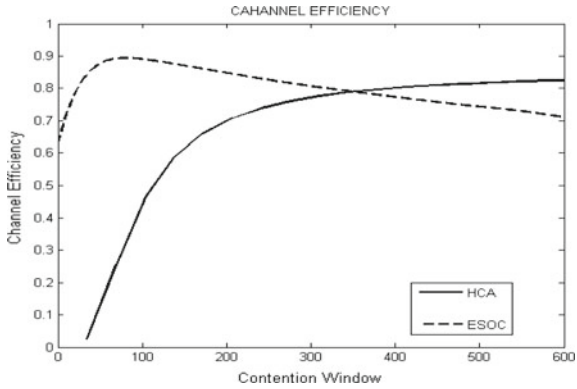


Fig. 9 i. Lifetime versus contention window ii. Power consumption versus lifetime

4.2 Channel Efficiency

Figure 10 shows that the channel usage with respect to average time for data transmission (T_{avr}) increases with contention window size. At 1000 value for contention window, 83.86% channel efficiency is achieved. The time spent for queuing RTS packets and addressing the unsensed CTS on the channel is responsible for the 6.14% reduction of channel efficiency with respect to ESOC.

Fig. 10 Graph of channel efficiency



5 Conclusion

This paper presents how energy consumption of IEEE 802.11 WLAN can be greatly reduced by HCA-CSMA/CA. Ideal channel conditions and finite contention window value were considered in this model. Simulation results prove the efficiency of the algorithm in conserving energy. The CSMA/ESOC offers a 97% maximum energy consumption over the ESOC and the peak theoretical battery lifetime exceeds that of ESOC by approximately 60hrs.

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Work in Progress: River Water Collection System Using Embedded Systems for the Analysis of Basic Characteristics in Real Time

Jean P. Mata-Quevedo, Ricardo Romero-Gonzalez, Sebastian Quevedo-Sacoto, Sandro Gonzalez-Gonzalez, and Luis Serpa-Andrade

Abstract Due to the importance of the treatment and care of water, there are projects around the world that help to have a better control over the quality of the water that help as a basis for proper treatment. This system is proposed after a literature review with the intention of obtaining data from different water characteristics such as: pH, conductivity, turbulence, temperature, and dissolved oxygen, it is intended to obtain the data for later consultation through a mobile application or PC. This system consists of three stages: the first one consists of data collection through sensors to a microprocessor; the second part involves a LoRa wireless network for data transmission; and the third one in which the data is presented in a mobile application.

Keywords Water treatment · Learning · Embedded systems

1 Introduction

Fresh water is the vital liquid for human health and essential to keep ecosystems in balance and in turn to be able to supply food for daily consumption. According to [1] approximately 2.5% of the Earth's total fresh water is fresh and of this a large amount is not within our reach and even worse the little resource that is available to

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us is affected by population growth, and this implies that urban areas represent the greatest threat to water resources.

Rivers constitute a system in balance of physical, chemical, and biological characteristics necessary for animals and plants that subsist on it. The quality of the water in a river depends on the nature and concentration of the substances that may be present; some are of natural origin, as a result of the path taken by the river in its hydrological cycle; but others are introduced by man when using the receiving body as the ideal place to dump waste of all kinds; thus, pollution comes from human activities, and favors decomposition processes, generating undesirable products, some of which are volatile [2, 3].

2 Bibliographic Review

In order to support and focus the present proposal, a review of works related to the subject is carried out to adopt ideas and characteristics that are useful in addition to understanding the approach and current development of similar systems.

According to Juan et al., the factors that predominate in the quality of a surface flowing river and that should be analyzed before determining river pollution are: conductivity, TDS, salinity, pH, temperature, dissolved oxygen, turbidity, among others.

A work done by Rodrigo Herrera in [4], shows the process to be performed for the measurement of each of the variables involved in determining the water quality of a river, giving predetermined steps for sampling, sampling points, frequency, periodicity, and laboratory tests [4]. In the case of Badillo in [2], they show a mechanism for real-time monitoring of hydrometric and water quality data, which has temperature level and pH as fundamental sensing variables. The equipment designed has a renewable energy system through solar panels, in addition to a data storage system [2].

In Mexico, there is currently a project called "Plan for real-time monitoring of river pollution," [3] which aims to create a pilot system for real-time monitoring of water quality. Its fundamental basis is to obtain the chemical reality of the rivers and the changes in their variables and the times when the highest peaks of impurities occur. Some of the results obtained in previous studies have detected the presence of metals such as lead, mercury, aluminum, among others in Mexican rivers. A situation that exceeds fifty chemical elements threaten the quality of river water [3].

Monitoring is essential to be able to manage systems, prototypes, and thus record information of all kinds in a safe, reliable, and efficient way. Therefore, it is convenient to advance in automated processes that help to this end, from low-cost systems.

The general problem of a river leads to carry out a study coupled to its reality that allows to know the reality in which the water quality is, and thus to obtain results that are publishable and somehow lead to immediate action by the authorities in charge of managing its care.

The monitoring of water quality is mostly controlled manually that, although they are favorable results, a system can be optimized to obtain data in an automated way and in real time, features that allow better use of time and resources when performing such control, this can be evidenced in "Monitoring water quality in rural drinking water system" where the authors propose a system for collecting data from sensors in an Arduino Uno to link it to a Raspberry Pi4 that through node network upload the data to the cloud to monitor them in real time [5] (Figs. 1 and 2).

This system presents good expectations due to its low cost in reference to similar commercial technologies and its scalability since it allows adding new sensors and alarm functions as required by the user [5].

With the aim of introducing technology in the world of natural sciences in 2014, Cristhiam Mora and Alvaro Santa in Pereira designed a system called "Living Machine," which consists of 3 sensors to monitor in real-time physicochemical variables of a wastewater system from a computer that is commanded from a GUI graphical environment and linked to the prototype through a wireless communication protocol ZigBee [6]. The prototype has been designed by Cristhiam Mora and Álvaro Santa in Pereira.

At the University of the Republic in Uruguay, the engineering faculty materialized the SDHS project: Soil Moisture Sensor, which consists of a network of wireless sensors that are made up of MOTEs. These devices function as autonomous nodes, which are necessary to generate a mesh network that allows intercommunication and connection with external devices wirelessly. These devices work as

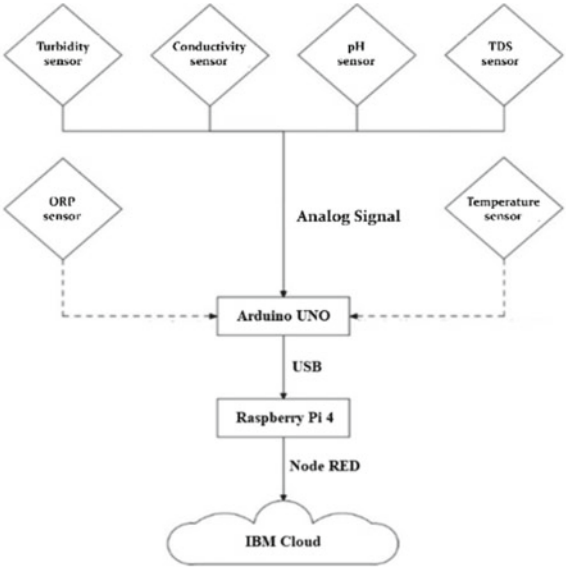

Fig. 1 Process diagram

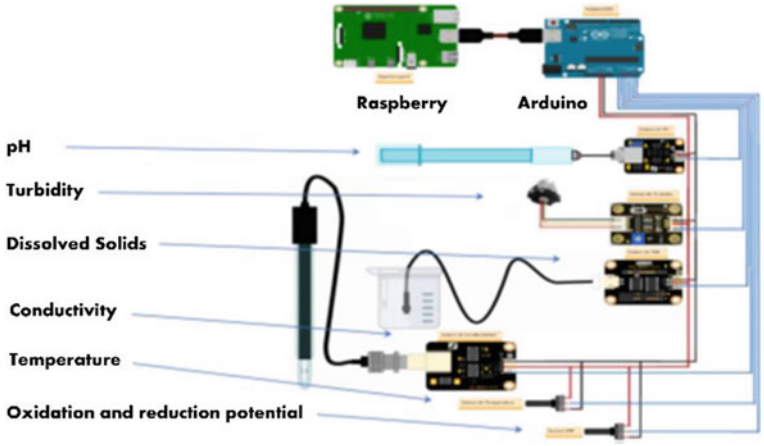

Fig. 2 Wiring diagram

autonomous nodes, which are necessary to generate a mesh network that allows intercommunication and connection with external devices wirelessly [7].

In Cuenca Ecuador, the implementation of a prototype Monitoring Station (MS) for the analysis of environmental variables is proposed, developed using an Arduino Mega 2560 development board linked to the Thinger.io software through an A7 GSM module for the visualization of the data collected in real time [8] (Fig. 3).

In Tarapoto-Peru, a sensor network was generated to monitor in real time the different water characteristics in tilapia fry ponds, using an Arduino Mega development board that receives the data from the different linked sensors, which in turn sends this data using an Ethernet Shield to a computer, in addition to sending text message alerts in case the variables go out of the normal range by means of a GSM module [9] (Fig. 4).

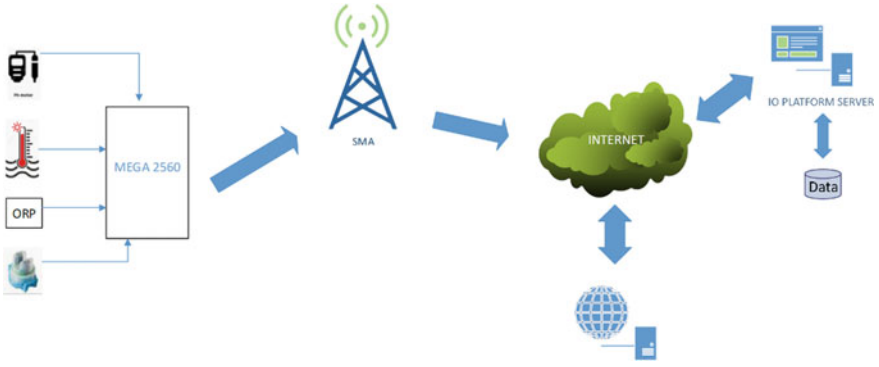

Fig. 3 General scheme

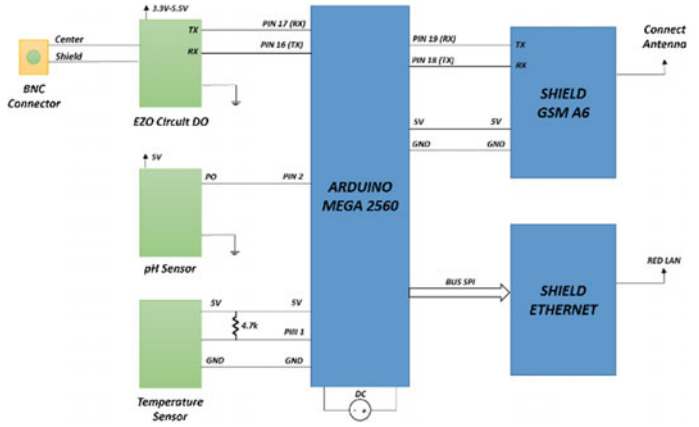

Fig. 4 General scheme

A low-cost system for Real Time Water Quality Monitoring and Controlling using IoT" measures temperature, turbidity, conductivity, pH, and water flow. Using as a central processor a development board ESP32 that has included the peripheral for wifi connection to transfer the data collected by each of its sensors to a cloud on the internet so that from a mobile application can be monitored [10] (Fig. 5).

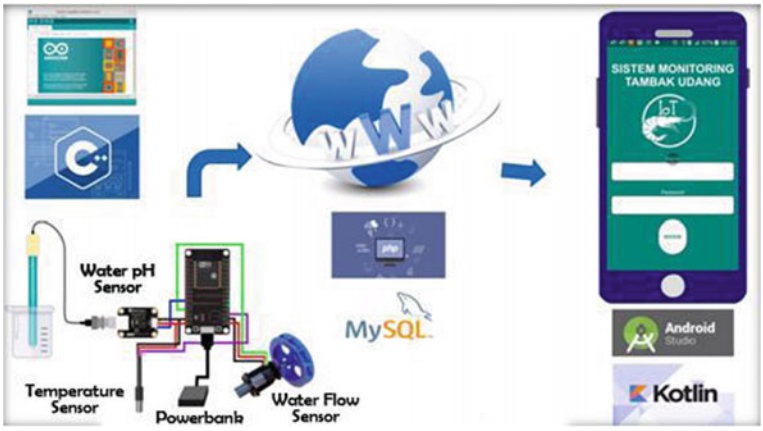

Fig. 5 General scheme

3 Proposal

The characteristics of water in rivers are relevant for the study and treatment thereof. That is why, based on the literature review and considering neglected needs, a prototype is proposed to collect different characteristics of water such as:

- pH
- Electrical conductivity
- Turbidity
- Temperature
- Dissolved oxygen.

Characteristics will be measured by their respective sensors and processed on a development board to be transmitted via wireless connection to a database.

The prototype proposed below consists of 3 stages (Fig. 6):

- Stage 1: This stage consists of 5 different sensors whose signals are received by an Arduino Mega development board, where each of these is processed and normalized to have a value that can be interpreted by an operator.
- Stage 2: Once the values have been normalized and sorted, they go to stage 2, where, thanks to a long-range wireless connection created with LoRa wireless technology, the data is transmitted from a transmitter located in the plant where the sensors are being measured to the receiver, which is located approximately 5 km away.
- Stage 3: In this stage, the receiver that has the data sent from the plant uploads it to the database in the cloud so that it can be consulted in real time by an operator.

The proposed system allows the measurement of different data and their review in real time, as well as the issuance of an alert message in conditions that are not

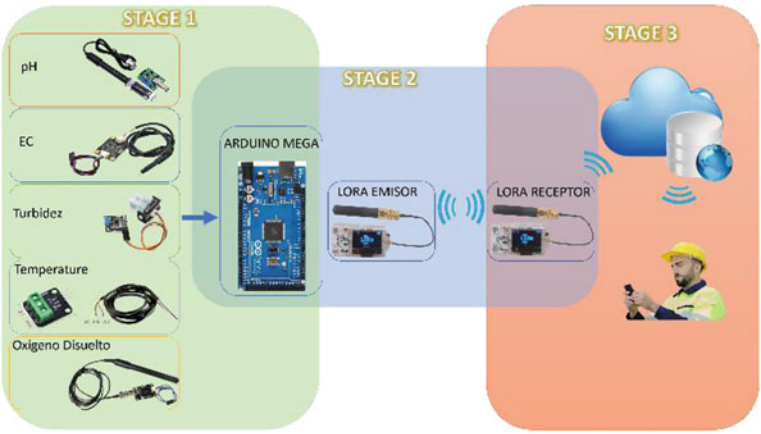

Fig. 6 General outline of the proposal

adequate in any of the measured characteristics and in turn to keep a record of each of the entire process in a database in the cloud thanks to a freely accessible application so that they can be consulted in the posterity as required.

4 Conclusions

According to the bibliographic review, it was possible to appreciate the motivation and effort dedicated to each one of the projects, of which for the present proposal some essential characteristics of several of them have been considered, adapting them to our own needs and trying to improve both the physical and the logical part of the systems.

This type of system is proposed as a solution to the manual measurement that is performed in the local environment, this leads to the optimization of time and effort that is usually made at the time of moving to the places to make such measurements and take a manual control of the data obtained.

This device is designed to work in a local river, but has the particularity that thanks to the proposed sensors it can be used in different environments such as lakes, lagoons, tributaries, ponds, etc., thanks to the water collection mechanism for its analysis.

As a negative point of the proposed system is the power supply of the plant, since at the moment it is intended to use an electrical point both in the plant for the sensors, as well as in the receiving plate of the data, to solve this disadvantage in later versions it is planned to implement a renewable energy system with solar panels and battery banks thus removing the limitation of the place to be analyzed.

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Technological Solutions for Collecting, Analyzing, and Visualizing Traffic Accidents: A Mapping Review

Adrian Peralta, Hector Zatarain-Aceves, and Karina Caro

Abstract Traffic accidents are the reason that approximately 1.3 million lives are lost worldwide. In addition, between 20 and 50 million people suffer injuries from traffic accidents, which could cause some disability to the people involved. Furthermore, these injuries can cause significant economic losses for the people involved, their families, and the country where the accident occurs. In Mexico, in 2020, traffic accidents occupied the ninth cause of death. Delayed prehospital attention to this type of collision increases the severity of the injuries since sometimes these injuries can be of high impact on the person, and in minutes, they can cause death if they are not treated on time. This paper presents a mapping review to identify which works have been designed and developed with technological systems to support the prevention of traffic accidents. This review was conducted in three main phases: (1) planning, (2) execution, and (3) reporting. In the planning phase, we defined the research questions, the keywords, the search query, and the inclusion and exclusion criteria. In the execution phase, we executed the search query, downloaded and stored the results, and selected the articles based on the inclusion and exclusion criteria. We also defined several selection criteria for filtering the results. As a result, the different areas of opportunity that exist with the development of technology for collecting, analyzing, and visualizing traffic accident data are discussed.

Keywords Traffic accidents · Mapping review · Technological systems

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1 Introduction

The World Health Organization (WHO) estimates that approximately 1.3 million lives are lost due to traffic accidents worldwide. Between 20 and 50 million people suffer injuries that sometimes cause some disability to the people involved. Therefore, this cause of accidents has become an important problem in the health sector worldwide. Injuries induced by traffic accidents can cause significant economic losses, both for the people involved and for the country where the accident occurs, costing about 3% of their gross domestic product in most countries. Delayed prehospital care for traffic accidents increases the severity of the injuries since sometimes these injuries can have a high impact on the person and, within minutes, can cause death if they are not treated on time [23].

There are different risk factors concerning traffic accidents. Driver, road infrastructure, and mode of transportation often categorize these factors. Some examples of these factors are driving at excessive speed, driving under the influence of narcotic substances, not using seat belts, among others [10].

In the last years, the WHO recommended increasing the capacity for collecting data related to traffic incidents through practical and effective systems. In this way, being able to count on data and analyze information adequately becomes essential for improving the conditions in which society mobilizes [23].

In Mexico, during the year 2020, traffic accidents occupy the ninth cause of death. Therefore, the Technical Secretariat of the National Council for Accident Prevention (STCONAPRA, by its acronym in Spanish: Secretariado Técnico del Consejo Nacional para la Prevención de Accidentes), aims to create and implement strategies and actions to reduce morbidity and mortality by injuries caused by accidents [7]. Agencies such as the Ministry of Health and the State Attorney General's Office want to identify behavior patterns, allowing them to reduce and act promptly on these incidents [10].

Most of the traffic accident data collected in Mexico are stored in databases. Unfortunately, these data are not analyzed or visualized. Instead, the data is simply stored without being used for further analysis. Additionally, each Mexican instance has its collecting system, which is a problem since data duplication, loss, and erroneous captures sometimes occur. With the current technologies, these data can be collected, processed, analyzed, and visualized, with the ultimate goal of predicting and preventing traffic accidents. In this sense, this paper presents a mapping review that investigates the technological solutions in the literature regarding traffic accident data collection, analysis, and visualization.

2 Background

2.1 Groups and Risk Factors Related to Traffic Accidents

The WHO categorizes the main risk groups regarding traffic accidents into three groups: depending on *socioeconomic situation*, *age*, and *sex* [23].

- *Socioeconomic status*: More than 90% of deaths caused by traffic accidents occur in low- and middle-income countries. Africa holds the record for the highest death rates.
- *Age*: Traffic accidents injuries are the main cause of mortality among children aged 5 and young people aged 29.
- *Sex*: Most of the people involved in traffic accidents are men. Approximately, 73% of all deaths are in men between the ages of 22 and 25.

In Mexico, pedestrian users are the ones who concentrate the highest percentage of deaths, due to runovers, followed by the drivers of motorized vehicles, and then cyclists [18]. On the other hand, different risk factors can cause a traffic accident, among which we can highlight; the driver, the road infrastructure, and the transport vehicle. The characteristics by which most traffic accidents occur, according to data from the National Institute of Statistics and Geography (INEGI) and the WHO, are: exceeding speed limits, driving while intoxicated or using drugs, not wearing a seat belt, not complying with traffic regulations, and the road infrastructure is not in optimal conditions [2].

Finally, in Mexico, in 2020, of the total of 32,334 accidents, 43.4% were traffic accidents, equivalent to 14,021 cases. The main states with the highest incidence are: Sinaloa, Zacatecas, Baja California, Nayarit, Chihuahua, and Sonora [10].

2.2 Prevention Measures in Traffic Accidents

The governments of each country must adopt measures to reduce and prevent traffic accidents; for this, it is necessary to work together with different sectors, such as the health, education, transport, and security sectors. The health sector must have fast and efficient prehospital care, so the intervention units act quickly and correctly if an accident arises. In the education sector, it is important to generate a culture of responsibility when traveling on a public highway, being any type of user, from a pedestrian, cyclist, motorcyclist or driver of a unit, and respecting traffic rules. As a security sector, it basically enforces and applies the law to any user who does not comply with it. If the user passes a traffic light, travels at excessive speed, drives under the influence of alcohol, among others, the user must receive a sanction [23].

2.3 Technologies Used in Traffic Accidents Analysis

Nowadays, different tools have been used for analyzing traffic accident data, so it is essential to define some elemental concepts such as *Big Data*, *Data Mining*, and *Machine Learning*.

Big Data is characterized by volume, velocity, and variety. It refers to data containing greater variety, in large volumes, and with more velocity than regular data. In this sense, the traditional data processing software cannot manage these data due to their volume characteristic. However, these massive data volumes can be used to address complex business problems that could not have been able to tackle before [14].

Data mining is a process that analyzes large amounts of data. Data mining allows filtering information from big data. The information resulting from data mining is essential for decision-makers in any project since it is possible to identify problems or opportunities [24].

Machine learning is part of the artificial intelligence field. It allows a system to learn from data without following explicit instructions (explicit programming). Different machine learning techniques are necessary to improve the accuracy of predictive models. The use of these techniques depends on the problem to be solved [8].

As previously mentioned, traffic accidents are a problem that must be addressed. Therefore, the data generated from traffic accidents should be collected, analyzed, and visualized using new technologies and simultaneously used to identify the causes of these accidents.

3 Methods

We conducted a mapping review in three phases: (1) planning; (2) execution; and (3) reporting. Mapping reviews are question based rather than topic based like the scoping review. The goal of a mapping review is to obtain a general perspective of a particular topic to know if there is evidence about the research area and the amount of evidence on a specific topic [13].

The *planning phase* includes the following activities:

- ***Define the research questions***. The research questions that guided this mapping review are:

1. What technologies or tools have been used for collecting, analyzing, and visualizing traffic accident data?
2. What type of traffic accident data are reported and how those data are visualized?
3. How have the collection, analysis, and visualization of traffic accident data been used for decision-making?
4. What are the collection, analysis, and visualization systems for traffic accident data in Mexico?

Table 1 Keywords used in the search query

Technology	Tools	Analysis/visualization	Accidents
Technology	Big data	Analysis	Accident prediction
System	Data mining	Dashboard	Traffic accidents
	Machine learning		

- ***Define keywords.*** Based on the research questions, we defined keywords for four main topics: technology, tools, analysis/visualization, accidents (Table 1).
- ***Define the search query***. We defined the search query using the keywords from Table 1:
  ("technology" OR "system") AND ("big data" OR "data mining" OR "machine learning") AND ("analysis" OR "dashboard") AND ("accident prediction" OR "traffic accidents")
- ***Define the search engines***. We selected the most representative search engines in the area of technology and Computer Science: ACM digital library, IEEE, and Elsevier.
- ***Define inclusion and exclusion criteria***. We defined the criteria by which the articles pass or do not pass to the next stage. The inclusion criteria used for the selection of articles were:

  - The article must describe how traffic accidents data are recorded, analyzed, or visualized.
  - The article language must be in English or Spanish.
  - Only journal and conference articles will be included.

  On the other hand, the exclusion criteria used were:

  - If the article is not related to traffic accidents, it will not be included.
  - For the case of repeated articles, the most current will be taken into account.
  - If the article is not available for review (full-text access), it will not be included, even if it is related to the topic.

For the *execution phase*, we executed the search query, downloaded and stored the results, and selected the articles based on the inclusion and exclusion criteria. We also defined several selection criteria for filtering the results:

- Sort articles by relevance.
- Conduct the selection by title from the first 200 results of each database.
- Conduct the selection by abstract (filtered from the previous phase).
- Analysis by results and conclusions (filtered from the previous phase).

The PRISMA methodology was used in the *execution phase* because it helps guide the reading process of articles from scoping, mapping, and systematic literature reviews in four phases: Identification, screening, eligibility, and included [16]. For

Table 2 Number of results for each database

Database	Total results	Filtered results
IEEE	121	19
ACM digital library	334	8
Elsevier	1826	17
Total	2281	44

details about the PRISMA flowchart resulted from this mapping review, see: https://drive.google.com/file/d/1P8S-G5q7JM1eR-u7MX_AS7Gap01FE7Bf/view?usp=sharingPRISMA flowchart.

Finally, for the *reporting phase*, we describe and discuss the obtained results, answering each research question defined in the *planning stage*.

4 Results

The results are described in this section, and a brief discussion is provided for each research question. Table 2 shows each database's total results,[1] the number of included articles after the screening process, and the selection criteria applied.

Notably, the total number of obtained results in the Elsevier database was considerably more significant than the other databases; however, the filtered results were reduced when the selection, inclusion, and exclusion criteria were applied.

4.1 Technologies for the Collection, Analysis and Visualization of Traffic Accident Data

From the 44 articles included in this mapping review, 37 (84%) answered the first research question: *What technologies or tools have been used for collecting, analyzing, and visualizing traffic accident data? Big Data* = 15 articles (34%), *Data mining* = 17 articles (39%), and *Machine Learning* = 8 (18%).[2]

An example is the work of [1], where they present an application that uses big data tools to store, integrate, and analyze traffic accidents. They used a dataset of traffic collisions in New York City to develop the application, which includes several data features, such as the common cause of accidents, accidents by district, streets where the accidents occurred, and the number of fatalities, among others. It also provides a web service to analyze and visualize information on major traffic accidents.

[1] For details about the results for each research question see: https://drive.google.com/file/d/1V2Y0gtD9zga7sz3s81Ys-LDC98P_CyYx/view?usp=sharingResults by research question.

[2] The articles were not mutually exclusive.

In [3], an analysis of traffic accidents is presented to create a system to make data-driven decisions. The authors preprocessed the data using different data mining tools to infer relevant information about the causes of the most frequent accidents. They concluded that this analysis could help to estimate future situations presented with similar data [3].

The work of [17] introduces a mathematical model exploring traffic accidents in Korea from 2015 to 2017. They analyze traffic accidents by identifying hidden patterns and they introduce a new quantifiable variable called “temporal impulse," based on a frequency analysis. The results suggested that the time boost helped to identify the variable effect of the driver conditions and the weather. The authors argue that this work can help create suitable policies for smart cities considering the collection of urban information with technology.

Finally, the article [20] has as a research’s main objective to identify traffic accident patterns. The authors use a data set collected by the Cyprus Police between 2007 and 2014 with the information categorized on three accident properties: human, vehicle, and general environmental or infrastructure information. Several patterns were identified using five data mining classifiers implemented in Python: Decision trees, random forest, gradient boosting, multi-layer perceptron, and voting classifier. The five classifiers were evaluated using a preprocessed data set and to visualize the extract accident patterns they use Graph Viz library.

4.2 Type of Traffic Accident Data and Visualizations

From the 44 articles of this mapping review, 26 (59%) answered the second research question: *what type of traffic accident data are reported and how those data are visualized?* 24 articles (55%) use text-type data. The data is visualized using several graphics, while two articles (4%) use text-type data and are visualized as maps.

An example is the work of [12] that presents the prediction of accidents on different types of roads by estimating the accident severity based on the accident type, pointing out the traffic collision data on the roads, and the frequency of highway traffic collision using different visualization techniques. The authors proposed a methodology for analyzing traffic accidents to improve the road safety management level and scope. The work also modeled accident data collected from traffic data and data gathered from the construction sectors.

On the other hand, the article [9] aims to identify the causes of traffic accidents. The authors proposed a system for analyzing historic accident data and identifying accident-prone areas and their causes by clustering accident location coordinates. This system can be helpful to warn drivers and help autonomous cars take precautions in accident-prone areas.

The article of [6] presents a big data analysis platform for analyzing traffic accidents in the UK. First, the authors grouped incidents on an interactive Google Maps to visualize accident attributes to uncover potentially related factors. The results demonstrated that the big data analysis platform could effectively handle a large amount

of data and provide insights about how the traffic accident originated and a reasonable prediction of what will happen in the future, supporting the decision-making process.

All the data analyzed in the articles mentioned in this section is in text-type format and was collected through questionnaires and available databases (datasets).

4.3 Analysis of Traffic Accident Data for Decision Making

The 44 articles (100%) included in this mapping review answered the third research question: *How have the collection, analysis, and visualization of traffic accident data been used for decision-making?* 25 articles (56.82%) are works related to the data analysis. In comparison, 19 articles (43.18%)[3] are works aimed at the prediction of traffic accidents.

The work of [4] analyzed the main factors that influence traffic accident occurrences, such as the driver, the vehicle, and the street infrastructure. The authors used data mining tools to collect, process, and classify the data to obtain information on the traffic accidents that occur most frequently. These data can prevent similar accidents in the future, identify the places with the highest incidence of accidents, and thus, be able to make decisions based on the analysis results.

The work of [19] proposed an analysis of the data stored in the cameras on board the cars to predict when a traffic accident will occur, considering different factors such as the driver, the vehicle, and the environment. The system analyzes the information from the video and the vehicle's location. The results showed that it is possible to determine when an accident will occur and in which specific area. Decision-makers can use this information to verify where the accident occurred and why it occurred.

In [11], the authors proposed the Rosa-Cloud system, which provides a web service that offers access to traffic accident information from any mobile device. They also developed a mobile application for Android operating systems called Rosa App. The results from the mobile application showed that it is helpful for the police service to avoid capture errors about the accident location because all smartphones have a location system, allowing GPS coordinates to be recorded with greater precision.

4.4 Technological Systems Related to Traffic Accidents in Mexico

Only three articles (7%) answered the fourth research question: *What are the collection, analysis, and visualization systems for traffic accident data in Mexico?*. Of these three articles, only one is related to traffic accident data; the other two are related to health services impacting traffic accidents.

[3] The articles were not mutually exclusive.

An example of the three articles is the work of [15]. The authors proposed the *Trafico CDMX* system that analyzes historical data from three geolocation applications to define different government transport policies to improve mobility in Mexico City. In addition, this system has a web service that allows accident visualization and prediction. To analyze these historical data is necessary to define the geographic area by the municipality and the initial and final date of the analysis, specifying the year, month, and day. The results obtained through the use of the *Trafico CDMX* system showed that one of the areas with the highest traffic congestion is the northern area of Mexico City, where they were able to identify the hours with the highest traffic and able to predict the average speed of the vehicles.

The second article is the work of [22], where the authors analyzed the problems faced by the Tijuana Baja California Red Cross unit concerning the ambulance service and prehospital care. Currently, the number of ambulances operating in Tijuana cannot cover the entire city, which generates delays in time to go to the emergency and provide medical care services. This work aims to compare and generate strategies using different optimization models to improve the service of Red Cross units, reducing response time and increasing coverage. As a result, the authors doubled the ambulance coverage distributed throughout Tijuana through one of their proposed optimization models.

Finally, the work of [21] addressed the response time problem of the emergency medical service by the Tijuana Red Cross, which is the unit that attends the city's most significant number of medical emergencies. This work aims to predict the estimation of ambulance travel time using machine learning techniques, comparing the travel time with the actual travel time, using different mapping systems, such as Google Maps. For this work, the authors analyzed the database provided by the Red Cross, where they obtained exciting results, showing that it is possible to predict the time differences between the trip provided by a mapping application and the actual ambulance travel time. That is, by correcting the ambulance travel time, a percentage of 100% coverage could be achieved.

Additionally, the work of [21] and the work of [22] used the EMS Track application, a low-cost and open-source computer platform designed to manage and optimize emergency prehospital services. It was developed by the University of California at San Diego, and it consists of a mobile App for Android designed to be used by ambulance crews, and a dispatch system developed as a web application to be used in 911 emergency centers [5]. The dispatch system has a visualization interface and a cloud database where calls, routes, distances traveled, and response times are collected. This information can be used later to perform historical and predictive analysis, advanced optimization processes, and dynamic simulation using mathematical models and artificial intelligence algorithms [5].

5 Conclusion

This paper presents a mapping review on collecting, analyzing, and visualizing traffic accident data. The results include 44 articles aimed at answering four research questions. Big Data, machine learning techniques, and data mining are used for analyzing traffic accident data. Most of the articles used publicly available datasets or collected the data through questionnaires. On the other hand, most articles show traffic accident data using several graphics, and only two use map-type visualization. Approximately, half of the articles are aimed at analyzing traffic accident data, and the other half are aimed at predicting traffic accident factors. Finally, only three articles were found related to traffic accident data in Mexico, uncovering an area of opportunity for researchers who wish to investigate the collection, analysis, and visualization of traffic accidents in Mexico.

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Wind Characterization for Energy Production. Case Study: Huascachaca Mines—Ecuador

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Abstract In the last few years, Ecuador has been developing changes in the use and harnessing of energetic resources, mainly due to the greenhouse gasses emission that cause damage to the climate system and also the depletion of oil. Since 2007, the change in the energy matrix seeks to reduce the consumption of fossil fuels and migrate toward clean alternative energies that reduce environmental pollution. The purpose of the following work is to develop a characterization of the wind of Huascachaca, province of Loja, by using data obtained from a meteorological tower on the site to determine the incidence of the wind, then with the help of the software Windographer, the wind characterization is modeled and dynamized to finally estimate the optimal turbine.

Keywords Wind · Characterization · Energy · Renewable · Generation

1 Introduction

The action of solar radiation that is dissipated by the earth's surface is the main cause of wind generation [1], being its greatest intensity in the equatorial sectors due to its greater solar absorption. The cycle begins with the rise of warm air in the tropics and is replaced by masses of fresh air that come from the poles.

Wind energy is the absorption of the wind through the use of wind turbines, which are capable of transforming it into mechanical energy of rotation and is in turn into electrical energy [3]. This type of energy is based on the renewable energies available

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in Ecuador and is considered a short-term solution. For this, potential areas for the exploitation of this energy have been explored for some time, with the crests of the mountains being the possible points of location [2].

The energy potential provided by the wind is considered clean energy, since it is characterized by its reduced environmental impact in relation to conventional energy sources and, above all, it is inexhaustible.

The wind resource is used by transforming the kinetic energy of the wind into electrical energy through wind turbines, which use a propeller to transmit the movement that the wind produces in its blades to the rotor of an alternator [4].

In 2021, approximately 93.6 GW of wind power capacity was installed globally, including a record 21.1 GW offshore. China led the market, followed distantly by the United States, Brazil, Vietnam, and the United Kingdom. At the end of the year, total global wind power capacity increased by 12% from 2020 to exceed 837 GW (791 GW onshore and the rest offshore). Wind power capacity in operation worldwide contributed about 7% of total electricity generation in 2021 [5].

The International Renewable Energy Agency (IRENA) in its latest global report presented in 2022 shows that 21.6% of the total energy consumed in the world was produced from renewable energies (RE). Of this percentage, 9.0% corresponds to other types of energy, while 12.6% concerns the so-called modern renewable energies, divided into renewable heat with 4.8%, hydroelectric with 3.9%, other renewables with 2.8%, and the remaining percentage 1.1% in biofuel [6]. The potential of renewable energies is growing rapidly due to the continuous fall in prices, various applications in areas such as agriculture, education, and health. [7].

According to the National Energy Balance, with a May 2022 cutoff, in the Ecuadorian electricity sector, the installed generation power is 8786.10 MW, where there is a contribution of non-renewable energies of 3428.38 MW corresponding to 39.02% and renewables with 5357.72 MW equivalent to 69.98%, of this is divided into hydraulic which contributes with 5155.30 MW (58.68%), wind energy 21.15 MW (0.24%), photovoltaic 28.65 MW (0.33%), biomass 144.30 (1.64%), and biogas 8.32 MW (0.09%) [8].

According to [9], Ecuador currently has three wind power generation parks: in the province of Loja, on the Villonaco hill, with an installed capacity of 16.5 MW; on San Cristóbal Island with a capacity of 2.4 MW and on Baltra Island with a capacity of 2.25 MW, the last two in the insular province of the Galapagos archipelago.

In the short term, Ecuador will incorporate new wind capacity, with the García Moreno wind project in the province of Carchi with an estimated power of between 22 and 33 MW; also with Villonaco II and III in the province of Loja with an estimated power of 110 MW and finally with the project in the El Arenal sector in the province of Bolívar with an estimated power of 57 MW [10].

For [11], the estimation of the wind speed and direction using software inserting several parameters such as the location and database of the wind at different heights can be done with a good approximation. In addition, the power and energy needed for the study site can be estimated, resulting in possible commercial wind turbines to be used in a project through the analysis of graphs and tables.

The authors [12] have analyzed the wind resource in a region of Argentina with the purpose of evaluating the changes in the wind potential in the place of study using data series where there are periods of malfunction of the measurement equipment that make the series not homogeneous. They have applied different methods to know the degree of correlation and to be able to correct the errors, establishing representative speed variabilities to estimate the variations of the wind at the required height.

The study of the aerodynamic characteristics of the unstable wind for the calculation of wind turbines based on a non-intrusive polynomial chaos expansion (PCE) is carried out by the authors [13]. A surrogate model of the turbines is obtained to estimate the extreme statistics in a more precise and efficient way, reducing the costs of the calculation.

Minas of Huascachaca Eolic Project (PEMH) is located in the south of Ecuador, 84 km southwest via Girón-Pasaje, in the province of Loja, parish of San Sebastián de Yuculuc in the coordinates 3.073420214191687, −79.42943841682101. This place was chosen due to the antecedents of the wind characteristics in the study area.

2 Methodology

The methodology used for the characterization of the wind in the development of this work is (see Fig. 1).

A. *Site wind data*

The data was taken from the years 2008–2020, in ten minutes time intervals, which are entered into the Windographer software through a Data.txt file obtained by the tower located in the Huascachaca sector of the Loja province. It should be noted that

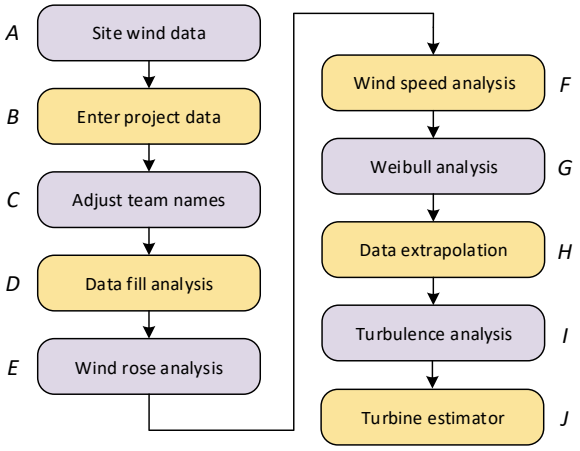


Fig. 1 Methodology

these data contain information from anemometers, vanes, and temperature sensors located at different heights (40, 60, 78, and 80 m).

B. *Enter project data*

Once the data has been entered, we proceed to validate the project data in the data configuration section, locating the name, description, location coordinates.

C. *Adjust team names*

In this section, we proceed to refine the data labels, placing the names of the channels according to the variable, choosing the heights corresponding to each of the sensors, and selecting the corresponding units and, if applicable, a color that can be differentiated between them.

After adjusting the data, the graphs (see Fig. 2) of the height versus the average wind speed, the frequency of the wind rose, the average monthly average speed, and the average hourly speed are obtained of the day.

D. *Data fill analysis*

Carrying out a general analysis of the data allows us to know if they were obtained continuously. Given that there could be some losses due to failures in the sensors, in the recorders or, in turn, power supply problems, these inconveniences would prevent the information from being affected in its temporal continuity, and therefore, the dynamics could not be optimally characterized. To solve these inconveniences, in Windographer, there is a section that performs the information scanning and shows the spaces in which there is no information. In addition, within its tools, the aforementioned software has the capacity to fill in this data through the use of algorithms. For this, we go to the ***check-fill gaps*** tab; then a window opens, where some vertical lines are shown that indicate the lack of data.

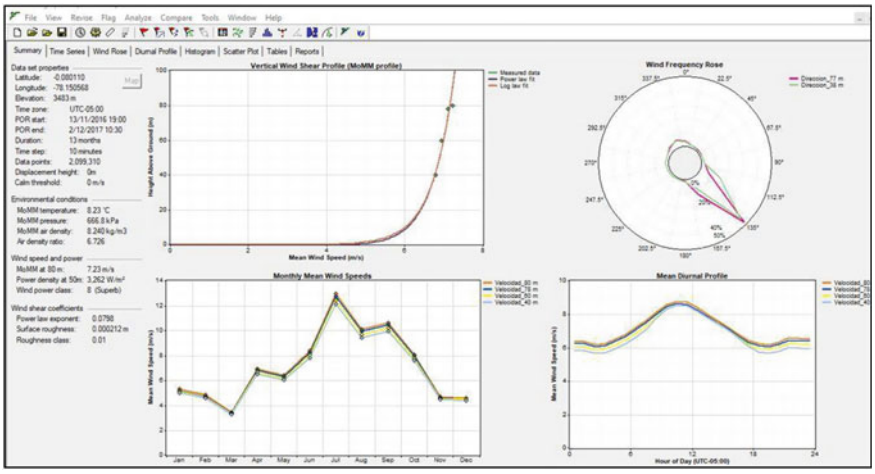


Fig. 2 General summary of data

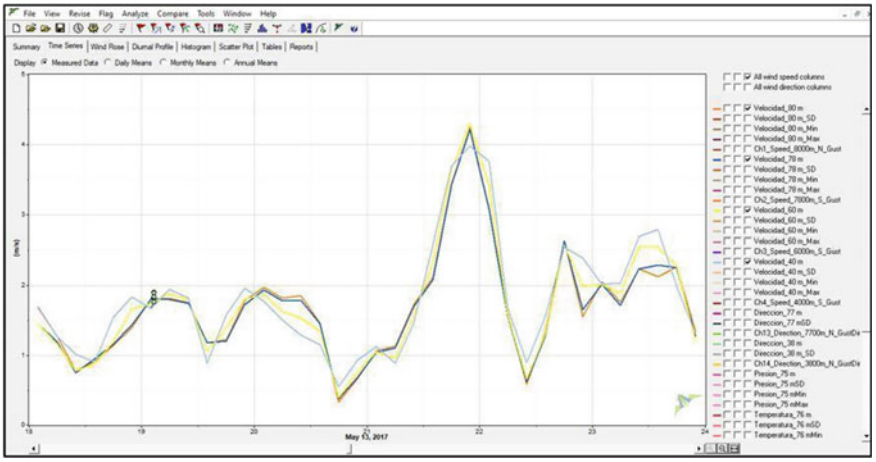


Fig. 3 Data filler using Markov

Finally, we give ourselves a check on ***use Markov-based mechanism to fill remaining gaps*** and click on ***fill gaps*** for filling in the missing data as shown in Fig. 3.

E. *Wind rose analysis*

In this section, the analysis of the speed and direction of the wind for different heights and for all the months of the year is carried out.

- Speed frequency at 40 m and direction at 38 m:

Figure 4 shows the wind rose for the different months of the year with a height of 38 m, giving the months of July, August, and September. In addition, something very particular about these results is that the wind direction remains constant throughout the year.

- Speed frequency at 40 m and direction at 77 m:

Figure 5 indicates parameters similar to those shown at heights taken at 38 m, with the difference that the wind speed increases.

F. *Wind speed analysis*

There is data generated for one year and with equipment that was installed at different heights, both anemometers and vanes, so it is feasible using Fig. 6 to perform the wind speed analysis. Observing that the variables of height and speed are directly related in a proportional way and that their average is established at 7.77 m/s; data that will serve for further analysis when choosing the right turbine for implementation on the site.

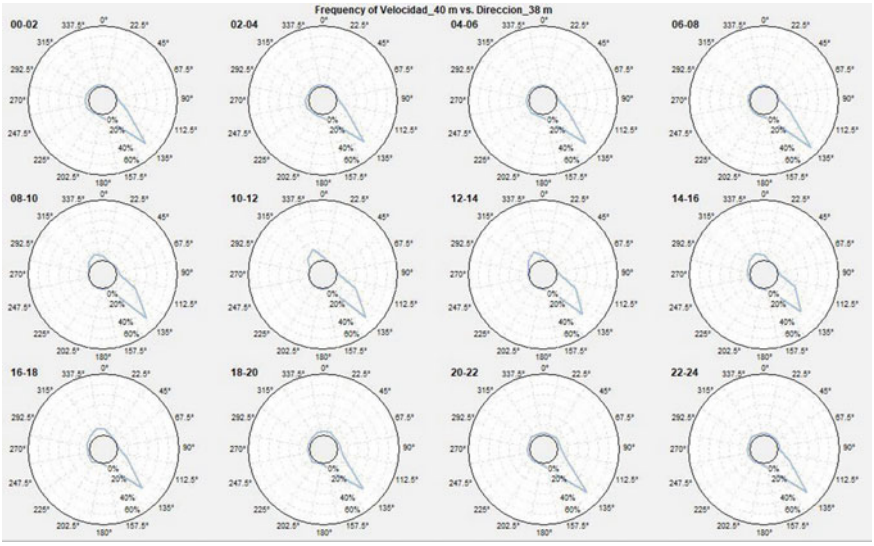


Fig. 4 Speed frecuency_40 m versus direction_38 m

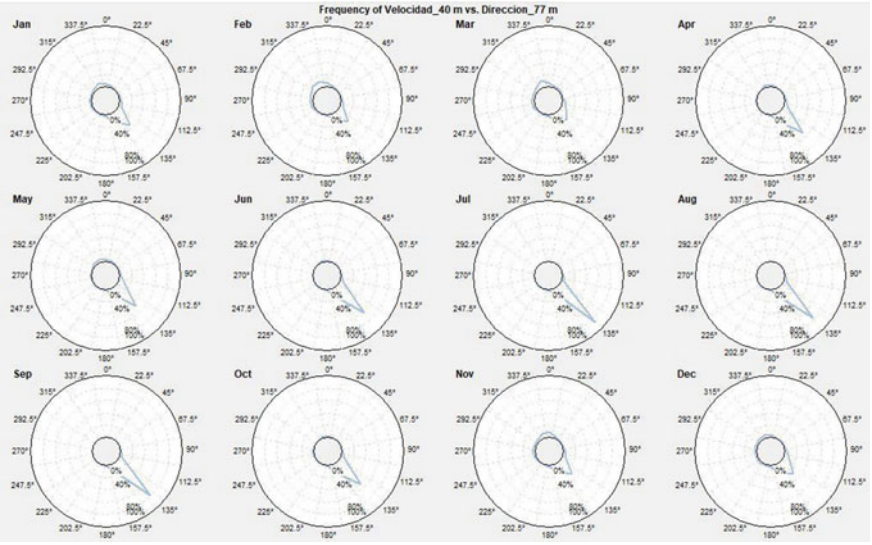


Fig. 5 Speed frecuency_40 m versus direction 70 m

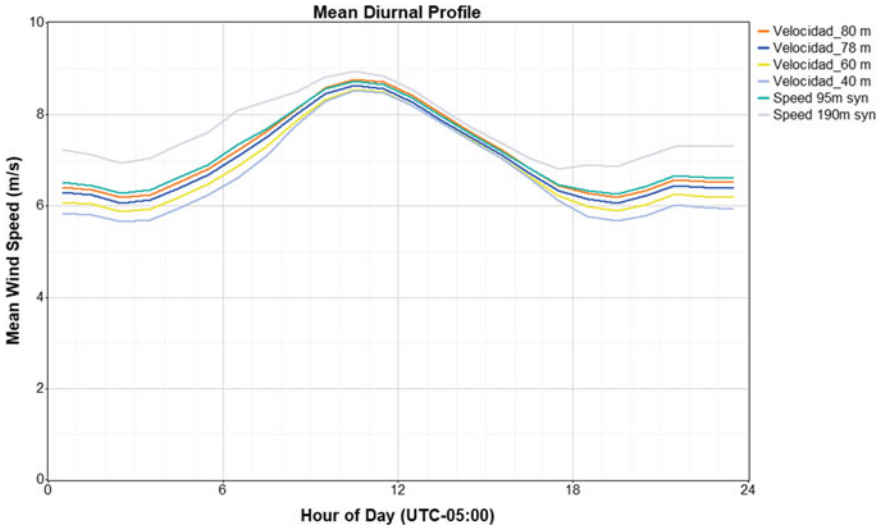


Fig. 6 Wind analysis

G. *Weibull analysis*

The histogram is a tool that allows us to know the repetition frequency of the wind speed (m/s). This is shown in Fig. 7. According to the results presented, it can be stated that the highest speed repetition is found at 2 m/s, and that its longitudinal permanence is in the range of 7–11 m/s. It should be noted that these results are good indicators to decide whether or not it is feasible to place a generator on the site, in addition to providing information to determine the turbine with the startup according to speed.

H. *Data extrapolation*

The data obtained by placing the meteorological tower on the site has limitations to determine parameters that may be needed at heights greater than those extracted from the sensors. The advantage that Windographer provides is that it allows data to be extrapolated and thus be able to simulate wind speed, among other parameters, at higher altitudes. Next, two data extrapolations are generated at 95 and 190 m, to analyze the results obtained in the mentioned program.

- Extrapolation of data to a height of 95 m.

Figure 8 shows the parameters obtained in the extrapolation that turn out to be similar to those shown at heights taken at 38 m, with the difference that the wind speed increases, and this is due to the fact that there is a directly proportional relationship of height relative to wind speed.

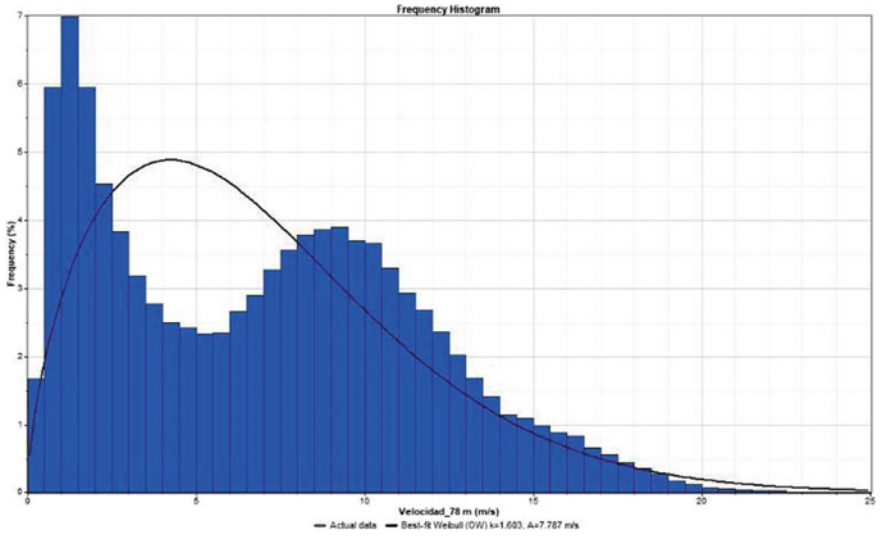


Fig. 7 Histogram

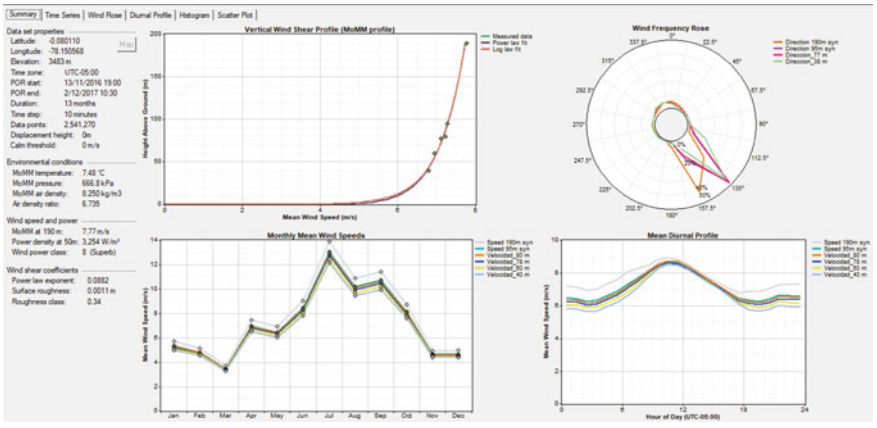


Fig. 8 Extrapolation of data to a height of 95 m

- Extrapolation of data to a height of 190 m.

Figure 9 shows the results obtained in the software for a height of 190 m. Where it can be concluded in the same way that the speed of the hundred increases; and in addition, a minimum variation in the direction of the wind of approximately 10° is observed.

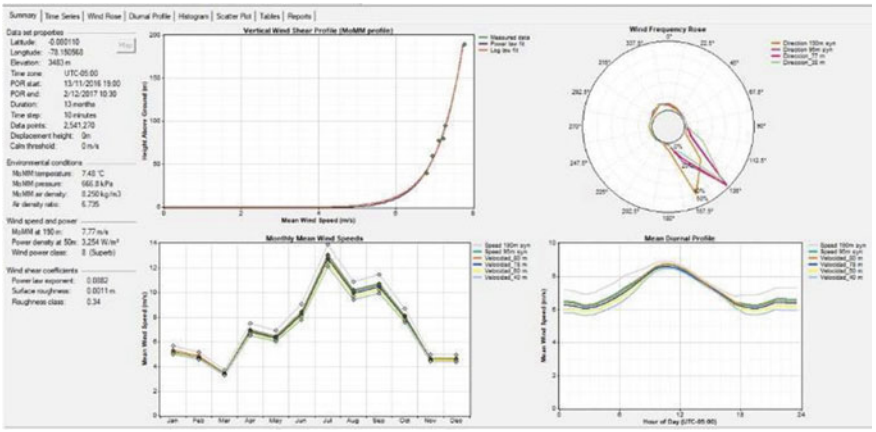


Fig. 9 Extrapolation of data to a height of 190 m

I. *Turbulence analysis*

Turbulence is a phenomenon that influences the power delivery of a wind machine, modifying its power curve. Usually, to obtain the power curve of wind turbines, manufacturers use a turbulence index of 10%.

Turbulence decreases the possibility of using wind energy effectively in a wind turbine. They also cause more breakage and wear on the wind turbine. Wind turbine towers are usually built tall enough to avoid wind turbulence near ground level.

The turbulence intensity is normally kept in the range of 0.1 to 0.4. In general, high values of turbulence intensity occur at low wind speeds, but the lower limit at a given site will depend on the specific terrain characteristics and surface conditions at the site. Figure 10 shows the relationship between turbulence as a function of the height at which the wind turbine is located.

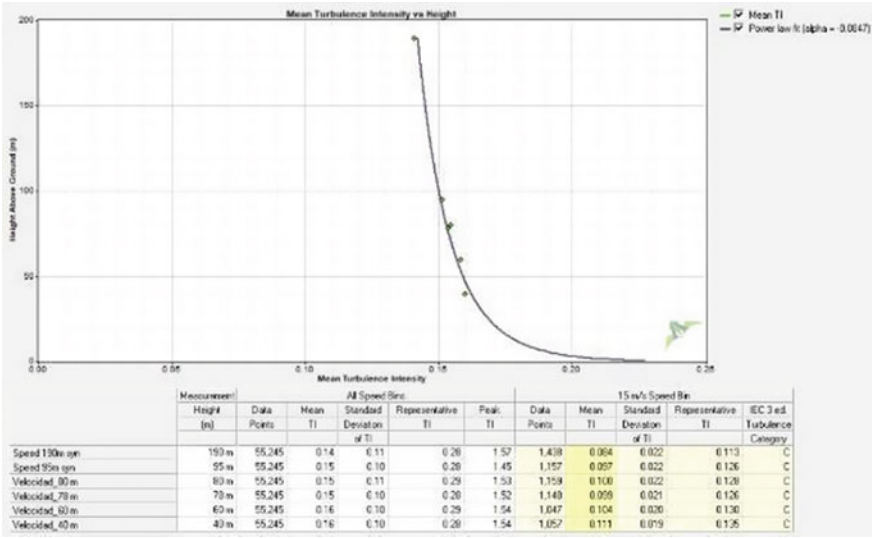
Turbulence as a function of wind speed is presented as an inversely proportional function between these variables and is shown Fig. 11.

Another important parameter to consider is the relationship between turbulence and wind direction, shown in Fig. 12.

J. *Turbine estimator*

For the selection of the wind turbine to be used, factors such as the power density produced, the average speed of the wind at the height of the hub, the type of wind at the site, and the load factor of the wind turbine are taken into account. Wind turbine classes are primarily defined by the annual mean wind speed (measured at hub height) and the amount of turbulence present at the site.

According to the characterization of the wind obtained in Windographer, it can be concluded that the wind turbine that would best fit within this project with the data obtained with the meteorological tower is the one shown in Fig. 13. That the



Measurement	All Speed Bins					15 m/s Speed Bin				
Height (m)	Data Points	Mean TI	Standard Deviation of TI	Representative TI	Peak TI	Data Points	Mean TI	Standard Deviation of TI	Representative TI	IEC 3 ed. Turbulence Category
Speed 190m syn	190 m	55,245	0.14	0.11	0.28	1.57	1,438	0.094	0.022	0.113	C
Speed 95m syn	95 m	55,245	0.15	0.10	0.28	1.45	1,157	0.097	0.022	0.126	C
Velocidad_80 m	80 m	55,245	0.15	0.11	0.29	1.53	1,159	0.100	0.022	0.128	C
Velocidad_70 m	70 m	55,245	0.15	0.10	0.28	1.52	1,149	0.099	0.021	0.126	C
Velocidad_60 m	60 m	55,245	0.16	0.10	0.29	1.54	1,047	0.104	0.020	0.130	C
Velocidad_40 m	40 m	55,245	0.16	0.10	0.29	1.54	1,057	0.111	0.019	0.135	C

Fig.10 Height dependent turbulence

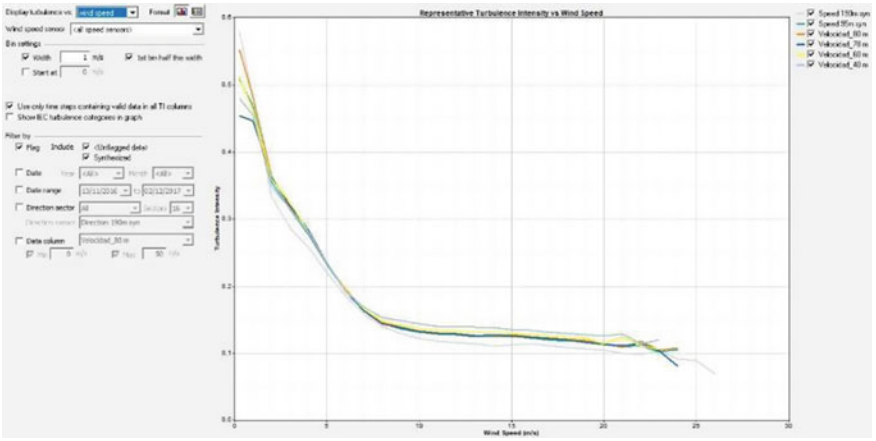


Fig. 11 Speed dependent turbulence

data to consider is the location of the anemometer at a height of 50 m. The average wind speed is 7.7 m/s. The starting speed (Weibull k) is 2.

Through the support of the Windographer estimator, the wind turbine that meets the requirements can be located from among several options; among which the Acciona AW 82/1500 Class III b wind turbine has been chosen for this project (see Fig. 14).

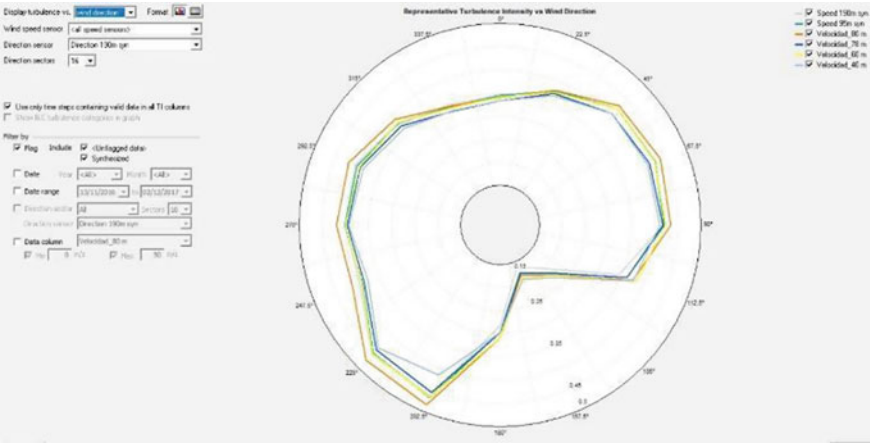


Fig. 12 Direction dependent turbulence

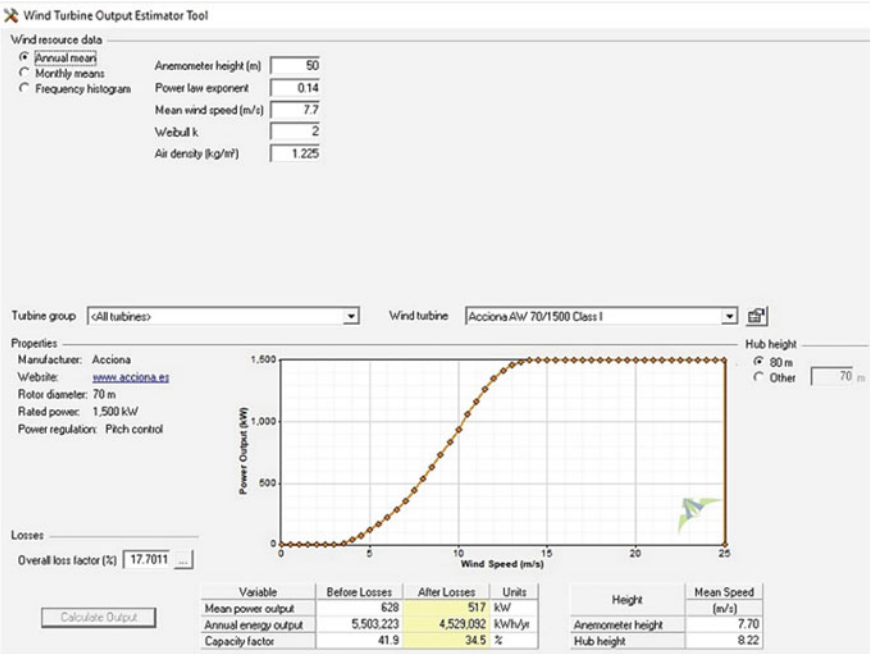


Fig. 13 Turbine estimator

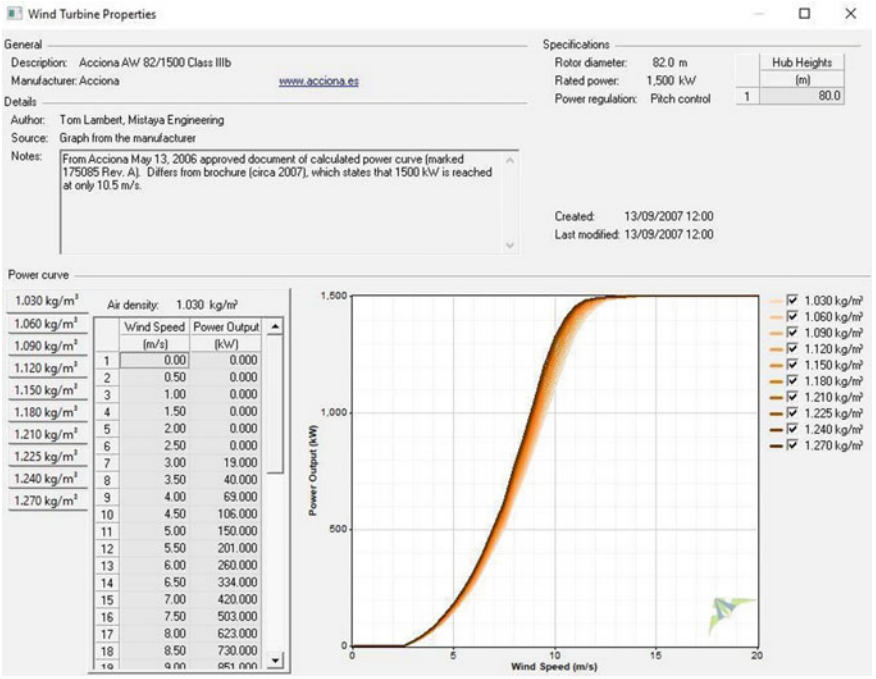


Fig. 14 Wind turbine properties

3 Conclusions and Discussion

The gross power calculated at the height of the rotor hub at 70 m is available for wind turbines with a power of 1.5 MW, and the most representative months are June and July, which must be taken into account for energy production.

The Windographer tool is a software that estimates the average annual net energy production, its value is 4529.09 KWh/year, and the capacity factor is 34.5%.

The short-term prediction methodology is considered important in the design of a wind farm and must be taken into account for the planning of energy production.

Learning to use specialized software to characterize the wind is of the utmost importance since not only can results be obtained from existing data from meteorological towers, but data can also be estimated using extrapolation, which is one of the advantages of the program. The benefits of the program to be able to estimate a wind turbine according to its characterization are of great help when choosing the turbine.

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Communication Between Supply Chain Actors: A Risk Reduction Factor in Supply Chains

Yasser El Ouarrak and Aziz Hmioui

Abstract The growing complexity of supply chains and the increase in risks make communication between supply chain actors in these chains crucial to reduce the risks inherent there. Indeed, each supply chain forms a communication node between a large number of highly interconnected actors (producers, suppliers, transporters, distributors, retailers, and customers). Information sharing, information systems, and technology as some of the most important components of this communication and contribute to the reduction of risks surrounding the activities carried out by actors within supply chains. This paper presents a review of the literature on the importance of communication between supply chain actors. It explores the impact of information sharing on the quality and effectiveness of communication within a supply chain and highlights the importance of information systems and technology to ensure effective communication between its actors. The influence of this effective communication on supply chain risk reduction is also discussed. In addition, the main supply chain risks reduced by an effective communication system are as well examined.

Keywords Supply chain · Communication · Risk · Information systems and technology · Information sharing

1 Introduction

A supply chain constitutes a node of highly interconnected corporate relationships aimed at optimizing goods, information, and financial flows across a supply chain with the objective of offering better value creation. However, these flows are surrounded by multifaceted risks making supply chains vulnerable to varying

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degrees. Effective supply chain risk management requires stronger coordination of activities between supply chain actors. Communication is the cement of this coordination.

Communication, the formal and informal exchange of information among companies [1], is essential to support closer interactions among today's supply chain actors. It minimizes the risk of dysfunction and increases the benefits that all parties can obtain from their relationship [2]. Thus, full communication ensures the synchronization of partners' operations [3]. Moreover, by reducing the degree of uncertainty in the relationship between partners, communication has a positive impact on trust and commitment among them [4].

Indeed, the sharing of information and the use of information systems and technology are some of the main keys to the success of any form of communication between the actors in a supply chain. They both participate in the efficiency and quality of the communication system. This system allows the definition of common actions and strategies between supply chain actors to reduce the risks surrounding supply chain activities.

First, we will present the contributions of information sharing and the integration of information systems and technology for a supply chain and more specifically in the effectiveness of communication between supply chain actors. Second, we will discuss the importance of having an effective communication system to reduce the risks inherent in supply chain activities and examine the main risks that can be mitigated through effective communication among supply chain actors.

2 Communication Between Supply Chain Actors

For Laville [5], the transition from the global enterprise to the extended enterprise requires the ability to be in communication with other supply chain actors. Li et al. [6] consider that the efficient communication of a company with downstream and upstream business parties is more of a necessity than a factor that can enhance its competitiveness.

Communication is seen as an important component of the various logistics partnerships created between supply chain actors. It is the essential link for the success of logistics partnerships [7]. In fact, the sharing of information between the supply chain actors and the use of information systems and technology can be considered as instruments to obtain an efficient communication system. Indeed, the latter is very important because the reliability of a supply chain is highly dependent on it.

2.1 Information Sharing Between Supply Chain Actors

Recent interest in supply chain management has focused on the quality of the communication system established between the various actors in a supply chain including

suppliers, manufacturers, distributors, wholesalers, retailers, and customers. An important device for effective communication in supply chains is the sharing of information among supply chain actors. This sharing contributes strongly to the efficiency of the supply chain communication system by providing the appropriate information to the appropriate partner, at the appropriate place and time.

Basically, the key to ensuring the quality and effectiveness of the supply chain communication system is to improve the quality of the information shared. In [8], this quality comprises aspects of accuracy, timeliness, adequacy, and credibility [9–11]. The quality of communication is thus influenced by the quality of the information shared directly and positively. In the context of partnerships, such quality is a key success factor and without it, the success of the partnership is at risk [8].

Metters [12] found that information sharing in supply chains can minimize the bullwhip effect and enhance profitability. Furthermore, information sharing savings range from 3.4% [13] to 10% of total supply chain costs [14]. Moreover, in partnerships, information exchange facilitates the coordination of partners' actions [15]. Indeed, systematic availability of information is a significant indicator of the success of partnerships [16].

2.2 Information System and IT, as a Communication Vehicle in a Supply Chain

Today, more and more supply chain actors are deploying information systems and technology to improve communication efficiency and decrease response time to various changes in the supply chain environment. Information technologies (IT) are adept at managing information flows and providing links that foster communication throughout the supply chain [17]. They can offer a variety of tools for facilitating, streamlining, and improving the reliable communication and exchange of information among organizations [18]. Among these tools, we can cite enterprise resource planning (ERP) systems, advanced supply chain planning software, customer relationship management (CRM), and supplier relationship management (SRM) tools [19]. Thirteen types of IS/IT have been identified by Bayraktar et al. [20], which they group into three categories: Enterprise-Wide IS/IT, integrating IS/IT, and facilitating IS/IT. These information systems and technologies ensure the standardization of data exchanges within a supply chain and facilitate decision-making among its actors. They, thus, enhance the dissemination and processing of information between the supply chain actors, which consequently promotes the efficiency of the supply chain communication system.

The integration of information technology (IT) into supply chains is increasingly important in a globalized and competitive economy [6]. For Jin [21], the deployment of information technologies is more of a necessity than a choice. Indeed, today's IS/IT tools are much faster, extensive, and provide increased visibility into supply chain events. In addition, information sharing, through information systems (IS), will be

easier across the company and more widely in the supply chain with the deployment of cross-organizational systems [22]. This information sharing based on IS/IT tools allows a better integration and synchronization of the activities of each member of the chain, improves the planning process, and thus facilitates operational, tactical, and strategic decision-making. Each member of the chain will be able to make decisions based on information specific to his or her organization, but also based on accurate, timely, adequate, and reliable information provided by the information systems and technology within supply chains.

3 Communication and Supply Chain Risks Reduction

Thierry and Lamothe [23] have defined supply chain risks as uncertain or unpredictable events, which negatively affect the partners of one or more supply chains as well as their processes and the achievement of their objectives. In a supply chain, risks are analyzed all along the pipeline from the supplier of the raw material to the consumer or end user of the product. Managing these risks requires effective communication between the different actors in the supply chain, which will allow a deeper knowledge of the risks in the chain, an increased monitoring of these risks, and an increase in the reactivity of intervention at each level of the chain and the coordination of actions in terms of risk management. In addition, effective communication can help develop strategies that can be used to mitigate a number of risks inherent in supply chain operations.

3.1 Impact of Effective Communication on Supply Chain Risks Reduction

An effective communication system implemented in a supply chain enables supply chain actors to develop a common understanding of potential environmental changes, to mitigate the uncertainty and risks surrounding supply chain activities, and to deal with the complexity of decision-making at different stages of the risk management horizon. Effective and timely information exchange can lead to early recognition that change is needed [3]. Recognition of problems as they arise can allow members of the supply chain to present solutions to situations before they become crises. In addition, IS/IT tools in supply chain, ensuring effective communication between supply chain actors, can be used to model and analyze different “what-if” scenarios within the supply chain, including crises and large-scale unforeseen events [24]. Moreover, IT implementation can minimize the uncertainty of the environment and enhance supply chain efficiency, through the use of accurate and timely information on product availability, inventory levels, delivery status, and market needs [25].

Effective communication in a supply chain also enables risk monitoring. This process of monitoring involves periodically checking for the emergence of new risks and the evolution of existing risks [5]. In addition, one of the benefits of effective communication between supply chain actors is responsiveness. The latter has been defined by Biteau and Biteau [26] as being the ability of a system to respond to an external solicitation in a given time. Efficient communication offers this capacity and allows to respond to the different risks generated by the possible changes of the supply chain environment in a very short time. This reactivity provides a competitive advantage for a supply chain.

In addition, effective communication between supply chain actors serves an essential function in implementing mechanisms to coordinate actions. It leads to increased coordination of actions between supply chain actors, enabling them to address risks that may compromise supply chain operations. The supply chain actors achieve this coordination by sharing risk management information through frequent exchanges in the different directions of a supply chain.

Moreover, the coordination of actions between supply chain actors can lead to the elaboration of a risk map in which the risks inherent to a supply chain are identified and evaluated. It also helps to identify and implement strategies dedicated to reducing risks.

3.2 Main Supply Chain Risks Reduced Through an Effective Communication System

The implementation of an efficient communication system between the different actors of the supply chain constitutes a guarantee of success in the management of the risks inherent in supply chains. This system helps to reduce supply chain risks from one level of the chain to another and between a company and its partners. This is to ensure the smooth running of supply chain activities and to ensure the best possible value creation.

According to a number of research studies, there are at least three main risks inherent in a supply chain that can be reduced through an effective communication system. These are information distortion risk, forecasting risk, and customer dissatisfaction risk. It should also be noted that these three main risks are closely related to each other.

Information distortion risk. The performance of a supply chain results from the ability of its members to manage the disruptions arising from the interactions between them. Among the disturbances, the disruptive power of information distortion within a supply chain is becoming increasingly apparent. This phenomenon is called “The Bullwhip Effect”. Lee et al. [27] point out that it is the phenomenon in which orders to suppliers have a tendency to have more variance than sales to buyers (i.e., demand distortion), which propagates upstream in amplified form. Indeed, the reason for

demand information distortion is that the retailer places orders based on her up-to-date demand forecasts and, consequently, the manufacturer loses sight of the real market demand [27]. This distortion is, therefore, caused by the uncertainty due to the miscommunication between the different parties in a supply chain, which can lead to significant costs throughout the chain [19].

To face the phenomenon, the authors propose to reinforce the efficiency of the communication system between the different actors of a supply chain, through the improvement of the mechanisms of information sharing and coordination between the supply chain components. There is a solution that has been proposed by Lee et al. [27], which is to allow the manufacturer to access the demand data directly at the retail outlet. Only the sharing of accurate, appropriate, and reliable information in real time between the actors of a supply chain is able to guarantee the reduction of information distortion. In this regard, new and powerful information sharing and coordination methods have emerged within supply chains. One of these methods is vendor managed inventory (VMI), considered by El Ouardighi [28] as an agreement in which the distributor entrusts its supplier with the responsibility of managing its inventory. It reflects a trusting approach on the part of the distributor, who avoids supply constraints by exchanging information on its sales and inventory [28]. By using the VMI method, the Bullwhip Effect could be decreased by up to 50% [29]. Other solutions proposed in the literature are the use of the electronic data interchange (EDI) system between retailers and producers or the use of the continuous replenishment program (CRP). All of these tools can help supply chain actors mitigate the risk of information distortion.

Forecasting risk. The increased volatility of demand, the speed of economic change, and today's technological changes have contributed to an increase in the risk of forecasting failure within a supply chain. Therefore, there is a need to change the way supply chain actors coordinate their forecasting activities, encourage collaborative forecasting, and strengthen the sharing of forecasting information among them.

The advantages of local forecasting, i.e., that which concerns a single company, are claimed by some authors to be fewer than those obtained in collaborative or joint forecasting within a chain. The local forecast decreases supply chain costs by an average of 11.1%, while collaborative forecasting can reduce supply chain costs by an average of 19.43% [30]. However, successful collaborative forecasting among supply chain actors requires an effective forecasting information sharing system. Indeed, one of the most critical fields of research in supply chain management is the sharing of forecasting information, as this information influences fundamental decisions within a supply chain [31]. To ensure this sharing, companies resort to a number of mechanisms, the main one of which is collaborative planning forecasting and replenishment (CPFR). In CPFR, supply chain actors exchange information and jointly manage important supply chain processes [28], including the forecasting process.

However, Lee et al. [27] stress that the availability of a common dataset for forecasting needs cannot be considered a complete solution because differences in forecasting methodologies will always result in larger variations in orders and a

distortion of demand. Therefore, to mitigate risks related to differences in forecasting methodologies, supply chain members can choose one member among themselves to handle forecasting and ordering for the remaining members [27].

Customer dissatisfaction risk. Information exchange is critical to successful supply chain relationships, but this exchange is not an end in itself, rather it is a vehicle for delivering added value to customers [3]. Creating responsiveness and providing reliable responses to customers are key aspects of effective customer communication. Responsiveness means that supply chain actors must respond quickly and effectively to environmental changes and evolving customer needs. Providing a reliable response means delivering what was requested on time and with better quality. On the other hand, not responding to customer requests can be financially costly and result in lower satisfaction [3]. For this reason, companies have realized that having more information about their customers means they are more equipped to meet their needs [32]. Thus, effective and timely information exchange, in the form of customer data exchange, frequent meetings between sales representatives of supply chain actors, etc., helps to cope with market changes and to quickly recognize evolving customer needs and prepare solutions for them at the optimal time and in the best quality, which, as a result, increases customer satisfaction.

In the quest for customer satisfaction, supply chain actors can resort to several techniques, namely efficient consumer response (ECR) programs and customer relationship management (CRM) tools. These solutions enable supply chain actors to respond more effectively to customer needs through a more flexible, responsive, and reliable communication structure.

4 Conclusion

The sharing of accurate, timely, adequate, and reliable information and the integration of information systems and technology within a supply chain are the main keys to the success of an effective communication system among supply chain actors. This system strongly contributes to the reduction of risks that can negatively affect supply chain activities. This is possible thanks to providing increased visibility on supply chain issues and enhanced responsiveness to changes in the supply chain environment. This can in turn enables supply chain actors to effectively manage the risks inherent in the supply chain through coordinated actions. The most important of these risks examined in this paper are the information distortion risk, the forecasting risk, and the customer dissatisfaction risk.

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Technology in the Development of Eco-Innovations

Zornitsa Yordanova

Abstract Emerging technologies have been increasingly used to transform products, processes, whole industries, and re-design innovation development. In the context of eco-innovations, emerging technologies such as big data, data analytics, artificial intelligence, robotics, augmented reality, and 3D printing have the opportunity to leverage and fasten up the process of addressing environmental issues in most industries. In this paper, we analyze the current adoption of emerging technologies in developing eco-innovation. The methodology used is the bibliometric analysis and aims at positioning the state of the art and at identifying further clusters for developing eco-innovations with the usage of big data, data analytics, artificial intelligence, robotics, augmented reality, and 3D printing. The source of the study is 708 English-language articles from the Web of science between 1991 and 2023, which have increased dramatically in the last two years. The results represent a grouping of the current scientific advancement in the field of developing eco-innovation with the support of emerging technologies. The study focuses on clustering analysis and thematic evolution in order to shed the light on this wide and cross-developing topic. A direct contribution is the clearly clustered sub-fields, which can be a base for further research.

Keywords Eco-innovation · Environmental innovation · Green innovation · Sustainable innovation · Emerging technology

1 Introduction

Growing concern about the environmental future of the planet forces researchers from all fields of science to encourage research on ecological innovation. Governments are gradually introducing regulations to ensure that companies do not fall behind in aligning their operations with best practices for future environmental

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health [1]. Companies are also increasingly focused on implementing innovations (products, processes, organization, and marketing) with the aim of significantly reducing their environmental impact [2]. On the other hand, new technologies are affecting every sector, creating dramatic changes for everyone involved, including nature. According to some authors, technology, especially innovation, is part of the means of eco-innovation [3]. Technology is seen as one of the determinants of environmental innovation [4]. Emerging technologies are widely researched through the prism of adopting new technological advances in different fields, usually associated with artificial intelligence, big data, data analytics, robotics, virtual reality, and 3D printing. The objective of this study was to group the main topics related to emerging technologies for eco-innovation adoption and development.

The bibliometric analysis in this research reveals the main spheres and categories, as well as the evolution in the existing scientific literature, focused on both eco-innovations and emerging technologies. The study is based on 708 scientific articles indexed in Web of science meeting a Boolean search covering topics related to eco-innovation ('eco innovation', 'eco-innovation', 'ecological innovation', 'environmental innovation', 'green innovation', 'sustainable innovation') and emerging technologies such as 'artificial intelligence', 'big data', 'virtual reality', 'augmented reality', 'Internet of things', 'robotics', and '3D printing'.

The thematic evolution analysis reveals the growing interest of researchers and the still developing area for further research. This is proved by the automated time period clustering of all the articles in scope which defined the third cluster for only the last two years (2021–2022).

2 Theoretical Background

2.1 Eco-Innovations

The concept of eco-innovation has emerged only in the last 20 years with the increasing emphasis on sustainability and the environmental impact of companies and humanity. Being a still new area of research, at the same time quite broad, it is difficult to be summarized and defined. However, the growing research shows that several terms can be combined as eco-innovation, and these are 'eco innovation', 'eco-innovation', 'ecological innovation', 'environmental innovation', 'green innovation', and 'sustainable innovation'. The theory of eco-innovation can be clustered as follows. Hazarika and Zhang [5] fall into the following categories: theory, institutional theory, stakeholder theory, evolution theory, and material-based theory. In terms of novelty, the same authors distinguished incremental innovation and destructive. Carrillo-Hermosilla, del González, Könnölä [6] grouped eco-innovation into sub-fields based on eco-efficiency, industrial ecology, or environment. According to Díaz-García, González-Moreno, and Sáez-Martínez [7], various terms in the literature summarize the concept of eco-innovation. They are usually associated with less

negative environmental impact and are associated with 'green', 'eco', 'ecological', and 'sustainable'.

Hojnik and Ruzzier [8] researched motivation for environmental innovation, incl. product eco-innovation, process eco-innovation, organizational eco-innovation, and environmental R&D investments, and led to the conclusion that these are motivated by common drivers, such as regulations, market pull factors, EMS, and cost savings. The authors also identified a positive correlation between the motivation of companies to develop eco-innovation and their scale. On the other hand, some studies suggest that eco-innovation organizational motivation achieves higher organizational performance [9]. Research on corporate sustainability [10] provides important theoretical and practical insights into how the use of sustainability-oriented innovation practices can help drive broader performance benefits. Therefore, managers need to increase their organization's ability to innovate. This can have a positive impact on performance impact and achieving sustainability goals overall.

2.2 Emerging Technologies in the Development of Eco-Innovations

Following Rotolo et al. [11], emerging technologies are defined by five attributes: radical novelty, fast growth, coherence, prominent impact, and uncertainty and ambiguity. These authors highlighted the policy-making perspective impact of emerging technologies, while in this study, we focus on emerging technologies potential to be adopted in the development of eco-innovation. Yet, this is quite a new area of research, and not many researchers have addressed the gap since the emerging technologies are already in use for developing eco-innovations, and no one research has been published to elaborate on the topic: which ones these technologies are and how they could be used.

According to Halaweh [12], uncertainty, network effects, and hidden social and ethical concerns and costs characterize new technologies. In a study by Bossle et al. [13] from 2015, on the drivers of the adoption of eco-innovation, technology is still considered in its role as a reason for the adoption of eco-innovation to reduce environmental impact with technology. For example, artificial intelligence and big data were not even mentioned.

3 Methods

3.1 Data and Scope

In this study, we extracted data from the Web of science database limited to articles in English languages, by using this Boolean search:

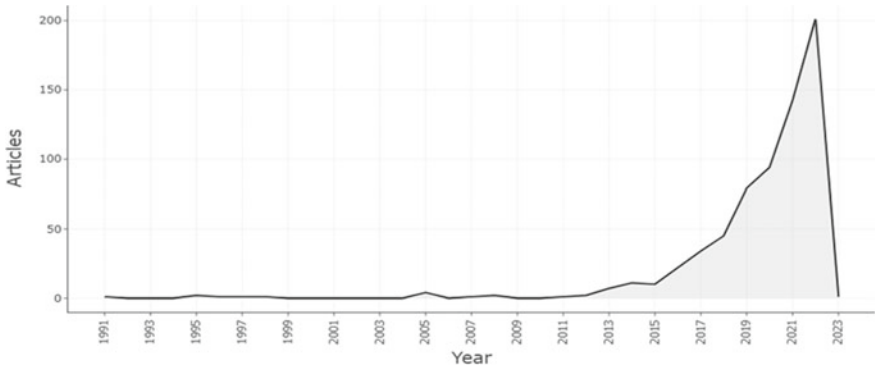

Fig. 1 Publications in eco-innovation and emerging technologies in Web of science

TOPIC ALL 'eco innovation' OR 'eco-innovation' OR 'ecological innovation' OR 'environmental innovation' OR 'green innovation' OR 'sustainable innovation'.

and.

TOPIC ALL'AI' OR 'artificial intelligence' OR 'big data' OR 'virtual reality' OR 'augmented reality' OR 'Internet of things' OR 'robotics' OR '3D printing'.

For further research and replication, the following query may be used:

https://www.webofscience.com/wos/woscc/summary/73f0fbb1-b411-4284-a55b-08e0b3af0a43-616c29d1/relevance/1

The obtained 708 articles are the basis for the bibliometrics research. The time span of these is 1991:2023 even though 68% of these articles were published in 2020, 2021, or 2022. The average number of citations per document is 18.52 which is considered to be quite high for a management field in a broad sense. 2207 have contributed to this research area so far, and only 94 of these articles were single-authored and authored by 92 authors. This observation shows the multidisciplinary of the research field which indirectly requires more collaboration in such research. Figure 1 shows the growth in publications in recent years.

3.2 Bibliometric Analysis

Bibliometric analysis is considered a rigorous method for investigating and analyzing large amounts of scientific data [14].

In this study, we performed bibliometric analyzes to address the multidisciplinary topic of eco-innovations and emerging technologies through a thematic evolution analysis (based on keywords, abstracts, titles, bigrams, and trigrams). This systematic approach to research themes and research areas aids in the identification of research interests and how they evolve over time, as well as providing insight into future research directions. In this study, R software and the Biblioshiny package were used for bibliometric analysis.

4 Results and Discussion

The first analyzes are focused on the thematic evolution of the topics through the authors' keywords in the analyzed 708 articles. For this reason, three separate times were identified: 1991–2019; 2020–2021, and 2022–2023. The intensity of the second and third periods when it comes to years is due to the dramatic change of publications in the last two years, which actually designed this field trajectory. Generally, the analysis shows that the first research was much more focused on eco-innovation-related topics such as sustainability and air pollution and management-related topics such as management and open innovation. In the second and third periods, terminology that is more technical occurred such as digital transformation, big data, data analytics, 3D printing, and deep learning. The term digital transformation appeared in the third period and demonstrated the more holistic approach of eco-innovation development through the whole process of digitalization and the use of many technologies simultaneously. Since this research takes place in H2 of 2022, the second period can be considered as completed. Thus, big data and the Internet of things are the two major sub-themes according to the authors' keywords (Fig. 2).

Figure 3 presents the thematic mapping of the first period where big data, technological adoption, data analytics, and Web services are still motor themes.

In the next period, some of the topics have already become basic themes because of their development and presence in the literature (such as big data, artificial intelligence from the technical side, and sustainability and business model innovation from pure eco-innovation). In this second time span, emerging technologies as a summarized concept of different topics are still under research, which also validates the urgency of this research. The Internet of things, agricultural innovation, and 3D printing seem to attract the researchers' interest. In this second time period, new hot topics evolved such as sustainable business model and shared economy in the context of eco-innovations. Virtual reality from another hand seems not to be central for the topic of eco-innovations so far (Fig. 4).

Figure 5 represents 28.5% of the publications no matter that the WoS extract was done in November 2022, and most of the research on the topic associated with

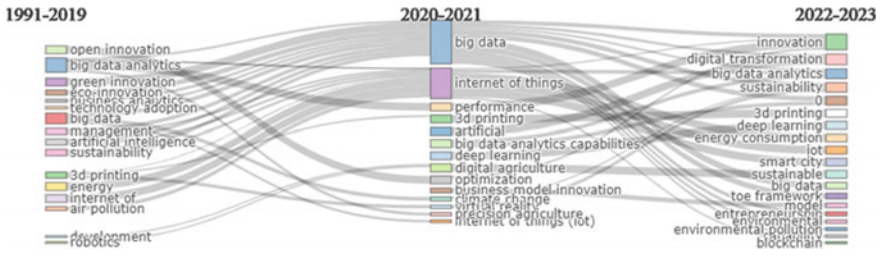

Fig. 2 Thematic evolution (3 periods) by author keywords

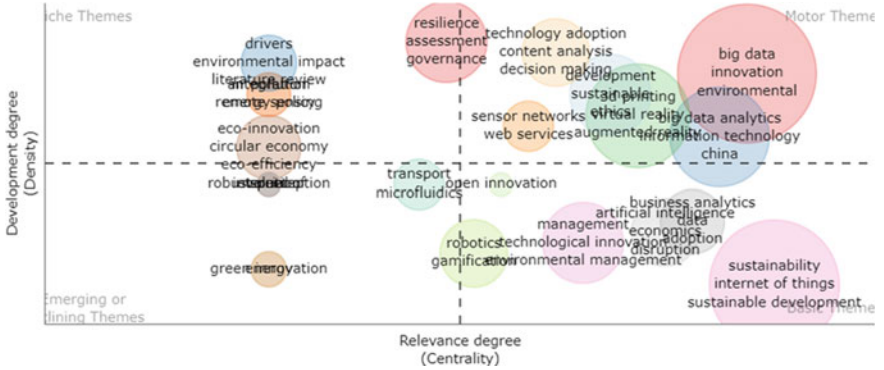

Fig. 3 Period 1 (1991–2019) by authors' keywords

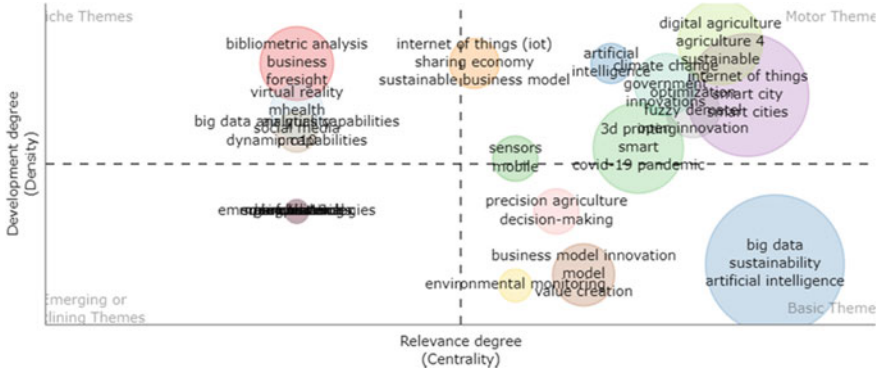

Fig. 4 Period 2 (2020–2021) by authors' keywords

2022 would be visible and available in the early months of 2023. However, the tremendous growth in the interest toward eco-innovations and technologies involved in their development has brought insights that we can undoubtedly categorize as 'hot press'. Digital transformation, circular economy, dynamic capabilities, integration, and digital innovation are just a small number of the more common terms used in this third time period. The more generalized approach in this period's research can also be recognized in the basic themes: the Internet of things and artificial intelligence, which both were already well developed in the previous periods. Still, digital twins and deep learning have not been analyzed so intensively. Digital public services and environmental dynamism have not been positioned at the center of research and still can be categorized as niche themes.

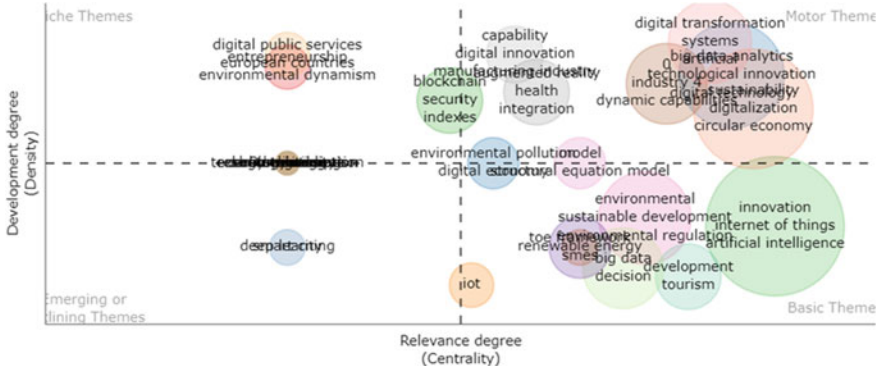

Fig. 5 Period 3 (2022–2023) by authors' keywords

The next bibliometric analysis focused on the thematic evolution is according to the words used in the titles of the scoped articles. The different approach here reveals more focused areas of research. In the last three years of research (second and third periods), topics such as supply chain, virtual reality, sustainable development, business processes, and machine learning appeared. This analysis was done on bigrams only (combination of two words) in order to reveal some hidden topics in addition to the evolution mapping of the authors' keywords (Fig. 6).

Only the third period is analyzed to reveal that deep learning with no doubts is under-researched when it comes to eco-innovation. In this dimensional perspective, the sectors of automobiles and agriculture appeared to be motor themes. Basic themes are already smart cities and sustainable development (maybe because of the increase in management articles in this period) (Fig. 7).

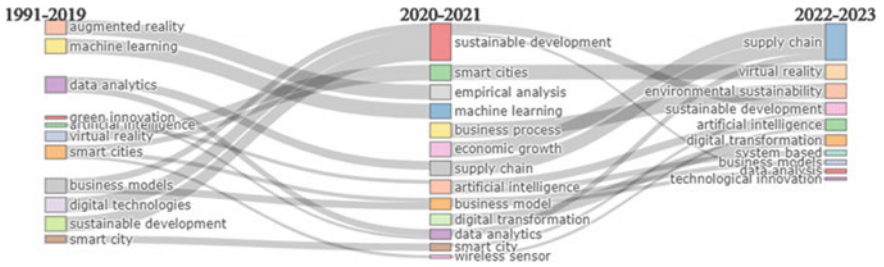

Fig. 6 Thematic evolution by titles (bigrams)

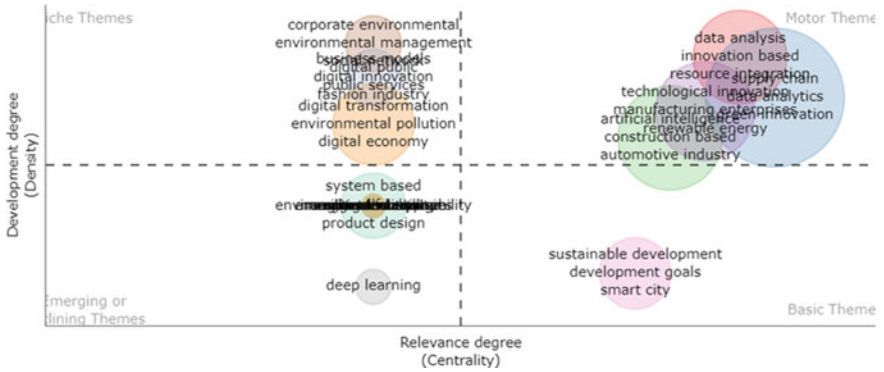

Fig. 7 Period 3—2021–2022 by titles (bigrams)

5 Conclusion

In conclusion, clearly, we can summarize that many of the emerging technologies are still under-researched on their impact over eco-innovations and their possible use in eco-innovations development. So far, Internet of things, big data, and artificial intelligence have received the interest of researchers. Some fields which different emerging technologies were utilized in the development of eco-innovations have been automotive industry and agriculture. From a management perspective, sustainable development, the business model for eco-innovation, and sustainability and digital transformation were the most analyzed topics as well as some tax management issues have been touched [15]. When it comes to business/corporate functions, clearly, supply chain and EMS were the fields where some researchers have already based cornerstones for further elaboration of these sub-fields.

Generally, from this study, we cannot define clear clusters for further research specialization. Mainly, the reason for this inability at the moment is the tremendous growth of research which is capable of changing the direction of such clusters at any point (the third cluster covers only less than a year of intensive research). However, the contribution from this research is the indication of some movements of research interest and identified niches and bases for its further development.

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Identification of Counterfeit Drugs Based on Traceability Ontology and Blockchain

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Abstract In the context of drug traceability, counterfeit drugs have a significant influence on customer health and trust towards the manufacturers. Therefore, the awareness of drug safety has led to a considerable need for improved traceability in the supply chain. To do so, we have proposed an approach combining blockchain and semantic web technologies to ensure drug traceability in a secure and trustworthy manner. The main contribution of this work is the construction of the Drug Traceability Ontology, then using this ontology alongside with the blockchain technology to check the drugs authenticity.

Keywords Blockchain · Semantic web · Drug traceability · Ontology · Sub-graph

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1 Introduction

The healthcare sector is one of the most sensitive sectors. Accordingly, awareness of human safety has drawn increasing interest to develop systems that enable safe and trusted use of healthcare data. In particular, drug traceability has become an important concern as it has a major impact on human lives, treatment outcomes and economic burden.

In this paper, we propose a drug tracking approach which follows the transportation and the storage chain that every drug goes through and predicts its authenticity. Our approach is based on a novel ontology that describes the drugs, their characteristics, the transportation and the storage chain. This approach is able to detect the counterfeit drugs thanks to the blockchain technology that provides an immune data and a trustful transaction history, that keeps track of every single transaction made in the system while checking the identity of the users who are responsible of such transactions. Our contributions could be resumed around (1) the construction of an ontology that describes drugs, their characteristics, the transportation and the storage chain (2) and the proposition of a query optimization method to identify and select relevant data during the authenticity verification step. The proposed approach is part of a research line with a wider scope, in which a framework for the traceability (ChainDrugTrac) has been proposed [1], in particular for pharmaceutical products. The framework is supported by mapping approach to update continuously changes in medical data sources relying on the semantics of the DrugBank[1] database [2]. The ultimate goal here is to complete the previous works by building the ontology that describes the drugs, their characteristics, the transportation and the storage chain. The proposed ontology relies on the DrugBank database and the drugs relevant information's description to generate the related semantics. The rest of this paper is organized as follows. In Sect. 2, we describe the proposed ontology for drug traceability. Then, we present our approach for drug authenticity verification in Sect. 3. Finally, Sect. 4 presents the results of our approach evaluation.

2 Drug Traceability Ontology

The Drug Traceability Ontology (DTO) (cf. Fig. 1) has been proposed mainly based on the DrugBank database knowledge [3]. This latter contains detailed FDA[2]-approved drugs; it contains 7387 drugs with taxonomic classification information. We have also used the concept of "Interval" from the Time Ontology[3] in order to represent the duration of every process that a drug goes through in the ontology. An "Interval" is defined by two temporal instants. Accordingly, the main concepts of DTO are

[1] DrugBank Online | Database for Drug and Drug Target Info.

[2] Food and Drug Administration.

[3] Time Ontology in OWL.

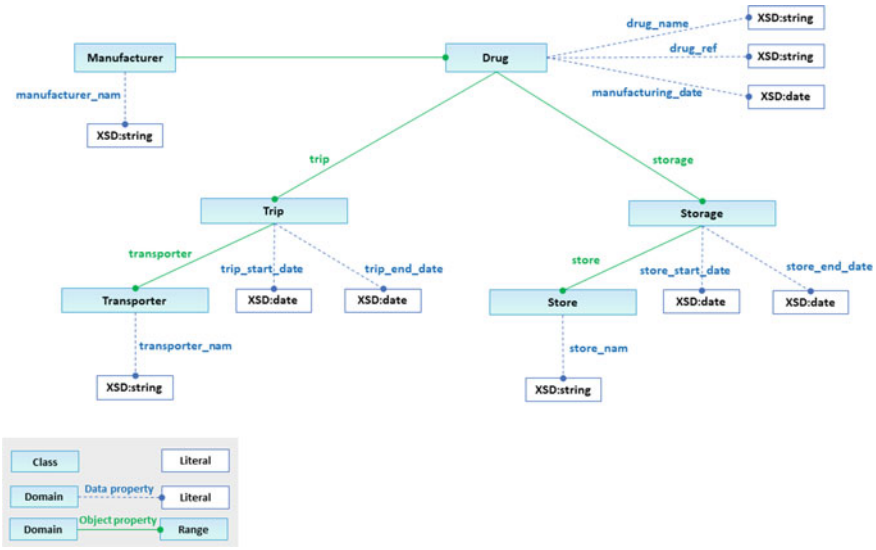

Fig. 1 Drug Traceability Ontology

- **Drug**: this concept represents a drug entity. It is linked to the set of data properties described in the DrugBank database such as the drug name, its reference and its manufacturing date.
- **Manufacturer**: the organization that owns and made the drug. It is recognized by its name.
- **Storage**: this concept represents the storage process. It is characterized by a start date and an end date. The storage process happens in a unique location (store).
- **Store:** this concept describes the location where the storage process has happened.
- **Trip**: this concept represents the transportation process that happens between two dates (a start date and an end date). It has one responsible transporter.
- **Transporter**: the person or the organization that delivers the drug between two points that could be stores or other transportation, the final destination (such as the pharmacy), or even another transporter.

3 Counterfeit Drugs Identification Approach

In this section, we first introduce our drugs traceability approach that relies on the populated Drug Traceability Ontology containing all the data deemed necessary to reach our objects. Then, we propose our proposed query optimization method that allows the selection of only relevant data during the verification of the authenticity of a specific drug.

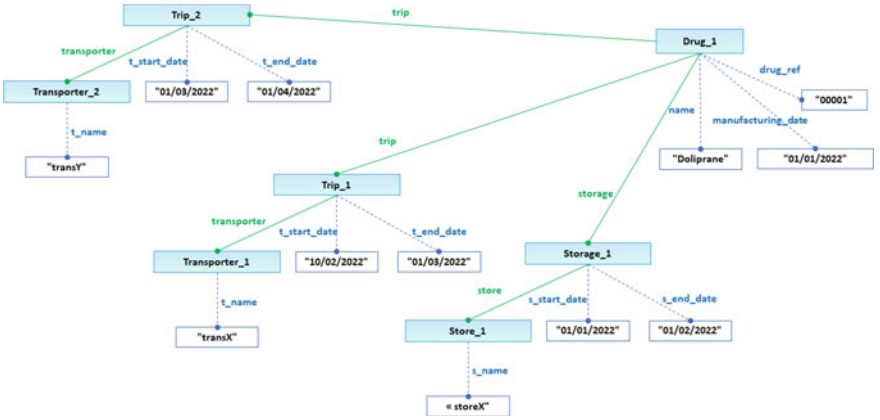

Fig. 2 Example of RDF graph built by the drug traceability approach

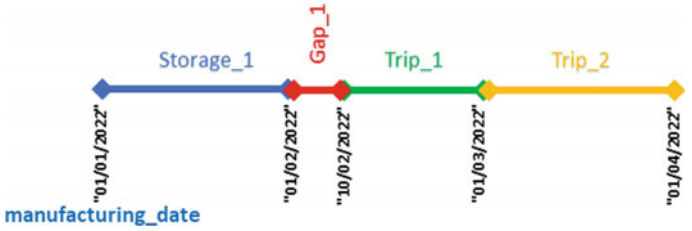

Fig. 3 Counterfeiting example timeline

The Traceability Approach

Our drug traceability approach is composed of two main steps; the first step is to feed the ontology with the produced drugs information. This populated ontology will be saved as an Resource Description Framework (RDF) graph in an Ethereum blockchain. We have used the Ethereum platform because of the smart contract system that offers a reliable level of control.

Then, every time a drug goes through a storage or a transportation process, a new triplet describing this process will be added to the blockchain to update the RDF graph.

The idea behind the traceability verification is to make sure that the location of every drug is well known between the moment of its fabrication and the purchase time. The solution is to query the RDF graph with SPARQL[4] and to look for any gaps between the different processes in the timeline. Finding an unjustified gap means a possibility for counterfeiting. Figure 2 shows an example of a possible counterfeit drug.

In Fig. 2, we can see an example of drug "Drug_1" having one storage process and two trips. Figure 3 shows the timeline of those three processes that "Drug_1" went

[4] SPARQL Query Language.

through. The drug is considered safe if there are no gaps between the time intervals of those three processes, from the manufacturer to the customer. The timeline presented in Fig. 3 shows an unjustified gap between the "Storage_1" process and "Trip_1", i.e. there is no data about the state or the location of this drug between 01/02/2022 and 10/02/2022. As a result, it will be considered as counterfeit.

Selecting a sub-RDF Graph From the Blockchain As every transaction made in the blockchain has to go through all the nodes in the network, which means that the larger the requested data, the longer the required read time. Indeed, querying a linked RDF data requires to read the whole graph, as a result, a large amount of data has to be treated by all the nodes in the blockchain network. This process will imply a slower response time. In order to solve this problem, we propose to read, instead of the whole graph, only a sub-graph that contains the information that are relevant to the requested drug. Thanks to DTO, we can easily select the information that contains the requested drug concept individual and its data properties, all the Trip's and Storage's individuals that are directly linked to the requested drug as well as all their properties. The requested drug is distinguished by its reference.

This method will allow to read a smaller portion of the RDF graph that contains the necessary information to trace the selected drug.

The traceability checking process is made through three steps:

1. Reading in the blockchain the data concerning the requested drug (the sub-graph data). To select such sub-graph, we used SPARQL queries to select the relevant data related to the referenced drug. This step will help improving the system performance.
2. Constructing the sub-RDF graph using those data to get it ready for querying.
3. Query those data looking for any gaps in the timeline. This step will also use SPARQL queries to look for any unjustified gaps in the timeline of the drug processes (storage and transportation).

4 Experiments

We have implemented our system using Ethereum[5] platform, the smart contracts are developed using Solidity.[6] We also have used SPARQL to query the RDF data. In these experiments, we have used three sets of synthetic drugs that contain 25, 50 and 100 drug individuals, and 393, 768 and 1518 RDF triples, respectively.

Table 1 and Fig. 4 show the run time as a function of the graph size for three testing sets. It details the execution time of each step of the traceability checking process when applied on a sub-graph that contains the necessary data and compares it to the traceability process running time when applied to the whole graph. For the first step of the traceability checking process, only reading the relevant data halved the run

[5] Ethereum web site.

[6] Solidity documentation.

Table 1 Comparing the run time of the traceability checking process between requesting the full RDF graph and the sub-graph

Drug number	Triple number	Blockchain reader time		Graph construction time		Query time		The whole process	
		Full graph	Sub-graph	Full graph	Sub-graph	Full graph	Sub-graph	Full graph	Sub-graph
25	393	5.474	3.269	0.022	0.003	0.119	0.117	5.615	3.389
50	768	18.198	8.891	0.039	0.003	0.121	0.117	18.358	9.011
100	1518	Time out	27.201	0.079	0.003	0.139	0.117	Time out	27.321

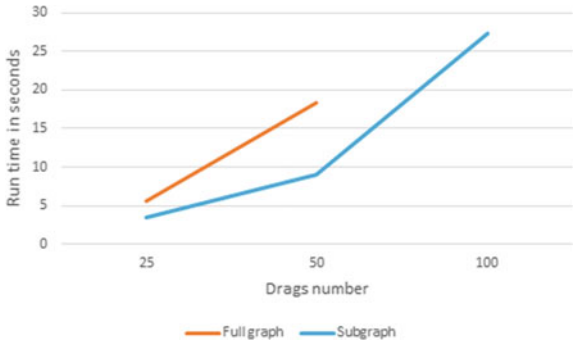

Fig. 4 Comparing the global run time of the traceability checking process between using the full RDF graph and the sub-graph

time compared to reading all the data. We can also notice that reading the full set of data for 100 drug individuals has returned a time out.

In addition, constructing the graph from the data has given an incremental time for the full graph case (because it depends on the incremental data size), but a significantly smaller and stable run time for the sub-graph case. This refers to the fact that we always read the data that are relevant to only one drug and we obtain sub-graphs with fairly similar sizes. The querying step has returned similar results as the previous step for the same reasons; an incremental query time for the full graph (that depends on its size) and quite stable run time for the sub-graph case. As a result, the traceability checking process global run time has shown that only using the relevant sub-graph has performed a way better (about twice faster) than using the full graph that has also returned a time out for 100 drugs graph (with 1518 triples).

We can conclude from this comparison that using a sub-graph with only relevant data will allow the system to perform much better than using the full graph with the large majority of data that are not relevant.

5 Related Works

The release of the blockchain systems has resolved the data immunity problem. The blockchain keeps track of all the transactions made within the platform, all the data

exchange history is well guarded and accessible any time. On top of that, the smart contracts system proposed by Ethereum [4] platform has pushed data security further and added more control to data access. Since the data in the blockchain is immune and traceable, it has been used to keep track of the supply chain of physical goods [5]. Other approaches combined the blockchain with the semantic web that contributes with the semantic links so the blockchain can benefit from this functionality and save the data as RDF triples [6, 7]. However, this comes with a downside that is relevant to reading and querying the RDF data compared with other data format [8]. Some approaches [9–11] have addressed this problem, and they proposed to link the blockchain content with an external triple store via the URIs. This way, they can keep the system performing while, also, keeping the benefits of the semantic data.

Among the most powerful features of the semantic web are the ontologies. The ontology allows the modelization of data according to recommended standards by W3C such us owl.[7] When the blockchain relies on ontologies and RDF to describe their metadata and content, it can benefit from another W3C standard: the SPARQL queries. SPARQL allows querying, efficiently, the semantic data stored as triples inside or outside the blockchain. Authors in [5, 12, 13] have used an ontological models to represent their data.

6 Conclusion

In this paper, we have proposed an approach that ensure the tracking of drugs from the manufacturing moment till its deliverance to the customer. We first defined the Drug Traceability Ontology that models the drugs descriptions and all the processes that they may go through. We then proposed the traceability checking approach to detect the counterfeit drugs. In future work, we plan to replace the querying phase with a reasoning process by defining semantic rules not only to predict counterfeit drugs, but also to predict other events that may accrue to the drugs during the storage or the transportation processes such as non-compliance with storage or transport conditions. This approach can also be generalized on other types of products and physical goods.

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[7] Web Ontology Language (OWL).

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Gamified Proposal to Stimulate Reading in Primary School Students

Hugo Arias-Flores, Blanca Montenegro, and Mireya Zapata

Abstract The lack of motivation and interest in reading in students is a fundamental problem since the minimum levels of reading competence for their age and educational level are not being reached. This research was developed with the aim of identifying motivation problems and using gamification as a pedagogical strategy to encourage reading in students. The study had a quantitative and descriptive approach that involved 30 students. Data were collected through the survey technique. The results of the research showed that reading demotivation is due to the lack of support at home, boredom and low reading comprehension that results from the use of traditional resources such as books that fail to capture and maintain the attention and interest of students. In addition, it was identified that the students present as main reading difficulties: problems of recognition of compound phonemes, lack of reading habit and motivation, as well as the deficit of reading comprehension, so it was necessary to implement a virtual strategy based on gamification through the digital tools Genially and Classflow. With the development of the research, it is concluded that the use of gamification as a pedagogical tool allows to motivate the reading of children, since its interactive elements and rewards create a stimulating and pleasant atmosphere that generates a positive impact on the performance of the student body.

Keywords Pedagogical strategy · Gamified proposal · Virtual environment · Stimulate reading

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1 Introduction

At present, there is a lack of interest in reading. Globally, more than 387 million children of primary school age (approximately 6–11 years old) are not reaching minimum levels of proficiency in reading which means that more than half (56%) of all children are unable to read competently for their age and academic level [1].

The reality in Latin America is much more complex, since less than half of the population reads. In Chile, there is a 20% non-reading population; in Brazil, it is 50% as in Venezuela; in Argentina, it is 45%; and in Colombia, it is 44%, but these figures are even more depressing if one considers the motivations to read that in these countries are not for pleasure but for exclusively academic reasons or for the acquisition of general knowledge [2].

In Ecuador, only 73.5% read in contrast to 26.5% who do not spend any time for reading; of the latter percentage, 56.8% do not read due to lack of interest and 31.7% due to lack of time and the rest due to concentration problems and other factors [3].

These figures show the deficient habit of reading worldwide and locally, which is a concern of educational agents and organizations related to education, science, and culture because mastering reading is one of the essential factors for the integral formation of the person, in terms of its scope oral and written expression is developed, spelling and intellectual and social skills that allow us to make judgments, assessments, points of view and act according to their own ideologies [4].

Promoting reading in students requires innovative strategies that contribute to the training of students, construction of knowledge and meaningful learning. In this sense, active methodologies that integrate information and communication technologies seek to generate changes in the classroom, transforming rote learning to an interactive one, since it originates in the interests, needs, learning styles, and context of the student [5].

The low interest in reading in primary school students and the lack of motivation added to the deficient reading comprehension are problems detected in teaching practice. The pandemic and the change of education to virtual modality deepened this problem in the student body. This research presents a proposal, in which gamification used as a pedagogical strategy in the classroom helps the teacher to motivate students to read in a fun way, because by not having virtual teaching resources, and maintaining interruptions in the face-to-face, the teacher must maintain interest in the student body.

1.1 Related Works

In the pedagogical field, several studies have been developed focused on improving basic learning processes such as reading, in which gamification has been applied as an innovative strategy. Prados et al. [6] point out that implementing gamification in learning environments allows satisfactory results both in reading comprehension and

in promoting positive attitudes in students. The emotional and social impact generated by the gamification strategy by its design, multiple challenges and obtaining new knowledge, improves students' skills, allowing teachers to create collaborative environments where their students can solve problems creatively without fear of making mistakes [7].

Gamification as a strategy increases engagement in the educational environment, by incorporating elements of the game, with the aim of generating levels of involvement equal to those usually produced by games, improving certain skills, introducing objectives that give a purpose to learning, involving students, optimizing learning, supporting behavior change, and socializing [8, 9].

In this sense, the application of gamified strategies has advantages such as the stimulation of effort for students, increased interest of students in the subject, positive feedback through the evidence of failures and areas for improvement, promotion of teacher work in the classroom, the possibility of exercising a more exhaustive control of the level of students in less time and that allows to achieve the objectives expressed in the official curriculum to through the favoring of the inclusion of students in the proposed activities [10], it constitutes an innovative, motivating, and pleasant way of teaching and learning, because the game undoubtedly allows human development because it stimulates the personality, supports social skills, and encourages reasoning and logical and critical thinking [11, 12].

2 Methodology

2.1 Participants

The research involved 30 students with a mean age of 8.23 (SD = 0.43), where 77% (23 students) were eight years old, and 23% were nine years old. In terms of sex, the group was composed of 16 women (53%) and 14 men (47%). Participants belong to Ecuador's public education system. The socio-economic level is medium and medium–low. For the selection of participants, inclusion and exclusion criteria were considered: students who wished to participate in the research, students who answered the survey in the established time and have informed consent and assent to participate in the research.

2.2 Instrument

A questionnaire composed of 11 multiple-choice questions was used, which has a consistency of Cronbach's alpha = 0.896, in which the causes that produce demotivation for reading were addressed, as well as basic aspects for the design of the virtual gamification strategy [13]. The application of the survey was conducted by

several means: Zoom, Teams, via telephone and through Google Forms. The descriptive analysis of the variables was conducted, and the strategy to be used as a pilot in the classroom was defined.

3 Results

The aspects analyzed show that reading is a fundamental part of learning and should be the basis of the training process according to teachers; however, for students, it is not at all, because they consider that it is not always useful (43%), which is why it is only practiced to comply with school activities (50%) or by demand of others (23%).

The causes of reading demotivation are varied, ranging from lack of support at home (67%), to boredom (40%), and low reading comprehension (25%) that results from the use of traditional resources such as books (80%) that fail to capture and maintain the attention and interest of students. The main reading problems identified in students are problems of recognition of compound phonemes, lack of reading habit, motivation, as well as reading comprehension deficit.

3.1 Technological Proposal

The proposal is structured by cover, introduction, description of the digital gamification tools used and activities. Each of the proposed activities is based on a reading and to comply with the activities, all the tasks set must be fulfilled. Once the activity is over, you can get a badge.

The proposal, according to the digital strategy used, is divided into two main sections:

First: The tasks to be developed in Genially are presented (Fig. 1).

Activity 1: Participants start by entering the library using the key and select a book from the shelf (Fig. 2).

Activity 2: Students go to the laboratory and must solve an experiment, for which they must select a book and solve the questions (Fig. 3).

Activity 3: Students now enter the science classroom and must solve the challenges posed (Fig. 4).

Second: The tasks to be developed in class flow are presented (Fig. 5).

Activity 1: The student must select one of the maps and solve what was raised in the reading (Fig. 6).

Activity 2: Students must select the story they want to read, each image has a different adventure (Fig. 7).

Activity 3: Students must help cross the river, for which they must respond to the challenges posed (Fig. 8).

Fig. 1 Start of activities

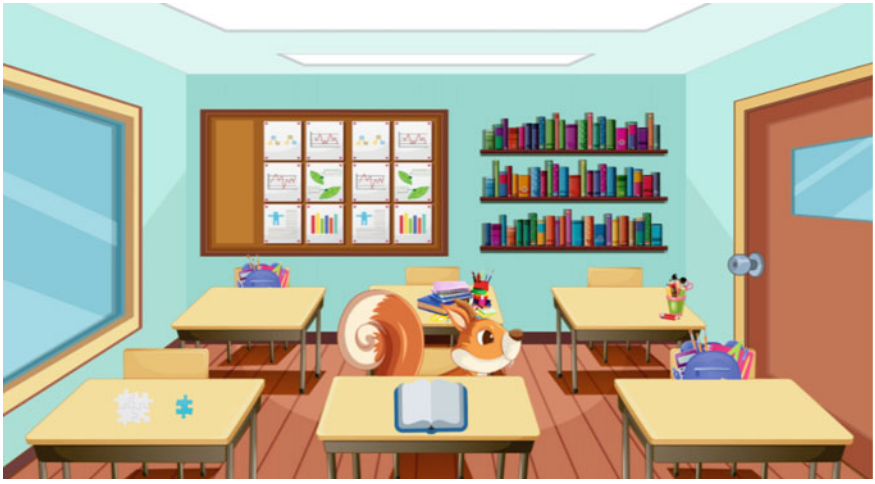

Fig. 2 Activities in the library

The last section of the proposal corresponds to the badges that will be awarded to students according to their progress.

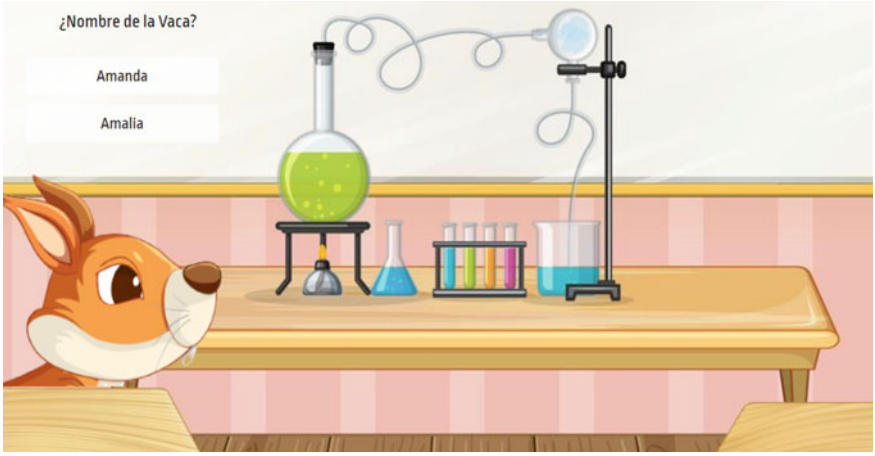

Fig. 3 Activities in the laboratory

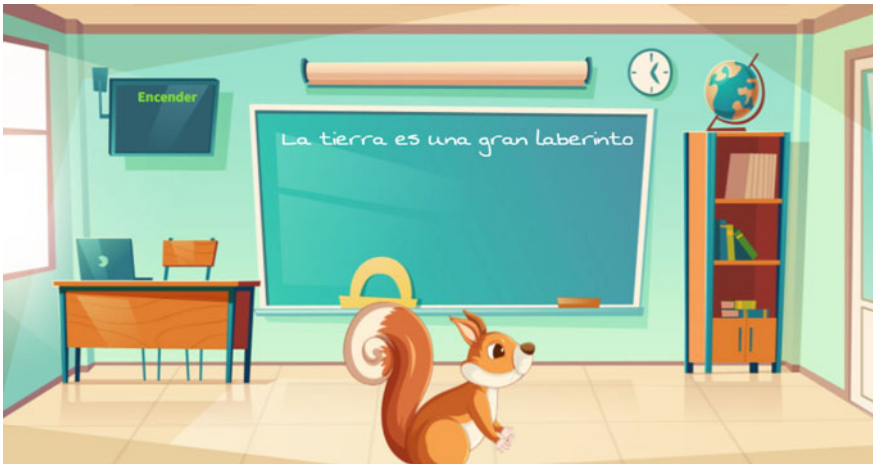

Fig. 4 Science classroom activities

4 Discussion and Conclusions

This work analyzed the problem of motivation for reading in children from 8 to 9 years old, in which a gamified strategy was applied to encourage reading play. Preliminary results confirm that its application has positive results, since improvements in reading comprehension and motivation for reading were found. Designing a guide that allows the teacher to adapt gamified strategies in the classroom and direct them toward reading will allow students to improve their reading skills. This guide

Fig. 5 Read and have fun

Fig. 6 Map selection

contains elements that can be constantly fed and address other issues in which active methodologies contribute to training.

In this regard, they have conducted the previous research where the linguistic status of children has been favored. For example, the article by Ramos-Galarza et al. [14] created a toy that improves the emotional part of children and with this helped the skills of articulation and understanding of language. Likewise, the digital resources provided an opportunity to maintain interaction with children and continue with their learning process during the pandemic, participate in games and stay connected with their friends and teachers [15].

Fig. 7 Selection of the story

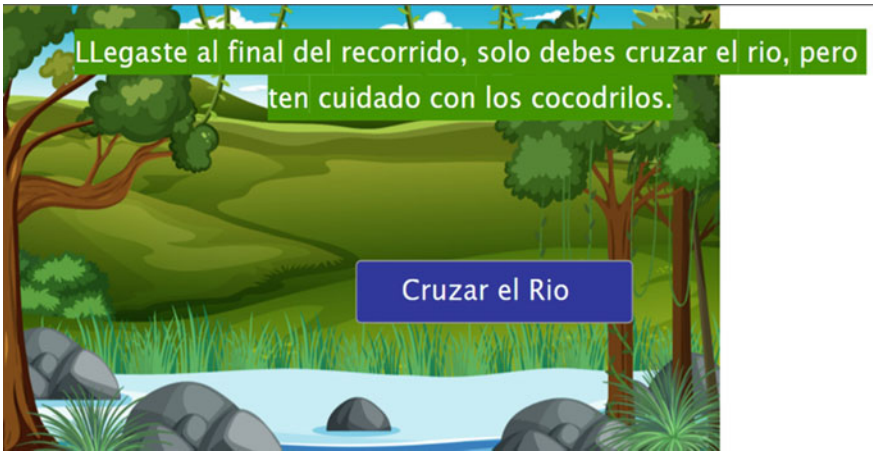

Fig. 8 Crossing the river

Technological advancement offers countless tools adaptable to gamification that can be used to improve reading comprehension in basic education students. These educational resources can be board games [16], virtual assistants and robots [17], and gamified virtual environments that simulate learning scenarios that motivate participants in their training [18].

In future, it is proposed to develop new strategies through technological devices that contribute to the strengthening of reading in the student body, considering that active methodologies are a tool that is in constant evolution and can generate great contributions; at the same time, it could cause rejection in teachers. Because developing these resources takes more time in its elaboration.

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Hybrid Learning in Schools: Analysis of the Community's Role in ICT-Based Learning Facilities Management

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Abstract The background of the unprepared implementation of hybrid learning actually depends not only on teachers but also on the readiness of schools, students, parents, and the community. In fact, the demands for community participation at this time are becoming greater and greater. The purpose of this study is to investigate the role of the community in the management of ICT-based learning facilities, in order to optimize the success of hybrid learning. A multi-case design research approach was used in this study. This research was carried out in three regions with different conditions (low, medium, and advanced), with three data collection techniques, namely interviews, observations, and documentation studies. Data triangulation is carried out to check the validity of the data, while data analysis is carried out with the stages of data reduction, presentation, and withdrawal of impulses, then cross-case data analysis is analyzed constantly. Research findings show different strategies, roles, and forms of community participation according to the conditions of regional peculiarities, but in general, the form of community participation in the form of material and non-material can also be active and passive. This research contributes practically and theoretically.

Keywords ICT-based learning facilities · Hybrid learning · Pandemic

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1 Introduction

Education in the digital era is the education of the era of globalization that is affected by the advancement of ICT, and existing technological advances have facilitated all the complicated challenges faced by humans. The rapid development of ICT has changed the views, ways, and patterns of human life. The application of ICT in the world of education is actually not new, because ICT and education go hand in hand and in rhythm [1, 2]. The existence of digitalization in the field of education is strongly felt in the use of computer-based devices and the Internet, for example, in the form of laptops and smartphones that are able to run various applications for learning (e-learning).

When the world of education is shaken by the presence of a pandemic, making it no longer possible to interrupt face-to-face learning between teachers and students, the availability and use of ICT become a solution to overcome the education crisis [3, 4]. But it is possible to overcome this shock and to turn a crisis into an opportunity. In schools that are quite developed in Indonesia, although not yet optimally used, the availability of ICT to meet the needs of the learning process of both teachers and students in recent years is quite widespread and has been considered common as a necessity, not a luxury, expensive, and rare item [5, 6]. In reality, online learning during the pandemic is considered problematic because schools and teachers are not ready, expensive, ineffective, troublesome for parents and boring. Research by Dahlia and Supriatna [2] about the response of parents in Indonesia to the implementation of online learning shows that in general, parents do not agree with online learning because they consider online learning to be considered ineffective, besides that teachers in using learning media are less varied and wasteful of Internet costs so that it burdens parents, especially out-ga who have low financial criteria. Furthermore, the results of research by Sormin et al. [7] show that the percentage of mothers experiencing stress due to the implementation of online learning.

The unprepared implementation of online learning actually does not only depend on teachers but also on the readiness of schools, students, parents, and the community [8]. Even demands for the involvement of parents to accompany their children more intensely occurred, as well as demands for the community to contribute more to the implementation of education in schools. An important step is to successfully protect student health and prevent students from losing learning, namely using a hybrid learning model [9, 10]. Various research results show that hybrid learning models are more effectively applied than just applying online-based learning. The unavailability of learning facilities to support the implementation of hybrid learning both in schools and at home for students is a problem that must be immediately found a solution [11, 12].

Quality education in the current context, namely the implementation of hybrid learning, requires integrated responsibilities between schools, government, parents, and the community [13, 14]. The availability of adequate learning facilities for students requires good management of the school, as well as participation from the community [12, 15]. In this study, there were nine (9) excellent schools that were

used as research targets. The nine flagship schools located in three different districts/cities with different statuses. Tana Tidung District, North Kalimantan Province, is a newly born area with inadequate infrastructural support (low level). Bondowoso District, represents a district with middle economic status, and has just emerged from the status of the poorest region in East Java province. Meanwhile, Malang city represents developed urban schools.

This research refers to the main aspects, namely the trend of information technology development leading to digitalization and the pressure of COVID-19 which affects various aspects of human life, including education and schooling [10, 16]. The orientation of learning facilities management in optimizing the success of hybrid learning implementations in Indonesia basically refers to the availability and utilization of learning facilities in the midst of uncertainty when the pandemic ends, it is one of the important factors in optimizing the successful implementation of hybrid learning; therefore, the availability of learning facilities for students needs to be ensured, where the management of learning facilities is the key in ensuring that learning facilities are available to students [17, 18]. This situation is the initial reasoning for the need for research that leads to an analysis of the role of society and parents in the learning facilities management model in optimizing the successful implementation of hybrid learning in the context of the digital era and pandemic.

2 Method

A qualitative approach with a multi-case study design is used to identify the role of the community in the management of learning facilities in supporting the success of hybrid learning. The research locations were conducted in nine excellent schools spread across three districts/cities from 2 provinces in Indonesia, each of which represents low, middle, and advanced status. The researcher aims to understand the phenomena that occur emis in the research subject, where the researcher describes the research results in the form of words obtained during observations, documentation studies, and interviews with a number of informants.

Structured interviews were conducted with principals, teachers, education staff, parents, and community leaders. Meanwhile, observations are made to deeply recognize the condition of schools and communities related to the focus of the study. Observation is important to make in order to obtain more comprehensive data, by completing and testing the validity of the data by comparing the results of incomplete interviews with the results of observations. The triangulation process is used for the measurement of the validity of the data. Some of the stages carried out in the triangulation process can be described as follows: (1) comparing interview data, with observation data; (2) comparing one's circumstances and perspectives with those of others; (3) compare the results of the interview with the content of the relevant document; (4) comparing facts with one or more theories as a comparative explanation; and (5) discussions with peers. Data analysis begins with the process of systematically searching and compiling interview transcripts and field notes, then the data is

systematically sorted according to the research focus. In more detail, the data analysis follows the recommendations of Miles et al. [19], namely data reduction, presentation, and drawing conclusions. The presentation of data is based on establishing the focus of the research found through this study. In addition, cross-case data analysis is carried out in a constant comparative manner.

3 Finding

3.1 The Role of Schools, Parents, and Communities

Schools, parents, and communities synergize with each other in optimizing the successful implementation of hybrid learning in schools. Parents of students are involved in a hybrid learning-based learning program plan both from the availability of learning support devices, namely communication technology tools and Internet networks as a support for the implementation of hybrid learning learning. Schools together with parents and the community share their respective roles in providing assistance to student learning activities. The school provides full mentoring and supervision when learning is carried out face-to-face. Meanwhile, when learning is carried out online, parents have an important role to accompany student learning activities in their respective homes.

The roles of schools, parents, and the community from the three research locations are the same, especially in the success of online learning during pandemic. Parents are directly involved in hybrid learning, and this is very visible when parents provide learning support facilities such as smartphones and internet networks to their children, especially to support online learning. More specifically, the school collaborates with organizations in the school environment to support the availability of learning facilities in schools, for example, SMP Negeri 1 Bondowoso by collaborating with the Tutoring Institute (LBB) where the school buys a learning management system (LMS) account to support learning, and the results of the collaboration produce three learning studio rooms.

The role of schools as educational providers and providers of learning facilities makes this educational institution in accordance with its functions and objectives. What affects the success of the goal of preparing the equipment and equipment needed for the implementation of the educational process and providing meaningful learning alternatives for students to be able to participate. To optimize the success of hybrid learning, it is necessary to have the role of several parties including parents, the role of parents, namely by facilitating, supporting, and motivating and monitoring directly or indirectly. In addition, the role of parents is as school partners in providing learning facilities to students. In addition to the role of parents, there is also the role of the community, where the role of the community controls the use of learning facilities to optimize the success of hybrid learning or it can be said that the community is the supervisor of the learning process in an unstructured manner. The planning process

Table 1 Role of schools, parents, and society

Case	Malang city	Bondowoso district	Tana Tidung district
The role of schools, parents, and communities	a. The role of schools: Principals and teachers have similar perspectives regarding the successful use of learning facilities, namely through the preparation of supporting facilities and infrastructure, both hardware and software devices b. The role of parents: support when learning from home by providing supporting facilities such as cellphones, laptops, and Internet networks c. Community role: through policymakers by providing learning quotas	a. The role of schools: the use of technology as a means of learning b. The role of parents: facilitation of learning support (smartphones and Internet networks) c. Community role: collaborating with organizations around the school, for example, by purchasing an LMS account to support learning, as well as providing a learning studio space	a. The role of schools: preparing equipment and equipment for the implementation of hybrid learning b. The role of parents: facilitating, supporting, and motivating and monitoring directly or indirectly c. The role of society: unstructuredly control the use of learning facilities to optimize the success of hybrid learning

for optimizing facilities in hybrid learning pays attention to several things such as (1) flexibility, utilizing online surveillance tools and supporting platforms, (2) easy accessibility, students easy to access with remote management, (3) safe learning, with the LMS will create a comfortable and safe learning environment, (4) a personalized approach, with online learning easier for teachers to see the capturing power of learners, and (5) detailed reports, which can provide broad insights for some parties. In this planning process, competent people are involved, so that the formulation of learning facilities are more targeted and effective. In more detail, the findings of the roles of schools, parents, and communities are shown in Table 1.

3.2 Forms of Parent and Community Participation

The form of parental participation in the success of hybrid learning from the three locations is to play an active role in communicating with schools regarding the problems faced by schools in implementing hybrid learning. The contributions given

Table 2 Forms of parental and community participation

Case	Malang city	Bondowoso district	Tana Tidung district
Forms of parental and community participation	Play an active role in communicating with schools regarding problems faced by schools in implementing hybrid learning	a. Material and non-material support	a. Parent participation: support student activities including providing learning facilities and accompanying when learning is at home or carried out online
		b. Communication with homeroom teachers regarding the operation of digital platforms	b. Community participation: as much as possible to provide networking and supervision in using ICT

include (1) providing both material and non-material support to schools, (2) coordinating with teachers to solve specified problems, (3) providing assistance with unlimited zoom account providers, and (4) being involved in providing learning materials carried out by parents and other parties, one of which is from tutoring. The form of parental participation is to provide support in the form of materials to their children such as smartphones, always communicating to the homeroom teacher when experiencing difficulties in operating the e-learning platform, as well as the assistance of credit and learning quotas for students.

The form of parental participation in the management of learning facilities for the optimization of hybrid learning is by supporting all activities including providing learning facilities such as laptops, cellphones, and networks and accompanying when learning at home or carried out online. Meanwhile, community participation is as much as possible in providing networks and supervision in using media tools. For example, the participation of parents at SMPN Terpadu Unggulan 1, Tana Tidung District, is also quite enthusiastic when there is a teacher's visit to the homes of students who have to pass through the river, namely by providing speed boats as a means of crossing transportation, that way this will be one of the easy accesses to be able to get to the location or home of students, not infrequently parents also give their garden fruits to teachers as a sign of gratitude. Parental participation is not only in student academics but also technical and non-academic matters that support the success of hybrid learning. The form of participation of parents and society more concisely can be seen in Table 2.

3.3 School Strategies in Providing Learning Facilities

The strategy in optimizing the successful implementation of hybrid learning in Malang City is to build open communication with parents of students about the urgency of implementing learning with a hybrid learning model in schools. Socialization activities to parents of students are carried out online using applications such as zoom as part of an effort to introduce hybrid learning forms to parents of

students. Meanwhile, in Bondowoso Regency, the strategy carried out is to involve all teachers, parents, and interested parties in the management of education. The existence of socialization activities to parents of students is carried out online using applications such as zoom as part of an effort to introduce hybrid learning forms to parents of students. The principal also applied for assistance to the local Education Office to continue to provide assistance in the nature of facilities and training to teachers.

Some of the strategies formulated by schools in Tana Tidung Regency are budgeting some facilities from school finances for student learning facilities, preparing activity sheets for students who are not reached by Internet connections, and reformulating the school's vision, mission, and goals. The impact of the strategy implemented is (1) all students get their right to learn even though some of it is carried out at home, (2) it can improve the digital literacy skills of teachers, students, and parents, and (3) the good cooperation between facilities and infrastructure officers with teachers and students is shown by reports from teachers and students regarding equipment that needs to be handled immediately. Table 3 shows a summary of school strategy findings in hybrid-based learning facilities management.

Further in Fig. 1, showing the role model of parents and society in the management of learning facilities in optimizing the success of hybrid learning in schools. The optimization of hybrid learnig in three regions shows differences in its implementation, and this is shown by different processes of planning, organizing, implementing, and evaluating. The management process in Malang City in general is more coordinated by the school and the local government, while for Bondowoso Regency, it is coordinated by the school, in contrast to Tana Tidung Regency where the management

Table 3 School strategies in the management of learning facilities

Case	Malang city	Bondowoso district	Tana Tidung district
School strategies in the management of learning facilities	a. Build open communication with parents of students about the urgency of implementing learning with a hybrid learning model in schools b. Work with organizations around the school	a. Involving teachers, parents, and interested parties in the management of education b. Socialization to parents using zoom, as well as efforts to introduce hybrid learning c. The principal applies to the local Education Office for teacher training	a. Budgeting some means of school finances b. Set up activity sheets for students who aren't reached by an Internet connection c. Reformulation of the school's vision, mission, and objectives

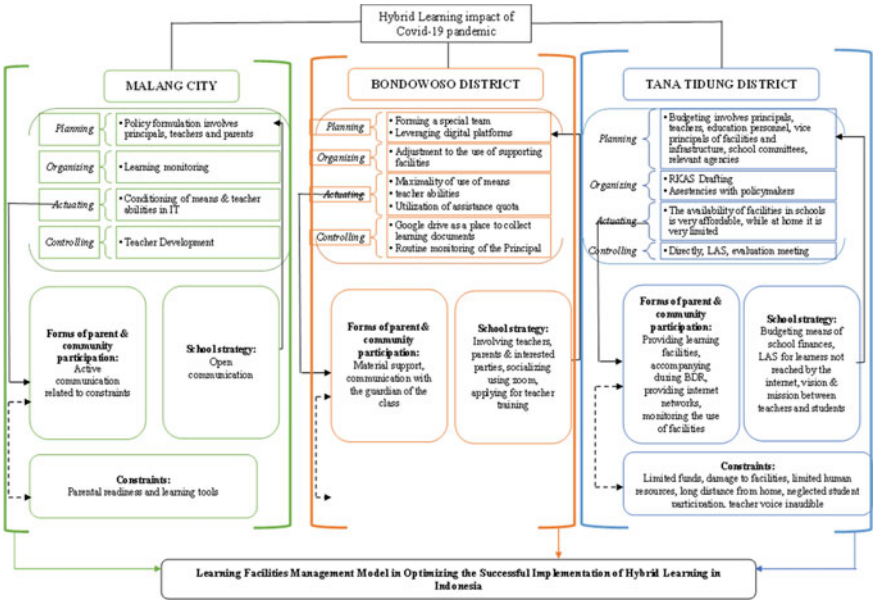

Fig. 1 Role models of parents and communities in ICT-based learning facilities management

process is coordinated by the school and parents, this shows a high synergy between the school and parents.

4 Discussion

The different conditions of each region are unique for each reason, in the concept of school-based management, autonomy is given to schools in developing their schools based on excellence in each region [20, 21]. Related to the concept of independent learning initiated by the government, all the uniqueness or excellence of the school can be developed toward achieving the objectives of the learning independence policy [13, 22]. This includes community involvement in supporting the policy.

The form of participation from the community based on findings in the three regions can be grouped into two, namely in the form of financial and non-financial support. Meanwhile, it can also be grouped types of participation, namely passive and active. Passive participation is support in the form of attitudes, behaviors, and actions that assist schools in implementing educational programs and services, while active participation is direct community involvement in every activity. The research findings show that the form of participation is adjusted to the characteristics of each region. As an example of the findings in Tana Tidung District, parents facilitate free water transportation to help students access to school. The mahakam River separates

the school from the student's home, making this an unusual situation, so to get to the school, there are several students who have to cross the river. Not only that, the active role of parents in learning activities from home also provides supervision of students by using student activity sheet (LAS) given by the school. The use of LAS is based on the obstacles faced by the community related to the availability of ICT at home which still has many obstacles such as the lack of availability of digital devices and Internet connections.

The findings in Bondowoso District are related to the form of community participation in facilitating independence learning in the form of assistance in providing LMS accounts for schools that do not yet have their own LMS platform, furthermore, assistance from school organizations, namely in the form of assistance in the form of complete physical facilities in supporting hybrid learning. Furthermore, parents contribute voluntarily, seeing the varying financial circumstances of parents so that schools do not compel parents to provide financial support. Furthermore, there is an SMS gateway which is used as a means of communication between parents and students. The findings in Malang City, in addition to the provision of ICT-based learning facilities by schools and communities, forms of community participation in are also carried out by several agencies such as universities. In an effort to increase university participation, schools empower interns as classroom teachers then reviews curricula with courses that are appropriate to the subject and empower certain departments within the university to innovate learning media for learners.

Related to various policies from the government in the field of education during the pandemic, it is important for schools to increase community participation, and innovative efforts from schools are required to boost community involvement [23, 24]. Schools need strong partners from the government, parents, businesses, and stakeholders in the local community [25, 26]. Community participation is recognized as a significant factor in further developing school quality, especially in the context of learning facilities management to optimize the success of independent learning [17, 27]. The school's strategy in increasing community participation can be carried out through open communication with the community regarding the urgency of implementing hybrid learning, giving responsibility to the community in terms of school development, community involvement in various activities, and fostering trust [22, 28]. All of the challenges associated with implementing hybrid learning, particularly during the pandemic, can be minimized by working together with all education stakeholders to fulfill schools' responsibility to provide high-quality educational services [13, 29].

5 Conclusion

Schools need to establish good collaboration with the government at the local level, parents, stakeholders, universities, industry, and various institutions around the school in supporting the effectiveness of learning facilities management in supporting

the success of hybrid learning. The role, form, and strategy are adjusted to the uniqueness and peculiarities of each region. The role of parents today is not only to accompany students while studying from home, parents also need to strive for the availability of ICT-based learning facilities for their children. As the research findings with various types of participation, both material and non-material, as well as in the form of active or passive participation. This research has at least contributed to two aspects. Theoretically, the findings of this research add references related to the role of the community in the management of learning facilities in the implementation of hybrid learning, and practically, the findings of this research provide alternative scenarios that can be applied to make the implementation of hybrid learning a success. This research is also inseparable from limitations, this research was only carried out in educational institutions at the basic level, and further, research can be carried out at a higher level of education.

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Machine Learning Approach for Diabetes Prediction

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Abstract One of the most deadly diseases, diabetes mellitus, affects many people. Diabetes mellitus can be brought on by many different reasons, including age, obesity, inactivity, genetics, a poor diet, high blood pressure, and others. Diabetes raises one's risk of contracting diseases, such as heart disease, kidney disease, stroke, visual issues, nerve damage. Hospitals presently use a variety of tests to gather the information required to diagnose diabetes, and depending on those results, the appropriate therapy is subsequently administered. Because these algorithms are exact and essential in the medical industry, they were utilised to predict the risk of type 2 diabetes. Once the model has been successfully trained, individuals can evaluate their own risk of developing diabetes. This work aims to create a system that can accurately detect early diabetes in 1a patients by combining the results of various machine learning algorithms. Using three different supervised machine learning methods—decision trees, random forests, and support vector machines—this work aims to predict diabetes. Offering a trustworthy mechanism for early diabetes detection is another objective of this research.

Keywords Diabetes mellitus · Prediction · Decision tree · Random forest · Support vector machine · Machine learning · Feature extraction

1 Introduction

The metabolic condition called diabetes, also referred to as diabetes mellitus (DM), is characterised by chronically high blood sugar levels. Increased hunger, continuous thirst, and frequent urination are all symptoms of high glucose levels. If diabetes is not treated promptly, it can progress to significant health problems such as diabetic

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ketoacidosis and hyperosmolar hyperglycaemia. Both of these conditions are life-threatening. This could result in long-term consequences like heart disease, stroke, kidney failure, foot ulcers, eye difficulties, etc. [1, 2]. Diabetes happens when the body's pancreas is unable to produce enough insulin or when the cells and tissues are unable to use the insulin that is produced. Three different ways might diabetes mellitus manifest itself [3, 4]; type 1 diabetes, also known as insulin-subordinate diabetes mellitus, is characterised by the pancreas producing less insulin than the body requires. In those with type 1 DM, exogenous insulin dosage is necessary to make up for the pancreas lower insulin production. Diabetes mellitus type 2 is characterised by insulin resistance because the cells of the body respond differently to the hormone insulin than they would under normal circumstances. As a direct consequence of this, the body may eventually stop producing insulin on its own. This condition is also referred to as "adult beginning diabetes" and "non-insulin subordinate diabetes mellitus," both of which are other names for the same disease. People who have this form of diabetes tend to have high body mass indexes (BMIs) or have sedentary lifestyles. The third prominent structure that can be observed during pregnancy is diabetes mellitus, also referred to as gestational diabetes. Blood glucose levels in an individual typically range from 70 to 99 milligrams per decilitre. Only when a person's fasting glucose level exceeds 126 mg/dL is diabetes diagnosed. Those who have blood sugar levels between 100 and 125 mg/dL are considered to be in a pre-diabetic stage by medical authorities [5]. A person like this is more likely to develop type 2 diabetes. Diabetes is an illness that is rapidly becoming more prevalent, even among youngsters. Before we can hope to comprehend diabetes and its aetiology, we need to be familiar with the physiological processes that take place in a healthy body. Our meals, mainly those abundant in carbohydrates, are the source of sugar (glucose). Everyone needs carbohydrates because they are the body's primary energy source, even those with diabetes. Bread, cereal, pasta, rice, fruit, dairy products, and vegetables are some foods high in carbohydrates (especially, starchy vegetables). When we eat foods that contain these nutrients, our bodies convert them into glucose [6]. Our brains must receive some glucose to function and think clearly. The remaining glucose is given to our body's cells as fuel and stored in our liver as energy for later use. The body needs insulin to utilise glucose as fuel.

2 Related Work

Beta cells in the pancreas are responsible for insulin production in the body. The excess of glucose in the blood is known as hyperglycaemia, and diabetes is a condition that occurs when either the pancreas does not generate enough insulin (known as an insulin deficit) or the body does not utilise enough insulin (known as insulin resistance) (insulin resistance). The presence of diabetes mellitus is indicated by high amounts of glucose (sugar) in the blood and urine [2, 7]. As living standards grow, diabetes is becoming increasingly common in people's daily lives. Therefore, learning to quickly and accurately recognise and assess diabetes is worthwhile.

Diabetes is diagnosed in medicine using fasting blood glucose, glucose tolerance, and random blood glucose values [8, 9]. The earlier the diagnosis is made, the simpler it is to control. People can make a preliminary diagnosis of diabetes mellitus using machine learning based on the data from their regular physical examinations. This diagnosis can then be used as a reference for clinicians [10, 11]. Selecting a reliable classifier and valuable features is the two main challenges in machine learning. The healthcare field has evolved considerably in recent decades due to information technology (IT) use. Integrating IT into health aims to make a person's actions less inexpensive and comfortable, much as mobile phones have personal lifestyles more straightforward [12, 13]. This might be accomplished by enabling medical innovation, such as by developing smart paramedics and sophisticated healthcare centres, which benefit patients and clinicians in various ways [14, 15]. It was found that the variation between both clients in genders is minor, and it was discovered that a large number were committed for the treatment of chronic disorders in 2014. The research was carried out annually for people suffering from long-term diseases at a particular location. Utilising both data from multiple sources yields more accurate findings than simply using a data warehouse. Because unorganised information includes physician's documents on patient populations related to illnesses as well as the participant's symptomatology and frustrations experienced by people, which is an additional benefit when used in conjunction with organised information such as patient information, illness specifics, living ecosystems, and lab result of the test [13, 16, 17].

In addition to the traditional machine learning approach, some current approaches used to predict diabetes include support vector machine (SVM), decision tree (DT), logistic regression, and others [18]. Polat and Günes [19] employed principal component analysis (PCA) and fuzzy neural inference to differentiate between diabetic patients and healthy persons. Weighted least squares support vector machine (WLS-SVM) and quantum particle swarm optimization (QPSO) were employed by Yue et al. [20] to predict type 2 diabetes. LDA-MWSVM is a system that Duygu and Esin [21] suggested to indicate diabetes. The authors utilised linear LDA, which stands for discriminant analysis, which will be used to reduce the number of dimensions and extract the features from this system. To manage the large dimensionality of the datasets, Razavian et al. developed prediction models for a range of onsets of type 2 diabetes based on logistic regression [22]. Support vector regression (SVR) was utilised by [13] to predict diabetes, a multivariate regression problem emphasising glucose.

Additionally, to increase the accuracy, more and more studies have been using ensemble approaches [13]. Ozcift and Gluten proposed a novel ensemble method called rotation forest that incorporates 30 machine learning algorithms [23]. The machine learning approach by Han et al. [24] altered the SVM prediction rules. Machine learning methods are increasingly being applied to diabetes prediction to achieve more accurate outcomes. Because it is so efficient at classifying data, one of the most common machine learning strategies in the medical industry is the decision tree. The random forest produces a significant number of decision trees. The neural network is a technique for machine learning that has been increasingly popular

recently due to its superior performance in various respects. Therefore, in this investigation, we attempted to forecast diabetes using decision trees, random forests (RF), and neural networks.

3 Brief Description of Machine Learning Classification

3.1 Support Vector Machine (SVM)

Support vector machines (SVMs) are a subclass of supervised classifiers used in machine learning techniques for both regression and classification. Most of its focus is on issues about classification, and SVM employs the most relevant hyperplane when classifying data points in a multidimensional space. A hyperplane can be considered as a barrier for the type of data points, and the data points that have the most significant distance between them and the hyperplane are the ones that it uses to classify them. Classification using support vector machines may be seen in Fig. 1 [25, 26].

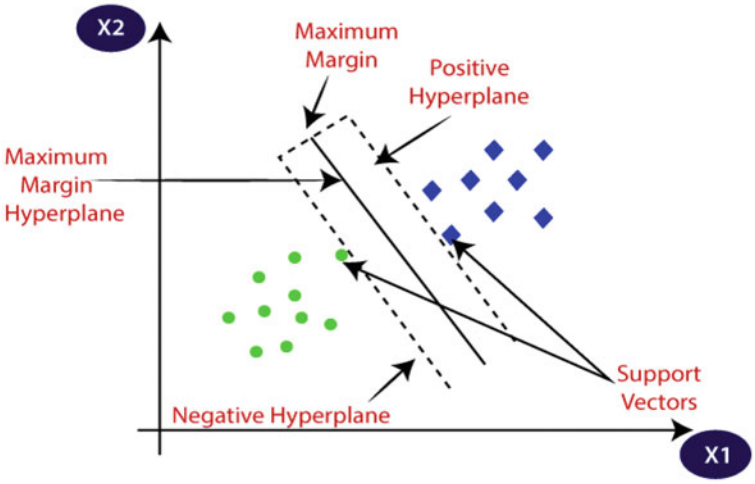

Fig. 1 Support vector machine (SVM)

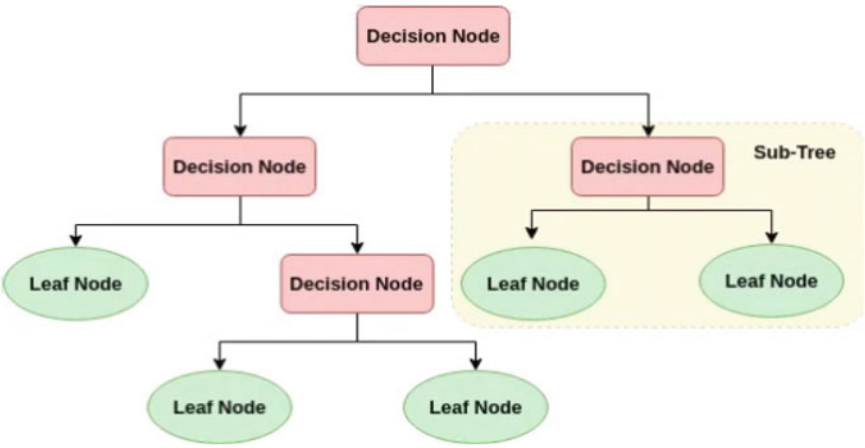

Fig. 2 Decision tree classification method

3.2 Decision Tree Classification Method

The cornerstone of a decision tree is the decision-making process, which has outstanding accuracy and stability and can be seen as a tree. In Fig. 2, a decision tree is displayed [27].

3.3 Random Forest Classification

The random forest method fashions many decision trees by drawing inspiration from a portion of the training dataset chosen randomly (see Fig. 3). The final class of test items is determined by taking the average votes received from each decision tree [28].

4 Materials and Methods

4.1 Dataset

The experiments in this work are conducted using a real-world dataset extracted from the UCI collection of machine learning datasets [29]. In order to prepare the data for the next stage of data mining, data must first be extracted from a data source. To enable the use of machine learning techniques, the heart disease dataset's preprocessed data are collected from the UCI repository. The UCI machine learning

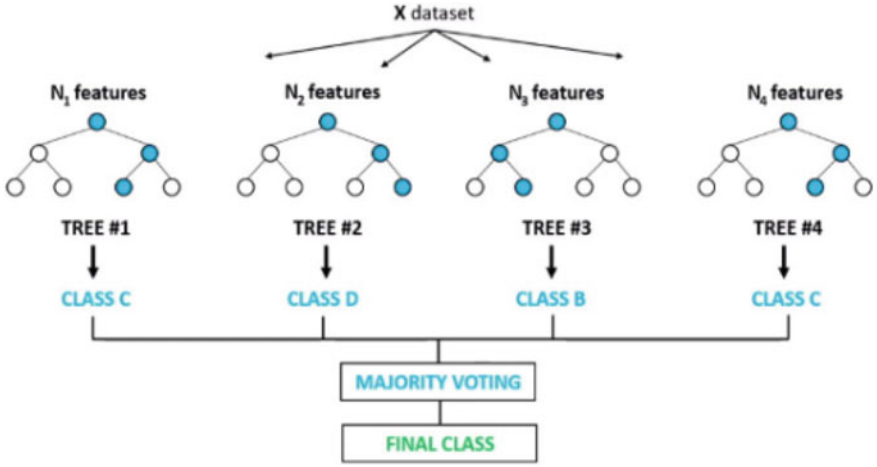

Fig. 3 Random forest classification

repository's diabetes mellitus dataset is located, preprocessed, and made accessible for the mining technique operation (Table 1).

Table 1 Characteristics of the UCI machine learning dataset for diabetic disease

Participants details (total participants 100)		
1	Age	18 or above
2	**Gender** • Male • Female	50 50
3	Family diabetic history	Yes–no
4	A high blood pressure diagnosis	Yes–no
5	Physically active	• None • Less than 30 min • More than 30 min • At least one hour
6	BMI	Numeric
7	Smoking	Yes–no
8	Alcohol consumption	Yes–no
9	Duration of sleep	Numeric
10	Regular medication intake	Yes–no
11	Intake of fast food	Yes–no
12	Blood pressure level	High/normal/low
13	Number of pregnancies	Numeric

4.1.1 Preparation of Data

Before training the model, all necessary preprocessing processes must be completed to acquire the best results [30, 31].

- **Data Preprocessing**

Inconsistent information is dealt with in this stage of the model to give more accurate and reliable conclusions. This database contains specific values that are missing from the table. Given that the final few variables, including age, skin thickness, blood pressure, glucose level, and BMI, can now have values of 0, we thus imputed missing data for these parameters. The data are then scaled so that every weight is at the same level.

- **Data encoding**

The dataset contains nine values, three numeric and seven presumably allocated. The vast majority of machine learning algorithms cannot function without actual numbers. A straightforward representation of the real numbers 1 and 2 is used to convert the nominal values into the corresponding real numbers. As an illustration, the male class is denoted by the number 1, while the female type is indicated by the number 2.

- **Normalisation**

The values in the dataset cover a wide variety of possibilities, particularly after the nominal values are transformed into real numbers 1 and 2. In this scenario, scaling is essential because it is required to prevent attributes with more extensive numeric ranges from dominating those with narrower numeric fields by distributing the weight of the attribute value more evenly. In addition, the execution speed of any algorithm can be increased by limiting the use of a diverse set of possible values [30, 32]. The importance of the attributes is scaled into a range from 0 to 1 using the formula (1), where x represents the attribute's original value, x normalised means the scaled value, mina represents the attribute's minimum value, and max represents its highest value.

$$X_{\text{Normalized}} = \left(\frac{x - \min_a}{\max - \min_a} \right). \tag{1}$$

4.2 Selecting the Best Features

The process for choosing the ideal subset of features is described in the features selection block. This process depends on the algorithm used and the effectiveness of the learning process.

- **Selection of Features**

At the beginning of each iteration, all features relevant to the chosen method are used. This is followed by an evaluation of the significance of each feature, after which the feature with the lowest priority is eliminated. This cycle is repeated until there is at least one characteristic that has not been found. This procedure is repeated until a noticeable drop in diagnostic accuracy is observed, which is covered in the section on the outcomes.

- **Cross-validation training**

Training using cross-validation: the discriminant performance is figured out by employing cross-validation, and there are ten iterations used in the process. As demonstrated in the following section, all trained models are stored away for future use in pattern recognition. This method is used to evaluate how well different feature counts perform in comparison to the performance of each method's model. The cross-validation results for each group of characteristics are then analysed to determine how effective the algorithms are [24].

- **Evaluation methods**

To compute a performance evaluation of the experiment, we must first designate True positive TP, True negative TN, False positive FP, and False negative FN. Only then, can we proceed to calculate the results of the experiment. As a result, the number of results that were accurately projected as needed, the number of results that were required, the number of results that were predicted mistakenly as necessary, and the number of results that were not required (number of results that were incorrectly predicted as not needed).

$$\frac{\textbf{True positive} + \textbf{True negative}}{\textbf{True positive} + \textbf{True negative} + \textbf{False positive} + \textbf{False negative}}$$

$$\textbf{precision} = \frac{\textbf{True positive}}{\textbf{True positive} + \textbf{False positive}}$$

4.3 Training Framework

As previously mentioned, many studies have concentrated on extracting particular features from the training model. The primary methods often made use of a feature

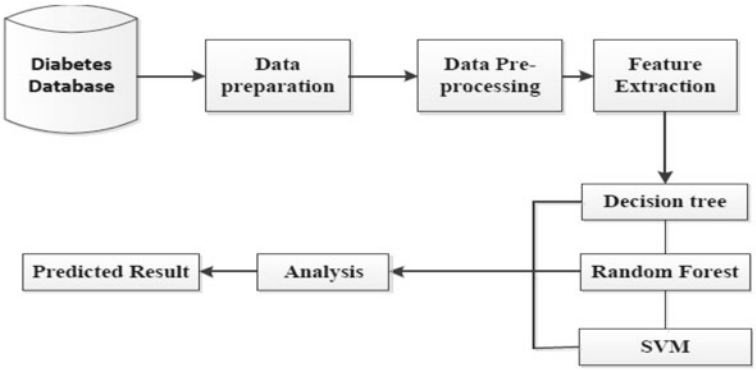

Fig. 4 Design of the proposed module

selection methodology that made use of traditional classification schemes. This technique can be implemented in any algorithm to categorise diabetes disease. There is a possibility that the performance of each model will differ depending on the kind of algorithm used and how the characteristics are represented. For instance, utilising features not best suited for a particular algorithm can cause it to perform less effectively than it otherwise would. The subsequent subsections both suggest and provide support for the use of a stand-alone platform for the diagnosis of diabetes disease. Beginning with the training framework architecture, the discussion then moves on to the testing framework architecture and, finally, the real-time diagnosis platform, which is used to address the problem of feature selection. Figure 4 illustrates the overall architecture of the training framework, and the following paragraphs will provide more in-depth explanations of each section. SVM was chosen as one of the algorithms for each of the three options [33] and DT [34, 35], and the process is repeated as stated in part before.

4.4 Testing Phase

The data set's unobserved portion was put through a mock test. The testing process is comparable to the data preparation process' training phase. Following the prepared data collection, a script forecasts using the ten pre-trained models. The conclusion with the highest probability is then chosen through a voting process, except for the scenario in which five models expected diabetes and five predicted health. Because the patient has to see a doctor, it is assumed they have the disease.

Table 2 Machine learning performance

	Accuracy	Precision
Decision tree	94.2	93.5
Random forest	97.3	97. 0
SVM	91.4	91

5 Results and Discussion

Making disease predictions based on symptoms is the primary goal of this disease prediction system. Based on the user's current symptoms, this system provides the outcome of a disease prognosis. The three algorithms' diabetes data are classified using decision trees, random forests, and SVM algorithms to determine whether a patient has diabetes or not. Therefore, these algorithms make good classifiers. Based on accuracy and precision, these three algorithms are evaluated to see which one yields the most noteworthy results. Models depict 0 as not having diabetes and one as having diabetes. An accuracy of 97.3 was provided by the machine learning methods utilised in random forests. The decision tree classifier had a 94.23% accuracy rate, and the performance of the support vector machine classifier was 91.4 (Table 2).

6 Conclusion Remarks

The primary objective of this disease prediction system is to provide disease forecasts based on symptom information. This system gives the result in the form of a disease prognosis, and it does so by establishing it on the symptoms that the user is currently experiencing. To determine if a person has diabetic or not, diabetes data are categorized using decision trees, random forests, and support vector machine (SVM) algorithms. This exercise aims to discover which of these three algorithms generates the most significant outcomes in accuracy and precision by comparing them. In the models, 0 indicates that the person does not have diabetes, and 1 indicates that the person does have diabetes. The application of machine learning strategies, which were used in random forests, resulted in an accuracy of 97.3%. The performance of the support vector machine classifier was 91.4, while the performance of the decision tree classifier was 94.23% accurate.

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Employing Big Data Analytics' Lifecycle in Money Laundering Detection

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Abstract This paper examines one of the most important benefits of big data analytics: the quick detection of suspicious financial transactions such as money laundering. Besides being one of the essential characteristics of big data, velocity is needed today for analyzing data and identifying risks to make quick and appropriate decisions. Worthy of mentioning here that this paper presents a model for exploring financial transfers and discovering suspicious transactions by employing the six phases of the big data analytics lifecycle: discovery, data preparation, model planning, model building, communicating results, and operationalization. This is a simplified model. It paves the way for a more inclusive methodology for reducing financial crimes in future, employing the big data analysis lifecycle.

Keywords Money laundering · Big data analysis lifecycle · Big data · Decision-making · Financial transactions

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1 Introduction

Features of the modern era have recently received more attention. The volume of data has continually expanded and increased due to the development of these technologies and analytical tools capable of extracting knowledge quickly and accurately [1]. The term "big data" has emerged, describing the most significant phases in developing information and communication systems [2]. Big data has several characteristics, such as the massive volume of complex data (structured and unstructured) whose size exceeds the ability of traditional analytical tools to store, process, and distribute it. In addition, analyzing big data and obtaining accurate results requires high velocity [3].

One of the essential features of big data is the ability to quickly analyze data for Websites, sensors, and social networking—social media are the most important sources of big data. The analysis of this data allows for finding correlations between a groups of independent data to reveal many aspects [4]. For example, forecasting companies' commercial trends, combating crime in the security field, and others. These predictions also provide decision-makers with innovative tools to better understand the conditions and thus make correct decisions that achieve the desired goals [5].

Big data analytics helps financial institutions prevent and reduce operational risks and combat suspicious transactions and fraud [6]. This makes it possible for banks to access the analysis results quickly and with high accuracy, which helps them make appropriate decisions. Moreover, it is possible to use big data analytics to predict customer behavior, which helps establish and develop strategies for financial institutions to achieve profits and raise customer service levels [7].

Billions of dollars move through global markets daily, and technical tools help monitor this data accurately, securely, and quickly to make predictions, detect patterns, and create predictive strategies. These tools are mainly based on how data are collected, processed, stored, and interpreted [8], unlike traditional analysis tools that cannot support unstructured data. One of the most important benefits for financial companies is to assist them in making the right decisions, such as improving customer services, preventing fraud, and assessing expected risks [9]. Data analysis relies mainly on creating hypothetical patterns for suspicious transactions and then applying them to financial transactions. Banks can immediately obtain results that help freeze the card, stop transactions, and notify the customer of security threats [10]. It also identifies suspicious transactions and signs of fraudulent activities by analyzing massive amounts of user behavior data in real-time using machine learning.

Currently, there are many challenges facing electronic financial transactions. Some of these challenges include the simplicity of money transfers and the lack of tools and techniques that help detect suspicious transactions and prevent financial crimes such as money laundering and fraud [11].

Even though nowadays, it has become easy to conduct a financial operation through technological channels at any time. There is a dark side to using these

techniques to conduct suspicious operations such as money laundering. Money laundering is a crime punishable by law. Vienna's 1988 Convention describes money laundering as a punishable crime, defining it in its article 3.1 as the concealment of the sources of illegally gained money. The said convention criminalizes anyone who does so or helps another escape legal consequences for doing so [12].

This paper seeks to present a methodology based on the big data analytics lifecycle for detecting suspicious financial transactions such as money laundering through establishing patterns based on several hypotheses that will be applied for detecting suspicious operations. Additionally, it discusses all stages of the data analytics lifecycle, starting from the discovery phase and ending with the operationalize phase.

2 Literature Review

Big data must meet a set of conditions, such as the difficulty of analyzing and processing it in traditional ways due to its size and unstructured data type [13]. Furthermore, big data combines structured, semi-structured, and unstructured data collected by organizations, which can be extracted to obtain information and used in machine learning projects, predictive modeling, and other advanced analytics applications. Currently, many companies are using big data analytics to improve operations, provide better customer service, as well as the ability to create customized marketing campaigns, and take other actions that can ultimately increase profits and reduce costs [14]. Consequently, it adds a competitive advantage to the company's ability to help make quick and accurate decisions. Big data can also be defined as a set of data whose size or type exceeds the capacity of traditional databases to collect, manage, and process data in an appropriate time. The characteristics of big data include large volume, high velocity, and a wide variety. Its most important sources are mobile devices, social media, and the Internet of things (IoT) [15].

The benefits of big data analytics include quicker and better decision-making, allowing businesses to access a large and diverse amount of different data sources, gain new insights, and take appropriate actions [16]. Moreover, it reduces cost and operational efficiency by discovering patterns and insights that help determine business performance more efficiently. Finally, it helps find potential risks by establishing patterns for suspicious operations and applying them to locate and identify risks.

The data analytics lifecycle is specifically designed to solve the problems of organizations that use big data. The big data analytics lifecycle comprises six phases that help reach practical results [17]. The data lifecycle helps analysts set priorities, define the necessary resources, and give a general perception of the needs and expected outcomes of the analysis. The data analytics lifecycle first identifies the problem, imposes appropriate hypotheses to solve the problem, identifies the resources needed, builds a unique plan to solve the problem, applies analysis tools, and finally operates results [18]. Accordingly, a step-by-step methodology is required to organize the activities and tasks related to collecting, processing, analyzing, and readjusting data.

Allaymoun [21] demonstrates the big data analytics lifecycle to obtain charts and graphs to aid decision-making. The paper also emphasized the importance of following the methodology and stages of the lifecycle, using Google Data Studio to get graphs based on the problem framing and hypotheses proposed in the discovery phase. Moreover, the paper discusses scenarios and outcomes for some charts. The stages of the big data analytics lifecycle were applied to a set of data of Islamic banks to monitor their performance in 2019 and 2020, as well as the impact of the COVID-19 pandemic on the banking sector. By following the big data analytics lifecycle, which consists of six phases, to reach the framework of big data analysis phases. The paper also dealt with all stages and aimed to generate results through charts and graphs that help decision-makers make decisions [19].

Allaymoun [21] also used the big data analytics lifecycle to generate graphs and charts to help those concerned make appropriate decisions. The paper has applied the data analytics lifecycle to Mega Start Company (virtual) facing problems that are difficult to discover by traditional methods and need to build an effective model that fits the problem. Furthermore, the paper focuses on the discovery stage to frame the problem and discuss the appropriate hypotheses to solve it. The rest of the steps were also applied to reach results that help decision-making [20]. Additionally, Allaymoun [21] illustrates the importance of the big data analytics lifecycle, helps take advantage of the results of big data analytics, builds predictive models to help improve operations and services provided to customers, and tracks sales operations, discovering risks and predicting the future. Moreover, the paper focuses on showing results in graphs and charts using the Google Data Studio application [21].

3 Research Methodology

For this paper, the previous studies related to money laundering, including money laundering modern tools, mechanisms, and techniques, were reviewed to help discover and reduce money laundering processes. To that end, the paper identified the necessary foundations and procedures to help develop a model for the big data analytics lifecycle phases. Among the papers reviewed were analyzes of cases and issues facing financial institutions, especially those dealing with money transfers. The paper effectively applied the big data analytics lifecycle to reach an overall view.

The primary data was collected, and the model was built through interviews and discussions. That's to say, semi-structured interviews were conducted with owners of financial companies and experts in money transfers. Semi-structured interviews allow the researcher to ask more questions whenever necessary. They also link the technical elements to the expected outputs and, thus, evaluate their effectiveness. More semi-structured face-to-face interviews were conducted to identify the hypotheses that help discover suspicious transactions.

This research paper deals with big data provided by money transfer companies. The idea is to review the big data analytics lifecycle phases to discover suspicious

transactions. So doing gives an overview of each phase, the effective transition between them, and the mechanism for measuring results and applying solutions. In addition, so doing examines and verifies solutions from all perspectives to ensure they can be used to achieve the desired goals.

4 Big Data Analytics Lifecycle

In this part, all phases (shown in Fig. 1) of the big data analysis lifecycle will be reviewed to reach a methodology capable of detecting suspicious operations such as money laundering. In other words, the methodology proposed here was developed to help exchange companies analyze their financial operations. To that end, the paper used hypothetical data and models to discuss the results.

Phase 1: Discovery

Finding the issue exchange companies face is the first stage of the data analytics lifecycle. During this phase, the data science team will determine and investigate

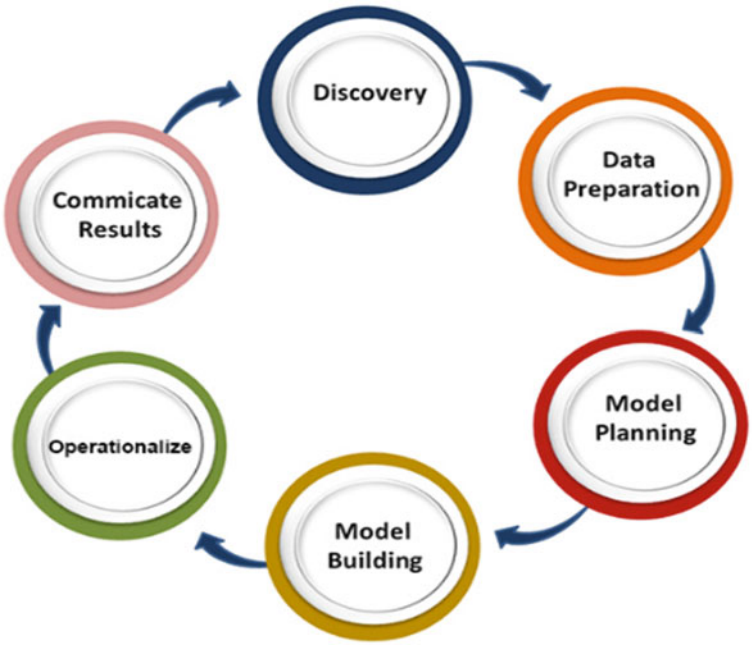

Fig. 1 Overview of data analytics lifecycle [22]

the matter, build context and understanding, and identify the necessary and accessible data sources for the task. The group also creates the initial hypotheses that the evidence can support.

- ***Acquiring business knowledge***

Understanding the problem's domain is vital. To improve financial procedures, enforce legislation, and monitor operations to halt-suspicious activity, the exchange company must be able to identify suspicious processes, money laundering, and fraud. Such problems are terrible and ubiquitous, so they require special attention. It could impact businesses, economies, and society locally and regionally numerous negative effects of money laundering on the economy. Financial organizations are exposed to experiencing abrupt changes in their assets and liabilities if they mistakenly engage in money laundering. News of money laundering at some banking institutions alerts public authorities. In this case, the audits of these institutions will be under additional pressure, damaging their reputation.

- ***Resources***

Exchange groups must guarantee the accessibility of resources, including technology, tools, systems, data, and individuals. To move on to the following step, evidence of each prior exchange company transaction from the preceding year is also required. The team can move on to the next stage if these qualities are present. Transactions must have the following information:

I. Customer details such as name, ID card or passport number, birthdate, address, phone number, and bank account number.
II. Details on questionable financial dealings.
III. The reason for the money exchange or transfer.

- ***Defining the issue***

Despite the amount of money exchanged, transactions may raise valid concerns, such as money laundering or financing terrorism. A variety of factors that individually would not seem significant but, when combined, raise questions about the possibility that a transaction is connected to the commission of a serious crime like money laundering, terrorism financing, or even both.

The exchange company line must be considered while evaluating a transaction. The conclusion to determine if there is cause for suspicion must be reached following a reasonable assessment of all relevant information, such as awareness of the customer's type of business, whether the transactions are by recognized industry standards, and financial background, history, and behavior. Exchange companies must identify suspicious transactions to improve their financial procedures and legal

compliance. This will allow the exchange company to prevent further transactions via monitoring measures.

- ***Addressing Major Stakeholders***

The exchange company team, which consists of the following individuals, is now being introduced:

- The company's CEO is the project manager, sponsor, and business user.
- A member of IT is the business intelligence analyst.
- A member of the IT department is a data engineer and data administrator (DBA).
- And the data scientist as a member of the IT as well.
- Develop preliminary hypotheses

One of the essential components of the discovery phase is forming a group of IHs. It was found after further investigation that the exchange company had many questionable transactions. The following is a list of the criteria that will be utilized to identify shady dealings in the exchange company.

IH1*: *The first theory we'll discuss is identifying clients paid by numerous sources [23].

According to this hypothesis, it is usual for one person to receive a regular payment, such as a salary or rent. Still, when fees grow and come from multiple sources, it is necessary to consider communicating with the client for clarification. However, we should contact the authorities if there are numerous sources with a substantial quantity. In terms of the team, the data engineer is mainly responsible for conducting analyzes of international trade and country profiles: which is data that is publicly available and can be analyzed to create profiles of the many types of items that different nations import and export, highlighting anomalies that could be signs of TBML activity. And also, analysis of the connections between ports and trading partners: Enterprise analytics software solutions can find hidden relationships between port facilities, trade partners, and other parties in the trade lifecycle in data. Additionally, they can spot potential shell firms or unusual activities. By employing this technique, concentrating on these clients, and enforcing the law against them, we will decrease suspicious transactions and enhance the company's financial operations.

IH2*: *The second hypothesis we'll discuss is deducting total transactions from or to a single sender or receiver that exceed a predetermined daily, weekly, or monthly limit [23].

The second hypothesis is that total transactions from or to a single sender or receiver surpass a predetermined daily, weekly, or monthly threshold. The data scientist should employ the text analytics technique as a team member. The capacity to automatically extract data from text files can open up a vast amount of data that can be used for transaction monitoring. The project sponsor should give the big data analytics tool to find out information about the clients utilizing Web analytics and Web crawling. These programs may methodically search the Web for shipment and customs details,

review them, and compare them to the relevant papers. For the hypothesis to be successful, this tactic is crucial.

Phase 2: Data preparation

The second stage of the data analytics lifecycle is data preparation, which includes data exploration, preprocessing, and case data before modeling and analysis. The team must establish a trustworthy data analysis environment outside the production environment. To begin collaborating with the IT and accounting departments and developing an analytical sandbox, the team has to be introduced to big data and projects. To get the data into the sandbox, the team must extract, transform, and upload it to ETLT. The strategy facilitates access to reliable data.

Furthermore, the group ought to have access to all kinds of data. At this stage, tasks related to information planning are completed, and preparations for information research, preprocessing, and condition before demonstration and inspection are made. The company must collect data from multiple divisions at this level and organize it purposefully for the next phase. It is not associated with dispersing the model through acquiring and managing information. Data and information were collected after visiting their Website, choosing particular clients, and conducting financial transactions before and after the prose.

Phase 3: Model Planning

The exchange company now provides resources to identify questionable transactions and money laundering. The hypotheses will be evaluated using the tools to ascertain whether the exchange company clients are engaged in money laundering or dubious activities. The team will now assess and scrutinize each client's transactions to see if they match the premise; if so, they will be marked as suspicious transactions. Each transaction must include details about the consumer, an explanation of the exchange or transfer of monies, and why the transaction appears suspicious.

Table 1 displays a few of Ali Mohammed's transactions. Ali is a client of an exchange company. He recently received payments from various addresses. Exchange companies run checks on those receiving payments from multiple sources and addresses to prevent fraud and money laundering.

Table 1 Transactions of a customer

Date	ID	Name	Bank account	Amount	Address
1/10	95011xxxx	Ali Mohammed	NBB7721xxxxx	↓ BHD 1000	Manama 324
21/10	95011xxxx	Ali Mohammed	NBB7721xxxxx	↓ BHD 3700	Riffa 913
21/10	95011xxxx	Ali Mohammed	NBB7721xxxxx	↓ BHD 1590	Zallaq 1057
30/10	95011xxxx	Ali Mohammed	NBB7721xxxxx	↓ BHD 2950	Al Hidd 244
31/10	95011xxxx	Ali Mohammed	NBB7721xxxxx	↓ BHD 1620	Muharraq 203

The business ought to issue a cautionary signal to its past clients. This method of detecting fraud is called continuous or behavioral authentication, as the company receives warnings of a suspicious transaction.

IH2: Total transactions from or to a single sender or receiver that exceed a predetermined daily, weekly, or monthly limit.

Table 2 displays a few dubious transactions involving users with a single sender or receiver and goes over the daily, weekly, or monthly limits. Therefore, if the total number of transactions from or to a single sender or receiver exceeds a set daily, weekly, or monthly limit, the exchange company is required to investigate due to the questionable nature of the transaction, which could result in fraud or money laundering.

Phase 4: Model building

The team employed a variety of analytical techniques in the fourth step. This contains the work of a data scientist who used strategies based on written explanations of the principles above to approach this issue. This enhanced the exchange company's financial operation, law enforcement, and process control to decrease the number of questionable transactions. Moreover, the pie charts and bar charts below, which were made using histograms and information from the social network investigation, show how the number of suspicious transactions will decrease after the study (see Fig. 2 below).

The methods used through this process, such as detecting fraud by continuous authentication and using international trade and country profiling analysis, network (relationship) analysis of trade partners, and ports in identifying clients who are being paid by various sources, have resulted in a decrease in the proportion of suspicious transactions. In contrast, the company's financial process has dramatically improved, as shown by the graph above. Furthermore, subtracting all transactions from or to a single sender or receiver that go beyond a set daily, weekly, or monthly limit utilizing text analytics and Web analytics technologies.

Table 2 Some suspicious transactions of a customer

Date	ID	Name	Bank account	Amount	Address
07/10	85012xxxx	Hasan Ahmed Khalil	ABC2376xxxxx	↑ BHD 55,000	Isa Town 318
08/10	85012xxxx	Hasan Ahmed Khalil	BBK5825xxxxx	↓ BHD 67,000	Muharraq 453
19/10	85012xxxx	Hasan Ahmed Khalil	BBK5575xxxxx	↓ BHD 100,000	Sanad 384
20/10	85012xxxx	Hasan Ahmed Khalil	BBK5435xxxxx	↓ BHD 77,462	Manama 324
21/10	85012xxxx	Hasan Ahmed Khalil	KFH5392xxxxx	↑ BHD 150,000	Saar 324

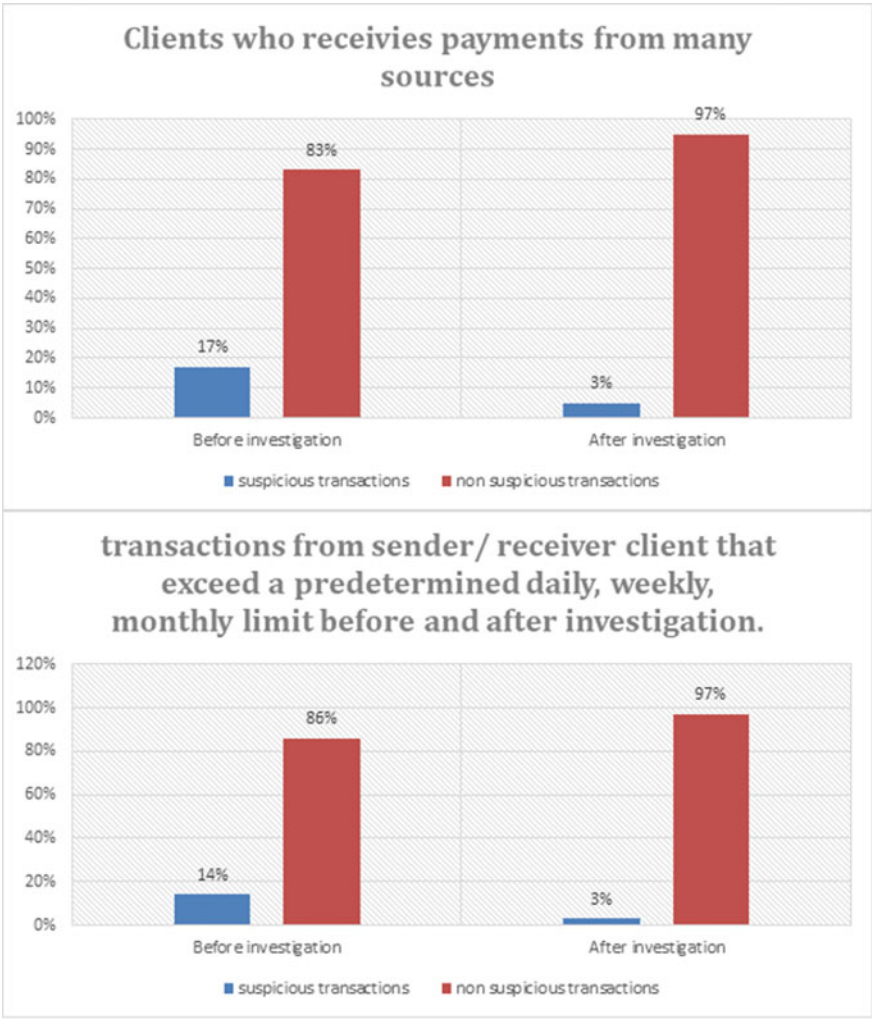

Fig. 2 Comparison of suspicious transactions and nonsuspicious transactions

Phase 5: Communicate Results

In the fifth step, the team developed several strategies to interpret the study's results and identify their significance. This study was found to be successful in locating questionable transactions and customers that were involved in money laundering. Based on the preceding stages' actions, the team must compare its characteristics to its goals. Stakeholders are just one group that is involved in this phase's execution. The group will also need to deliberate on the success rate of the results. The team will also need to summarize the findings for important stakeholders and evaluate the analysis's significance and business value.

The exchange company will have to evaluate the results and decide how to convey them to different parties, such as team members and stakeholders, while considering several variables, including account cautions, preconceptions, and limitations. The team will also need to use caution while correctly communicating the results. The team must choose the most precise results in addition to highlighting and demonstrating their investigation's conclusion. Generally, the techniques employed, starting with the use of hypotheses, resulted in a satisfactory conclusion to the study. Accordingly, the capacity to develop a practical and helpful solution to help with the reduction of suspicious transactions, the data scientists, and data engineers also played a vital role in the project being finished on schedule and within budget.

The project's outcomes include the ability to detect suspicious activity by detecting clients who receive payments from many sources or addresses as well as the total transactions from or to a single sender or receiver that exceed a specified daily, weekly, or monthly limit.

Phase 6: Operationalize

The cycles operationalize phase, which deals with concluding, entails coding, briefings, and providing papers to stakeholders in addition to preparing an extensive report that summarizes the initial findings. To evaluate the data to the intended targets, it has now been observed in the exact way that it was observed in the sandbox. If some inputs are inconsistent or ineffective, the team can go back to any phase and change them, which would produce new outcomes. For exchange companies, their teams will be able to assess the benefits of their operations in a larger scheme and reach a decision first to release the work under restricted circumstances. When introducing stage six to implement the new analytics method for the first time, going back to stage four whenever the model was sandboxed for data analysis will decrease the risks and enable the team to handle it successfully by trying to implement it on a smaller scale initially rather than instantly deploying the model to a broader scale. An effective system for preventing money laundering should be able to spot suspicious transactions depending on the client's background, if they were a political figure, whether their account name had just undergone an unusual change, and whether they had accounts in the border buildings. This was learned after putting the big data analytics lifecycle into practice. After the written notice is generated, the client must undergo a comprehensive examination by the compliance officer to confirm the suspicion of money laundering. The analysis will involve comparing documents, processes, and data to data in the system. It is now possible to use the data acquired during the "knowing your clients" approach.

5 Conclusion and Future Work

This paper attempts to build a model for identifying suspicious financial transactions using the big data analysis lifecycle. To that end, the paper used different hypotheses: an exchange company customer's reception of payments from various

sources and addresses and receiving amounts that exceed what's allowed daily, weekly, or monthly. The proposed model helps exchange companies detect money laundering, reducing suspicious financial operations. It warns companies of suspicious financial operations early, presents an integrated solution, and enables decision-makers to make appropriate decisions quickly. The importance of using the big data analysis lifecycle surpasses detecting money laundry to applying laws.

It is essential to mention that besides the graphical and analytical results, this paper provides for detecting suspicious operations, and it paves the way for building a more comprehensive model, employing a more considerable number of hypotheses. This model is expected to provide financial institutions with an integrated solution to help decision-makers identify and address suspicious operations promptly and very early.

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Blockchain Technology in the Supply Chain: The Benefits and Challenges

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Abstract The purpose of this research is to explain the current trend and recognize the benefits and challenges of blockchain technology in the supply chain. Blockchain technology enables organizations in the supply chain to become decentralized operations that are more secure and transparent than traditional forms. Blockchain technology has many benefits that can help organizations; however, we consider the most important one: People focusing on and discussing how, when, who, and where to use it. In terms of the current trend in the use of blockchain technology in the supply chain, the findings show the statistics on the increase in articles in recent years, publications by country, and top authors regarding this particular topic. Furthermore, content analysis of 35 articles related to the benefits of blockchain technology in the supply chain was conducted, revealing such benefits as traceability, transparency, security, cost reduction, trust, and information sharing. It also emerged that the advantages of blockchain utilization are being reaped across several industrial sectors. According to our research findings, when combining blockchain technology with IoT, RFID, or other digital tools, this will increase the efficiency of such technology working in the supply chain.

Keywords Blockchain · Supply chain · Benefits

1 Introduction

Technology has advanced more rapidly recently than in the past, and blockchain is one of the most widely discussed in regard to industry supply chains. Blockchain technology is a set of digital tools for decentralized operations that are secure, transparent, and allow information sharing [1]. There is a system in blockchain called

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"smart contracts," which is a computer program that can establish rules, conditions, and agreement states and subsequently, transmitting them to participants for confirmation or approval before sending them to be stored in the blockchain [1]. The use of blockchain will affect how many businesses operate in various industries [2]. To enhance performance and store data collected through IoT, RFID, and EDI for data security, blockchain can be integrated with these technologies [3]. The COVID-19 pandemic made it particularly important that people were able to access all data relating to the supply chain for its effective management, with this being especially the case for the food industry regarding such matters as food safety and hygiene [4]. In fact, during this period, blockchain technology increasingly emerged as a digital tool for effective flexible supply chain management. This technology uses a distributed or decentralized ledger to record the flow of goods or services [5]. Moreover, data traceability has been improved via blockchain technology (BCT) [6]. It provides benefits like immutability, increased information transparency [7, 8], and smart contracts that enhance connectivity and reliability [9]. Moreover, blockchain can support and improve supply chain performance in terms of cost reduction [1] and validation of product quality [8]. All these advantages of blockchain engender trust among stakeholders that promotes information sharing [10].

In the past, there has been relatively little research on the overall benefits of blockchain in supply chains. Most of the studies that have been carried out have been focused on a specific industry, rather than generalizing the benefits of blockchain operations in the supply chain. Hence, the overall benefits of blockchain in the supply chain regardless of the sector are not clear. Given the overall trend of blockchain growth, this makes it important to understand its potential benefits when adopted by any industry in different areas, thus leading to its better application. In sum, this study is aimed at examining the current trends in blockchain technology with the aim of identifying its benefits and challenges that need to be overcome.

This paper is structured as follows. Section 2 (theoretical background) reviews the literature defining the concept of blockchain technology and its function in the supply chain. The research methodology as a systematic review process is described in Sect. 3. In the final section, we present the findings and conclusion.

2 Theoretical Background

2.1 Concept of Blockchain Technology

Blockchain technology can be defined as a peer-to-peer, structured network, which is used to create and maintain decentralized databases [11]. Records of information in the blockchain are stored in multiple locations, instead of at just one, thus avoiding the need for intermediaries and ensuring greater trust in the environment [12, 13]. The information is checked and validated using a specific mechanism or smart contract before being transformed into a transaction and stored in the blockchain network

[11]. Once a transaction has been stored as a block of data, it can be linked to other blocks with identifiers and thus become part of the "blockchain" [11, 13]. Blockchain networks in terms of accessibility to information that is stored in them can be defined as having three types [13]. First, a public blockchain network is available for anyone to view or transact on [13]. Second, a private blockchain network is only for people with authorization to access the data or edit transactions in the network [13]. Third, a consortium blockchain is a combination of public and private ones that is usually used in partnering businesses, where some information, but not all, needs to have limited access [13].

2.2 Blockchain Technology in the Supply Chain

Blockchain is a digital distributed database of recorded transactions that are shared with the participant party(ies), with each being time stamped and verified by consensus of the participants [14]. Moreover, blockchain can work as a database of information and can help integrate all the tools in the supply chain. With blockchain, organizations can perform real-time transactions for all participants in the supply chain network [15, 16]. Organizationally, blockchain can facilitate demand forecasts, manage resources more effectively, and decrease inventory handling costs. Midstream and downstream in the supply chain and blockchain can improve logistics in terms of tracking orders [17] and dealing effectively with high volumes of product. Blockchain is often used with radio frequency identification (RFID) to increase the performance of the tracking of a product [16]. For example, in the midstream in manufacturing, blockchain with digital tools, such as RFID, records process flow to control and verifies the quality of the product [18]. Then, in the downstream, the customer can gain access though RFID to view the information about the product and make an assessment regarding the trust in its quality [18, 19]. In the agricultural and food supply chain, there is a blockchain-based traceability system for products that monitors data on the network. It improves the security and traceability of food products, thereby ensuring trust, traceability, and the effectiveness of delivery processes [20].

3 Research Methodology

We chose the Scopus database for this research. As can be seen in Fig. 1, the search was based on the keywords "blockchain" and "supply chain" being in the article title. The initial search turned up 1,136 documents, which included journal articles. After further searching for "English," "Article," and "Journal" as well as removing duplications, we arrived at 562 documents. Then, we chose to analyze only open-access and full-text articles, which left us with 263 documents. We decided to focus on the subject areas of business management and accounting; social sciences;

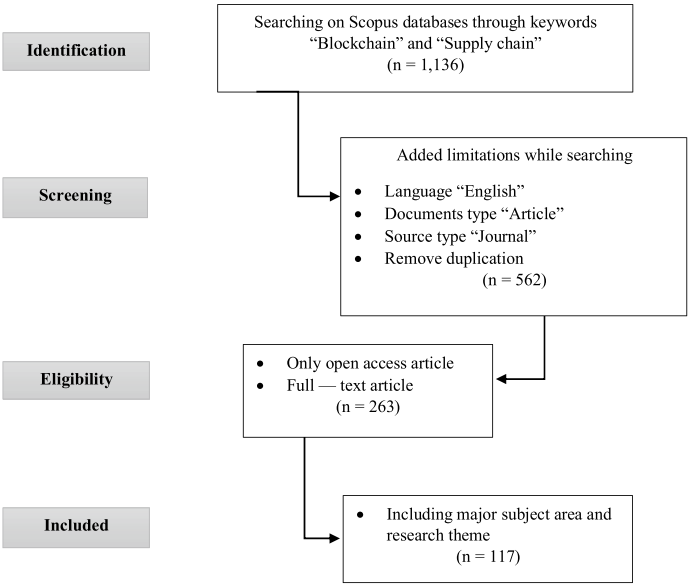

Fig. 1 Article selection process

economics, econometrics; and finance. As a result, the systematic review included 117 documents.

3.1 Content Analysis

The purpose of the content analysis in this study was to identify the key themes that have been explored in the field of supply chain blockchain research. We categorized and subcategorized the various aspects. The first category is "research focus," which included blockchain and supply chain as subcategories as we were interested in these two terms. The second category is "industry focus," with subcategories of food, finance, construction, agriculture, logistics, humanitarian, and other. Regarding these subcategories, 117 articles were obtained from utilizing the article selection process in Fig. 1. These were then filtered for containing references to the benefits and challenges of blockchain adoption in the identified industry subcategories. Finally, after identifying these two categories, we obtained 35 articles, as shown in Table 1. After that we made a checklist of the most discussed benefits of blockchain technology in the supply chain in these articles.

Table 1 Number of documents subject to content analysis

Industry/generic supply chain discussion	Number of documents found
Food supply chain	14
Financial supply chain	2
Construction supply chain	2
Agricultural supply chain	2
Humanitarian supply chain (when dealing with disasters)	2
Logistic supply chain	2
Other	11

4 Results

4.1 Overview

Starting with a keyword search for "blockchain" and "supply chain" in the article title on Scopus, we identified 1136 papers. Then, we added the limits of language "English," documents type "Article," and Source type "Journal," which resulted in 562 papers. After that, we reduced the scope of our search method by adding "open-access" type "all" and subject areas "business management, social sciences, economics, and finance" which whittled the total down to 117 papers. In 2017–2019, a small number of papers were published, which was followed by substantial growth in 2020–2022. The growth in publications increased most from 2019 to 2020 and 2020 to 2021, this being 300 percent and 195 percent, receptively. In addition, the most publications for a single year were 47 documents in 2021 and 24 in 2020, as shown in Fig. 2.

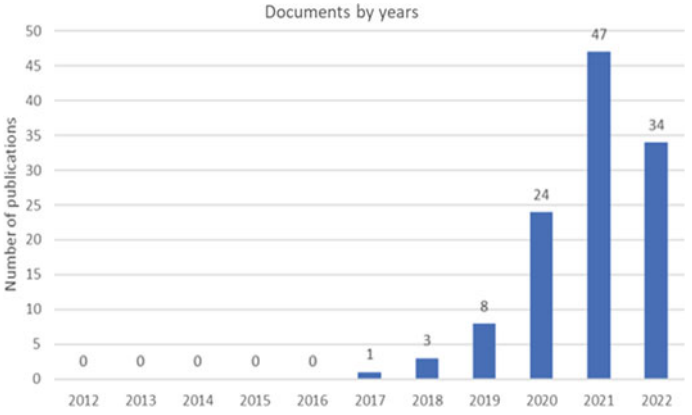

Fig. 2 Number of publications by year

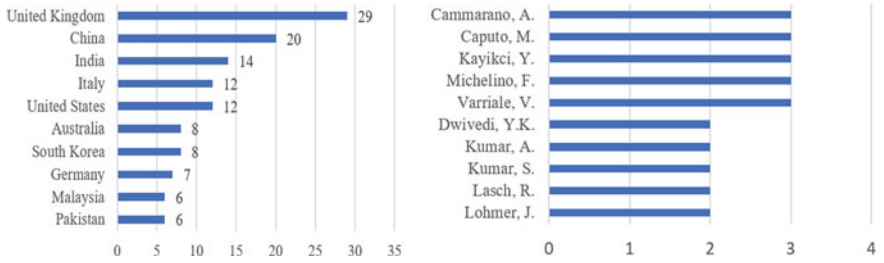

Fig. 3 Documents by authors' country and by author

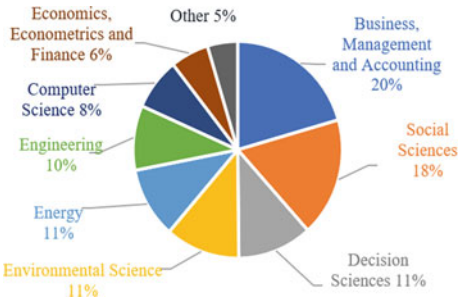

Fig. 4 Documents by subject area

In Fig. 3, most of the authors' affiliations are in the United Kingdom (29), China (20), and India (14), followed by Italy, the United States, Australia, South Korea, Germany, Malaysia, and Pakistan. Also, the authors with the most publications came from Italy, with four out five of them emanating from there: Cammarano Antonello, Caputo Mauro, Michelino Francesca, and Varriale Vincenzo. They were based at the "Università degli studi di Salerno" in Italy, while the last of those five with the most publications were Kayikci Yasanur from the "University of Sussex Business School" in the United Kingdom. They were experts in the topic of open innovation, except for Varriale Vincenzo and Kayikci Yasanur, who specialized in "Bitcoin; Ethereum; and the Internet of things," As can also be seen in Fig. 3.

According to Fig. 4, it can be observed that business management and accounting have 20%, social sciences have 18%, and energy, environmental science, and decision sciences have 11% for each subject area. The two main subject areas are business management and accounting and social sciences, which sum up to 38 percent of the total.

4.2 Content Analysis

As aforementioned, we used content analysis with the keywords "blockchain" and "supply chain" and then utilized the categories "industry focus" and "research focus."

In the category "research focus," we focused on the subcategories of supply chain and blockchain. Next, for "industry focus," we focused on financial, food, humanitarian, logistic, construction, agriculture, and other, as shown in Table 1. Then, according to our research, we have reviewed 35 articles, most of which are related to blockchain adoption in the supply chain and its specific benefits for the industry. Regarding content analysis, we will explain the benefits of blockchain that were found in articles based on the food industry, given that of the 35 identified, the highest number pertained to that industry (14) (Table 2).

We identified six benefits of blockchain, including transparency, traceability, security, information sharing, trust, and cost reduction, which we put into a framework, as shown in Fig. 5.

Transparency

In the traditional supply chain, lack of transparency has been identified as a problem for all processes from upstream to downstream. With blockchain, the customer can verify the source of raw materials and have a clear understanding of the process of product manufacturing [21]. This can engender trust in partners and stakeholders regarding the authenticity of data flow in the network [18]. For example, in the rice supply chain, they used blockchain technology for tracing from field to shelf, and once they had used it, they left such comments as "things became very transparent to

Table 2 Most discussed benefits from 35 articles

Benefits	Number of documents
Transparency	33
Traceability	33
Security	31
Information sharing	30
Trust	29
Cost reduction	19

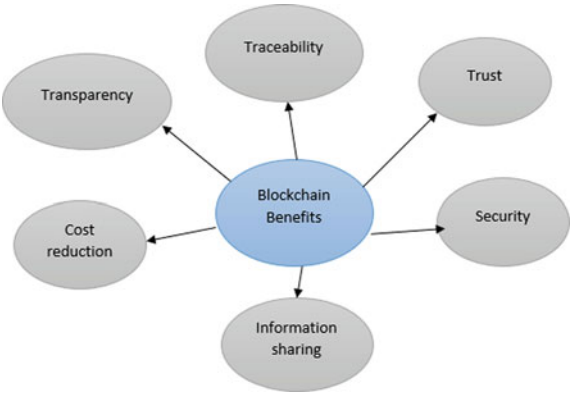

Fig. 5 Blockchain benefits framework

us," and "we can track the product for any possible detail" [22]. Hence, the evidence suggests that blockchain effectively increases transparency for businesses.

Traceability

Traceability refers to the ability to track product, transactions, etc., with items being tracked using blockchain, the Internet of things, or radio frequency identification (RFID) [22]. For example, in the food supply chain, they track the history of food products. This requires information sharing about product history, location, logistics, processing, transport, and traceability based on real-time information, which all help the customer to trust in the product and be able to recall it when there is a problem [23].

Security

This pertains to information security [24], that is, protecting it from the risk of being attacked [25]. If transaction records are subject to malicious cyber-attacks, data can be changed or lost, which will impact negatively trust in the supply chain [25]. Blockchain technology can contribute to increasing information security strength, thereby protecting trust in the authenticity of the product [25, 26].

Information Sharing

As aforementioned, blockchain technology is based on three types of networks: public, private, and hybrid [11]. Every network can grant an authorized participant access to view or edit records of data in the network. In the supply chain, all the information is recorded or linked through the network [27]. Information sharing is essential for transparency, security, trust, and real-time transactions, which blockchain can deliver effectively in ways that traditional supply chain management cannot guarantee [28]. For example, in the food industry, information sharing is necessary, because it helps participants to provide information about each product by accessing information in networks, like those of Walmart and Carrefour, which use blockchain technology to trace products and provide transparency in the supply chain, thus making customers feel safer about their food [15].

Trust

Trust in the supply chain affects information sharing and forecasting accuracy [26]. Trust refers to that in a product, information for stakeholders or partners, etc. Trust covers "transparency," "traceability," and "immutability" [24]. Regarding these three aspects of trust: [24] transactions, the flow of goods, and information need to be transparent for all participants; there has to be immutability, whereby information cannot be edited on the company network; and the flow of all processes from upstream, such as a farm, to downstream, such as a retailer or customer, must be traceable [24, 26, 29].

Cost reduction

Cost reduction can relate to cost saving or increased cost-efficiency. Blockchain helps the food supply chain reduce costs by eliminating intermediaries entirely through the

use of smart contracts [30, 31]. For instance, it allows for farmers to communicate with and make deals directly with distributors. A smart contract enables automated payments and thus, the elimination of transaction fees to intermediaries, which clearly reduces cost [30].

5 Conclusion

This study was aimed at examining the trend toward using blockchain in supply chain management and identifying its potential benefits. To this end, the main attributes of blockchain were probed through content analysis of articles, with a research focus on supply chain and blockchain. Blockchain technology is one type of digital tool, which can be integrated with RFID or IoT for the best solution to fixing challenges, such as tracking products and obtaining real-time data [24]. The response time of contracts in supply chains can be decreased by using smart contracts [32] and keeping an eye on real-time data [32] in case unexpected problems arise. The results have shown the benefits of blockchain pertain to transparency, traceability, trust, security, information sharing, and cost reduction. Each of these is important for improving the supply chain; i.e., in the case of the food supply chain, the matter of food safety and the source of ingredients can be improved through traceability and tracking processes from farm to customer, with the information being stored in a blockchain network being transparent, secure, and it cannot be edited. This creates confidence and trust among customers, who are skeptical about the safety of food or the nature of the ingredients. Also, it can improve product recalls, because the flow of the processes is recorded in the blockchain network, so the owner can find information about when, where, and who bought the product, thus making the recall process easier and cheaper. By taking advantage of these affordances of blockchain trust, including transparency, traceability, and the ability to not to change information, trust can be built between stakeholders.

In terms of current trends, it would appear that over the last three years the topic "blockchain technology in the supply chain" has received significant increased attention. According to our findings, it appears that publication in this topic has been steadily increasing. Clearly, future knowledge of blockchain technology in the supply chain from further research will lead to the improvement of supply chain performance. Blockchain can help industries improve the information available to participants, including stakeholders, alliances, and end users. Transparent information that is recorded on the network makes it easier for people to acquire the information they need to check the process of a procedure or the source of a resource in business [10, 33]. However, adoption of blockchain technology in the supply chain does pose some challenges for those firms wanting the adoption of it. For instance, there can be resistance to taking it up by some stakeholders in the supply chain, who are reluctant to instigate change. So, companies promoting this technology need to provide information to all stakeholders regarding the benefits from blockchain in terms of improving supply chain performance, thereby overcoming resistance to its

implementation [29]. For future research, researchers can explore factors influencing blockchain adoption in the supply chain, including barriers to blockchain implementation. This will help with understanding and supporting blockchain practices in the supply chain across multiple industries.

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Investigation of Systems with Normally and Exponentially Distributed Random Parameters by the Method of "Golden" Binary Structuring

Petro Kosobutskyy and Anastasiia Yedyharova

Abstract The binary structuring of CDF expands the range of characteristic points on the contours of the corresponding dependencies, which do not depend on the probability distribution law of random values. Modeling the differential spectra of the exponential distribution by the points of the "golden" division shows that the corresponding implementation is not unique. Many arbitrary relationships are based on the geometric mean, which significantly expands the possibilities of application for diagnosing complex systems of already developed optimization methods. Despite the universality of Gauss's law for diagnosing the reliability of systems, the two-parameter representation of the probability density function limits its application, as the height and width of the contour are interrelated, forcing to search for more complex models. This paper proposes one of the approaches to solving this problem by binary structuring of probability parameters according to the "golden" proportion.

Keywords Golden ratio · Quadratic irrationality · Probability distribution · Gauss's law

1 Introduction

Clausius began to use elements of probability theory in developing the kinetic theory of gases. After the fundamental work of Maxwell and Boltzmann, it became clear how important probabilistic approaches are in physical modeling. After all, the behavior of microparticles associated with their wave properties is indeterminate and probable [1]. Probabilistic modeling is used in the study of stochastic models to build probabilistic-statistical models of strength [2, 3].

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Statistical analysis of experimental data always begins with verification of the law of distribution of random variables, primarily normal. This is because, as experience shows, the measured physical quantity is always influenced by many random independent (or weakly dependent) factors. Since each of them mainly plays a non-dominant role in the overall result, the probability distribution of its random values leads to the normal Gaussian distribution—so says the central boundary tower of Lyapunov. Even though probabilistic methods have long been used to diagnose complex physical and technical systems, studies of the laws of binary structuring of probabilistic characteristics of systems into two unequal parts by the "golden ratio" (GR) were started recently [4]. Subsequently, this approach was developed for the binary structuring of electrodynamic systems [5–10].

In this paper, there is a set of theoretical studies of the laws of the "golden" division (GD) of integral (CDF) and differential (PDF) probabilities of random variables (RV) with exponential and normal models. As those most often used for mathematical modeling of physical processes in complex systems [11–15].

2 Basic Results and Discussion

2.1 "Golden" Division of Integral Probability

It is known from probability theory that arbitrary distributions and integral functions (CDF) have the same type of S-dependences, on which the condition of normalization is imposed.

$$P_\Sigma = \sum_{x=-\infty}^{x=+\infty} P(x) = 1 \tag{1}$$

From the point of view of the ideal model of continuous RVs, condition (1) expresses an infinite range of values of a random argument. The model GD with a well-known quantitative characteristic ($\varphi = +\,0.618$) of the additive parameter of the system into two unequal parts with a point with a coordinate in the interval (2) has the form shown in formula (3).

$$P_\varphi > \frac{1}{2} P_\Sigma \tag{2}$$

$$\frac{P_\varphi}{P_\Sigma} = \frac{P_\Sigma - P_\varphi}{P_\varphi} \Rightarrow P_\varphi^2 = P_\Sigma^2 - P_\Sigma * P_\varphi \tag{3}$$

$$P_\psi > \frac{1}{2} P_\Sigma \tag{4}$$

And in terms of the quadratic equation in general (5):

$$x^2 + px + q = 0 \tag{5}$$

On the plane of Cartesian coordinates, it corresponds to the phase point with coordinates ($p = +1, q = -1$) in the second quadrant. Moreover, the phase point ($p = +1, q = -1$) with the characteristics of GD is not unique. The second quadrant has a so-called phase direction (6) [16], along which the roots of the quadratic Eq. (3) show the properties of the GD additive parameter.

$$|p| = |q| = k \tag{6}$$

Let us make the proportion GD of the additive parameter of the system into two unequal parts with a point with a coordinate in the interval (7) [14].

$$\frac{P_\Sigma - P_{\psi}}{P_\Sigma} = \frac{P_{\psi}}{P_\Sigma - P_{\psi}} \Rightarrow P_{\psi}^2 = 3P_{\psi} - P_\Sigma^2 \tag{7}$$

The GD (7) is described by the quantitative characteristic $\psi = 0.382$, and from the point of view of the quadratic Eq. (5), the plane of Cartesian coordinates $p = -3, q = +1$ corresponds to the phase point with coordinates in the fourth quadrant. Phase direction (6) is transformed into a vertical line in the fourth quadrant.

As follows from the system of quadratic Eqs. (3, 4, 5) and (7), for GD, there are two points with coordinates (2), (4) each; in particular, the analytical connection is genuine.

$$3P_{\psi} - P_\Sigma^2 = P_\varphi^2 + P_\Sigma P_\varphi \Rightarrow \frac{\varphi}{\psi} = \frac{3 - \psi}{1 + \varphi} \Rightarrow \psi = \varphi^2 \tag{8}$$

The connection (8) is justified for $k = 1$ (6), and in general, it has the form (9) [13]. Whence for an arbitrary value k, the universal relation is true

$$\frac{\varphi(k)}{\psi(k)} = k\frac{k + 2 - \psi(k)}{k + \varphi(k} \tag{9}$$

Let us investigate the regularities of GD in models (6) of the differential probability density function (PDF) for the exponential and normal distribution of continuous RVs.

2.2 *Exponential Distribution with Density*

The constant normalization of the function (10) equals (11):

$$f(x) = \boldsymbol{\lambda} * \exp(-\boldsymbol{\lambda} \boldsymbol{x}) \tag{10}$$

$$C_{[\alpha,\beta]} \int_{\alpha}^{\beta} 1 \cdot f(x)\mathrm{d}x = \overline{1_{[\alpha,\beta]}}, \Rightarrow C_{[\alpha,\beta]} = \frac{1}{\exp(-\lambda\alpha) - \exp(-\lambda\beta)} \Rightarrow C_{[0,\infty)} = 1 \tag{11}$$

Further analysis will be performed for the standard $\boldsymbol{\lambda} = 1$ exponential distribution (SED). For SED, the statistical average $X = 1$ is only 5% higher than the coordinate value of the point GD $X = 0.962$ [4], for which the CDF ratio $\varphi = 0.618$. At the point with the coordinate $X = 1$, the ratio equals 0.632. In the interval $[0, \varphi]$, there is another point GD with a coordinate, for which the values of the ratio shown in (12), from which the coordinate $X_{P,\boldsymbol{\psi}}$ is equal to 0.481.

$$X_{P,\boldsymbol{\psi}} < 1/2 \tag{12}$$

Therefore, the ratio of coordinates $X_{P,\varphi}/X_{P,\boldsymbol{\psi}} = 2$, while the ratio of CDF values at these points is equal to $1 + \varphi$. Between the points, GD, the localized quantile of the division of CDF is in half with the coordinate 0.692.

For the SED, the CDF and PDF quantiles are the same. At the coordinate point, the CDF reaches the value $0.392 \approx 0.4$, and the corresponding point on the y-axis satisfies the inequality (13).

$$P_{X_{P,\varphi}} > P_{X=0.5} > P_{X_{P,\boldsymbol{\psi}}} \tag{13}$$

Points with coordinates $X_{P,\boldsymbol{\psi}}$, $X_{0.5}$, $X_{P=0.5}$, $X_{P,\varphi}$, together with their corresponding CDF values and the known characteristic of CDF relaxation in the exponential process $X_e = 0.46$ shown in Fig. 1, where the points with coordinates $X_{P,\boldsymbol{\psi}}$, $X_{P,\varphi}$, φ^2, φ form a rectangle with exponential diagonals. Note that for point $X_e = 0.46$, it is also possible to construct a GD model.

Indeed, given the inequality, $e^{-1} < 0.5$, we obtain

$$\boldsymbol{\psi}_e^2 - (2 + p_e) + 1 = 0 \Rightarrow p_e = e + e^{-1} - 2 \approx 1.086 \tag{14}$$

GD with a quantitative characteristic corresponding to the phase point $p = -1.086$, $q = +1$ in the fourth ($p > 0$, $q < 0$) quadrant. In the second ($p < 0$, $q > 0$) quadrant, the equivalent point GD has coordinates $\varphi_e = 1 - \boldsymbol{\psi}_e = 1 - e^{-1} = 0.632 \Rightarrow k_e \approx 1.087$.

Let us establish the regularities of GD for the amplitude of PDF $f(x)$ (10). For SED, the amplitude of the PDF is equal to one at a point $x = 0$, so the coordinates of the points GD of the CDF and PDF values are related by the equations:

$$X_{f,\psi} = X_{P,\phi} \quad \text{and} \quad X_{f,\phi} = X_{P,\psi}. \tag{15}$$

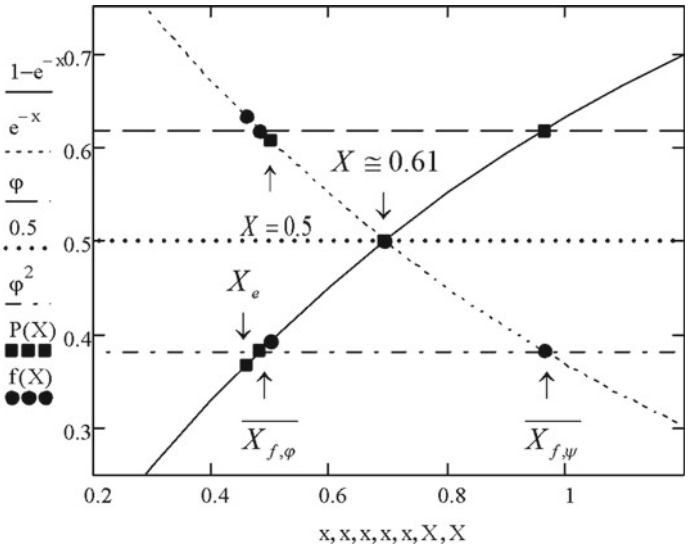

Fig. 1 Illustration of symmetry of localization of points of division of exponential spectra

At the point $X = 0.5$, the amplitude of the PDF decreases to the value $f_{X=0.5} = \exp(-0.5) = 0.607$, and at the poin $\underline{X_{[0,\infty)}}$, it relaxes to the value $f_{\underline{X_{[0,\infty)}}} = \exp\left(-\underline{X_{[0,\infty)}}\right) = \frac{1}{e} = 0.368$.

In the phase direction (6), the above-mentioned list of characteristic points of change of CDF and PDF refers to the point $k = 1$. The value $k = 2$ in the second ($p < 0$, $q > 0$) quadrant corresponds to a phase point with coordinates $(p, q) = (2, -2)$, which in the fourth ($p < 0$, $q > 0$) quadrant corresponds to a similar point with coordinates $(p, q) = (-4, 1)$. For phase point data, the quantitative characteristics of GD $\phi_{k=2}$, $\psi_{k=2}$ CDF and PDF are equal to (16):

$$\left\{\begin{array}{l}\phi_{k=2} = 0.732\\ \psi_{k=2} = 0.268\end{array}\right. \Rightarrow \left\{\begin{array}{l}\left\{\begin{array}{l}P_{X_{\varphi_{k=2}}} = 1 - e^{-X_{P,\varphi_{k=2}}} \Rightarrow X_{P,\varphi_{k=2}} = 1.317 > \overline{X_{[0,\infty)}},\\ f_{X_{\varphi_{k=2}}} = e^{-X_{f,\psi_{k=2}}} \Rightarrow X_{f,\psi_{k=2}} = 0.312 < \overline{X_{[0,\infty)}},\end{array}\right.\\ \left\{\begin{array}{l}P_{X_{\varphi_{k=2}}} = e^{-X_{P,\varphi_{k=2}}} \Rightarrow X_{P,\varphi_{k=2}} = 0.312 < \overline{X_{[0,\infty)}},\\ f_{X_{\psi_{k=2}}} = 1 - e^{-X_{f,\psi_{k=2}}} \Rightarrow X_{f,\psi_{k=2}} = 1.317 > \overline{X_{[0,\infty)}},\end{array}\right.\end{array}\right. \tag{16}$$

2.3 Normal Distribution

Calculate the values of the coordinates of the points GD Y_ϕ, X_ψ, and the coordinate of the quantile Y_{qu} for the $N(X, \sigma, m)$ distribution with a differential function of

probability densities (PDF):

$$f(x,\sigma,m)=\frac{1}{\sqrt{2\pi\sigma^2}}e^{-\left(\frac{x-m}{\sqrt{2}\sigma}\right)^2}, \tag{17}$$

where m, σ are mathematical expectation and standard deviation σ.

For the normal distribution, the confidence interval $[m\pm 3\sigma]$ covers more than 99.9% of the data. Therefore, to conduct a comparative analysis Y_ϕ, X_ψ, Y_{qu}, with in the interval $[m\pm 3\sigma]$ of the statistical characteristics of RV $\underline{X_{[m\pm 3\sigma]}}$ and $\sigma_{[m\pm 3\sigma]}=+\sqrt{D_{[m\pm 3\sigma]}}$ calculate them.

In the interval $[m\pm 3\sigma]$, the normalization of PDF (16) is equal to:

$$C_{[m\pm 3\sigma]}=\frac{1}{\int_{m-3\sigma}^{m+3\sigma}\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-m)^2}{2\sigma^2}}\mathrm{d}x}=\frac{1}{erf\left(3/\sqrt{2}\right)}, \tag{18}$$

$$\frac{1}{\sqrt{2\pi}\sigma}\int e^{-\frac{(x-m)^2}{2\sigma^2}}\mathrm{d}x=-\frac{1}{2}erf\left(\frac{-x+m}{\sigma\sqrt{2}}\right), \tag{19}$$

where the tabular integral is used (19) [17]. Since the integration interval $(m-3\sigma, m+3\sigma)$ is symmetric, the statistical mean $\underline{X_{[m\pm 3\sigma]}}=m$.

Calculate the root mean square error RV in the interval $[m\pm 3\sigma]$. If RV X and $\underline{X}$ are statistically independent, then variance is calculated by the formula (20).

$$\begin{aligned}D_X=\sigma^2&=\int_{-\infty}^{\infty}(x)^2Cf(x)\mathrm{d}x+\underline{X}^2\int_{-\infty}^{\infty}Cf(x)\mathrm{d}x-2\underline{X}\int_{-\infty}^{\infty}xCf(x)\mathrm{d}x\\&=\underline{X^2}+\underline{X}^2\int_{-\infty}^{\infty}Cf(x)\mathrm{d}x-2\underline{X}^2=\underline{X^2}-\underline{X}^2.\end{aligned} \tag{20}$$

Calculate the root mean square RV $\underline{X^2_{[m\pm 3\sigma]}}$.

$$\underline{X^2_{[m\pm 3\sigma]}}=\frac{1}{erf\left(\frac{3}{\sqrt{2}}\right)}\frac{1}{\sqrt{\pi}}\int_{\frac{\alpha-m}{\sqrt{2}\sigma}}^{\frac{\beta-m}{\sqrt{2}\sigma}}\left(\sqrt{2}\sigma t+m\right)^2e^{-t^2}\mathrm{d}t. \tag{21}$$

Thus, the variance will be equal to

$$D_{[m\pm 3\sigma]}=\sigma^2-3\sqrt{\frac{2}{\pi}}m\sigma\frac{e^{-\frac{9}{2}}}{erf\left(\frac{3}{\sqrt{2}}\right)}$$

$$\Rightarrow \sigma_{[m\pm 3\sigma]} = \sigma \sqrt{1 - 3\sqrt{\frac{2}{\pi}}\frac{m}{\sigma}\frac{e^{-9/2}}{erf\left(3/\sqrt{2}\right)}}$$

$$\cong \sigma\sqrt{1 - 0.027\frac{m}{\sigma}} \tag{22}$$

Thus, the transition from an infinite range of random values X of the argument to a limited $[m \pm 3\sigma]$ one only slightly reduces its width.

Calculate the coordinates X_ϕ, X_ψ, X_{qu}. For the standard normal distribution $m = 0, \sigma = 1$, their values are equal to

$$\begin{cases} X_\phi \cong +0.3 \\ X_\psi \cong -0.3\ , \\ X_{P=0.5} \cong 0 \end{cases} \tag{23}$$

Thus, the points GD with coordinates Y_ϕ, X_ψ are located almost symmetrically on both sides relative to the mathematical expectation m. If $m \neq 0$, the values Y_ϕ, X_ψ are calculated:

$$\begin{cases} X_\phi \cong m + 0.34\sigma \\ X_\psi \cong m - 0.33\sigma\ , \\ X_{P=0.5} \cong m \end{cases} \tag{24}$$

The results (24) are consistent with (23).

The localization geometry of the GD points of the CDF curve is shown in Fig. 2. We see that the numbers ϕ, $\psi = \phi^2$ are the points of intersection on the CDF $P2(x) = \int_{-\infty}^{X} f(x)\mathrm{d}x$ of horizontal direct integral probabilities $P3(x) = \int_{m-3\sigma}^{m+3\sigma} f(x)\mathrm{d}x$, $P4(x) = \int_{m-3\sigma}^{m-0.34\sigma} f(x)\mathrm{d}x$, the projections of which on the abscissa determine the values of the coordinates X_ϕ, X_ψ. The location of the points X_ϕ, X_ψ, symmetric with respect to the CDF quantile $P(x) = 0.5$, as the coordinates X_{qu} of the point of intersection of CDF with the horizontal line $P1(x) = \int_{m-3\sigma}^{m} f(x)\mathrm{d}x$. The coordinates Y_ϕ, X_ψ, on the abscissa axis ϕ, ψ on the ordinate axis form a rectangle with an area $S = 2\int_{X_\psi}^{X_\phi} P(x)\mathrm{d}x = \left(X_\phi - X_\psi\right)\cdot(\phi - \psi)$ of 8 right triangles equal to each other with an area $S = \frac{1}{4}\left(X_\phi - m\right)\cdot(\phi - \psi)$. The half value $S \cong \frac{3}{2}\phi(1-\phi)\cdot\sigma$ of the area of the rectangle varies in proportion to the parameter of the expansion of the contour PDF σ (16).

At the points X_ϕ, X_ψ, the values of PDF (16) are equal to

$$f\left(X_{\phi,\psi}, \sigma\right) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{\left(X_{\phi,\psi} - m\right)^2}{2\sigma^2}\right)$$

$$\cong \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-(0.24)^2\right), \tag{25}$$

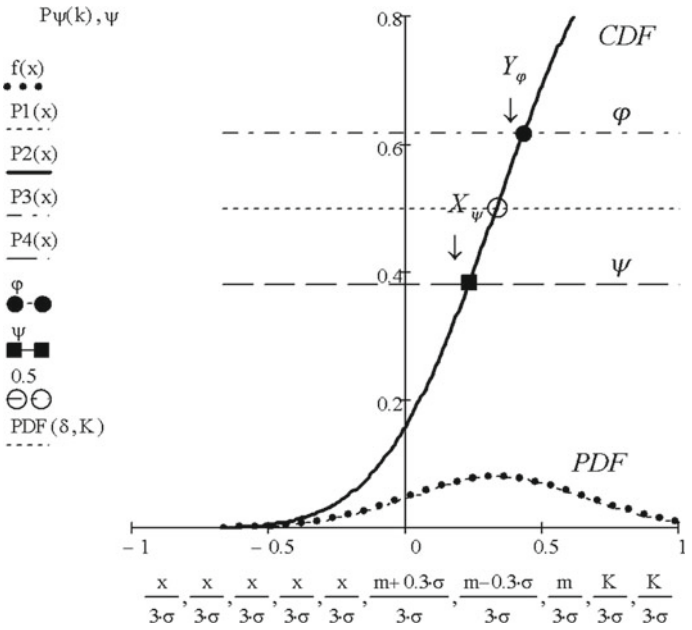

Fig. 2 Illustration the localization geometry of the GD points of the CDF curves

hyperbolically decrease with growth parameter σ, and the value of the exponent PDF, which in the distribution law (2.2.12) determines the width of the contour $f(x)$, does not depend on the parameters RV of m, σ. This allows you to calculate the RV parameter as σ:

$$\sigma = \frac{1}{\sqrt{2\pi}\, f\left(X_{\phi,\psi}, \sigma\right) \cdot \exp\exp\left((0.24)^2\right)}. \tag{26}$$

Let us analyze the regularities GD of the amplitude $\frac{1}{\sqrt{2\pi}\delta}$ of the PDF circuit (16). By analogy with GD, we introduce the corresponding coordinates Z_ϕ, Z_ψ, with quantitative characteristics

$$\phi = \frac{f\left(Z_\phi\right)}{\frac{1}{\sqrt{2\pi}\delta}} = 0.618 \quad \text{and} \quad \psi = \frac{f\left(Z_\psi\right)}{\frac{1}{\sqrt{2\pi}\delta}} = 0.382. \tag{27}$$

Substituting (27) in (16), we obtain that

$$\begin{cases} \exp\left(-\left(\frac{Z_\phi - m}{\sqrt{2}\sigma}\right)^2\right) = \phi \Rightarrow Z_\phi = m \pm \sqrt{2}\sigma\sqrt{-\ln\ln\phi} \cong m \pm 0.981 \cdot \sigma \\ \exp\left(-\left(\frac{Z_\psi - m}{\sqrt{2}\sigma}\right)^2\right) = \psi \Rightarrow Z_\phi = m \pm \sqrt{2}\sigma\sqrt{-\ln\ln\psi} = m \pm 1.387 \cdot \sigma \end{cases}. \tag{28}$$

Therefore, according to (27), the coordinates of the GD points of the PDF and CDF functions are linear functions of the parameter, which makes it possible, in addition to formula (26), to perform an additional estimate. Since there is a set of GD points in the phase direction (6) (Fig. 2), we have a set of implementations of the model (27).

3 Conclusion

The binary structuring of CDF allows the expansion of the range of characteristic points on the contours of the corresponding dependencies, which do not depend on the probability distribution law of random values. Modeling the differential spectra of the exponential distribution by the points of the "golden" division shows that the corresponding implementation is not unique. There are many of them and an arbitrary relationship based on the geometric mean, which significantly expands the possibilities of application for diagnosing complex systems of already developed optimization methods.

Despite the universality of Gauss's law for diagnosing the reliability of systems [17], the two-parameter representation of the probability density function limits its application, as the height and width of the contour are interrelated, forcing [18] to search for more complex models. This paper proposes one of the approaches to solving this problem by binary structuring of probability parameters according to the "golden" proportion.

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Advance of Interactive Playful Tools Used in Pandemic

Luis Serpa-Andrade, Roberto Garcia-Velez, and Graciela Serpa-Andrade

Abstract COVID-19 was a pandemic that affected all sectors worldwide, one of the solutions was teleworking, virtual classes, which not everyone had access, educational platforms were improved; but they did not cover all the demand, in some countries, audiovisual programs such as Educa Ecuador were adopted that everyone could hear and see on TV and radio, mobile medical assistance; however, it was not enough to adopt and improve the technology that was available at that time to reach all people, especially people with special needs, so interactive playful tools, such as therapeutic robots, ICT, improving digital platforms, among others; for good social and educational integration during the pandemic. Currently, the improvement of interactive playful tools and actions that were adopted during COVID-19 continues with the purpose of continuing to advance in education and socio-economically, always preserving individual and environmental safety and good health.

Keywords Interactive playful tools · COVID-19 · Pandemic · Education

1 Introduction

The coronavirus was discovered in November 2019 in the city of Wuhan-China causing the COVID-19 disease, there were many human losses, it spread quickly in Euro Asia, then in America; however, it was declared a pandemic on March 11, 2020 [1, 2]; moment when everyone went into confinement; paralyzing all socio-economic activity, exacerbating intra-family and micro-social problems [3, 4], increasing uncertainties such as "Marta, a twelve-year-old girl from Barcelona who was confined to her home for four months uninterruptedly" [5]; after a few months, the use of ICT

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and artificial intelligence increased [6]; updating digital platforms for all public and private activities, for teleworking, telemedicine, virtual classes [7, 8]; but it was not enough not all of us had access to a computer much less Internet, so the program Educa-Ecuador, learn from home-Peru, was transmitted on television and radio in such a way that everyone receives classes in their homes [9, 10], mobile medical assistance places of difficult accessibility, pedagogical assistance, medicinal with virtual therapies and therapeutic robots [11], to avoid contagion in the vulnerable population: children, the elderly, people with special needs, sick and pregnant, training on prevention measures, and innovation of interactive playful tools reaching everyone as human–AI–robot teaming HART, improving education, socio-economic situation, especially decreasing mortality rates from COVID 19 and maintaining our personal safety both physical and mental and our habitat [12].

2 Playful Tools

2.1 Playful

Playfulness acts in cognitive, emotional, psychological, linguistic, physical, social, moral aspects, in every action of being; that is; "playfulness refers to any action that, in one way or another, allows the human being to know, express, feel, and relate to his environment, a free activity that produces satisfaction and joy achieving the enjoyment of each of his daily actions" [13]; also "playfulness in its different expressions enriches positive manifestations such as admiration, enthusiasm, curiosity, joy, sociability, attention, security in their high self-esteem, dynamism, dialog, willingness to participate, contribute and build ideas and solutions, strive to compete and have fun, characteristics of the inherent and ideal state in the child" [14]. The playful promotes the development of a positive behavior, that is, interacts feelings-thoughts-situation-aptitude-behavior through games and constant reflections resulting in optimistic, innovative and favorable reactions and solutions for the integral development of people [15].

2.2 Playful Tools

Tools are considered any instrument that allows daily activities, consequently, interactive playful tools are those that allow us to do activities that develop skills, motivate, create pleasant environments, encourage learning by acquiring knowledge, increasing creativity, solving behavioral, cognitive, psychic problems, and helping people with special needs [16, 17]; obtaining improvements in self-esteem, social skills, overcoming phobias, depression, anxiety, among others; strengthening skills; developing skills throughout our lives [18, 19]. Consequently, it could be said that

one of the objectives of interactive playful tools involves developing a vital approach aimed at acting on opportunities and ideas, using the specific knowledge necessary to generate valuable results for other people, adapting the look to detect needs and opportunities; train thinking to analyze and evaluate the environment, and create and reframe ideas using imagination, creativity, strategic thinking and ethical, critical, and constructive reflection within creative and innovation processes; and awaken the willingness to learn, to risk and to face uncertainty. It also involves making decisions based on information and knowledge and collaborating in an agile way with other people, with motivation, empathy, and communication and negotiation skills, to take the ideas raised into action through the planning and management of sustainable projects of social, cultural, and economic-financial value [15, 20]. The playful tools used in pedagogy and therapies perform a functional analysis based on reaction situation, identifying areas for improvement, developing skills, and applying stimulating the being, child, or patient [21].

Playful tools used during the pandemic. When COVID-19 was declared a pandemic, all social activity was paralyzed, we entered quarantine [22], contact had to be avoided, during confinement, we had to go to work that demanded basic services, and they could not be virtual taking sanitary measures and minimum distancing of 2 m; simultaneously [1, 22], all activities were reorganized by going to the application of information and communication technologies—ICT and its challenges (see Table 1); to carry out labor, educational, medicinal procedures adopting teleworking, tele law, virtual classes, telemedicine; in general, most activities were carried out through technology; the system that collapsed [7, 23] was not enough and not everyone had access to the Internet [18] (Fig. 1); then, audiovisual programs were provided by the media for pedagogical, medical, and health education such as Educa in Ecuador, learn from home in Peru, flash information on prevention measures, mobile medical care, treatments, and therapies with therapeutic robots [24, 25]; to achieve, for example, an appraisal of the food quota, that is, pension that corresponds to children and adolescents by right for their sustenance and integral development through tele law, gamification in learning, therapeutic robots [15, 26].

Playful tools post-pandemic. The pandemic affected all areas, sectors of our daily lives [35], new techniques, playful tools were acquired, expanding research on the effects of this in the being, in the family, academic and socio-economic and environmental environment; as in the case of post-pandemic education [5, 36] (see Fig. 2), determining the "… radical changes and transformations, starting with the contextualization of educational models, based on the paradigms of this science, where constructivism, in theory, seems to be at the forefront, adapted to the situation of virtuality [37]"; optimizing ICTs, virtual platforms, therapeutic robots (see Fig. 3) and all kinds of recreational tools seeking greater efficiency and effectiveness [38] in the post-pandemic quality of life; habits were developed such as the use of virtual platforms: work, didactic, [17] health, and social such as Facebook, WhatsApp, and Instagram, during the pandemic for academic purposes, family; currently, they spend hours connected to social networks not necessarily for educational consultations harming their sleep time, sports, fun, among others [37].

Table 1 Playful tools used in the pandemic

Activities	Tools and therapies	Applications and users	Remarks
Labor	Email	Yahoo, Gmail, outlook	Level of knowledge predominates videoconferences, office tools Greater degree of domain in chat, emails, and the least content tools, penultimate LMS tools within video conferences, zoom is most used, followed by WhatsApp, YouTube, Google Meets, and My Teams [7, 15, 27]
	Forums	Google class, Moodle	
	Chat	Whats App Messenger Teams	
	Videoconferences	Zoom, Ms Teams, Cisco Eb	
	Collaborative work tools	Zoom, Slack, Trello, Workplace, Facebook, Wrike, Zoho	
	Information search tools	Google, Bing, Yahoo, Alta Vista, Lycos Wikipedia	
	Content curation tools	Feedly, List.ly, Pocket, Buffer, Linckedin Pulse, Summify	
	Office tools	Word, Excel, Power Pint, Open Office	
	Video editors	Blender, Avidemus, LightWorks, Da Vinci Results	
	Tools for creating educational content	Pearltrees, Padlet, Feedly, Thinglink	
	Mind mapping tools	Text2, Bubble, us.Gliffy, Popplet, Cmaps tools	
	Learning management platform LMS	Moodles, Canvas LMS, Chamilo LMS, Sakai, Blacknoard LMS	
	Systems responses in real time	Kahoot, Google forms	
	Content management systems—CMS	Wordpress, Magento, Droopal, Joomla	
	Platform for audiovisual content	Outube, Vimeo	

(continued)

Table 1 (continued)

Activities	Tools and therapies	Applications and users	Remarks
Education and medicine	Social communication skills	Children with ASD; ADHD; ID; people with dementia; CP; older adults with social interaction problems [28, 29]	Some therapies: CBT, BT, SLT, emotional support and social, language, speech rational emotional-TREC, occupational therapy-OT, meditation, etc. Some robots: robot, toy, build-a-robot, Popchila, NAO Kaspar, Pekee, IROMEC, TICO, PARO, Keepon, etc. used in rehabilitation centers; with the pandemic, its use was facilitated with mobile care, in therapies and teaching in homes [16, 24]
	Memory	Children with CP; older adults without CI; people with mild CI; dementia	
	Concentration	Children with ASD; ADHD [30, 31]	
	Attention	Children with CP; ID; people with mild and severe CI; older adults without CI [21, 32]	
	Visuo-spatial abilities	Children with impaired spatial abilities and WM [26]	
	Awareness	People with ABI [16]	
	Cognitive training (no specific cognitive function)	Children with ASD; older adults without CI; people with mild CI; dementia; ID; people post-stroke [33, 34]	
	Disruptive behavior problems	Children with DBD [16]	
	Anxiety	People with anxiety	
	Distress	Children with cancer [24]	
	Stress	People with stress	
	Psychological healing	Not specified	

(continued)

Table 1 (continued)

Activities	Tools and therapies	Applications and users	Remarks
	Hypnotherapy [20]	Not specified	
	Education	Children with dyslexia; ASD; severe PD; TBI; people with PMLD [19]	
	Vocational training	People with ASD; TBI [2]	

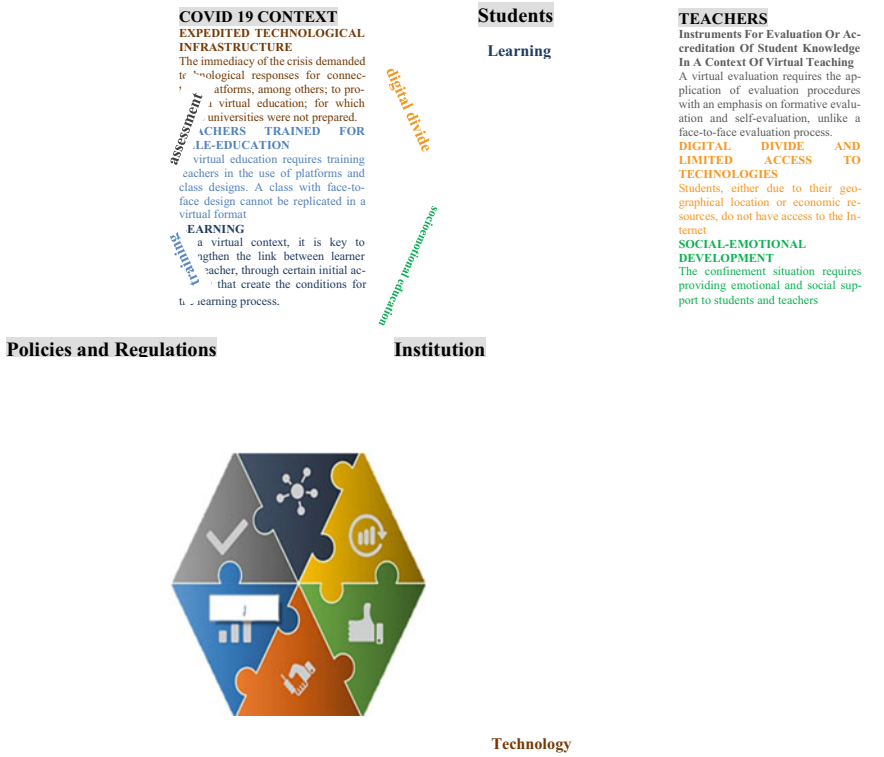

Fig. 1 Challenges of higher education in the context of crisis [18]

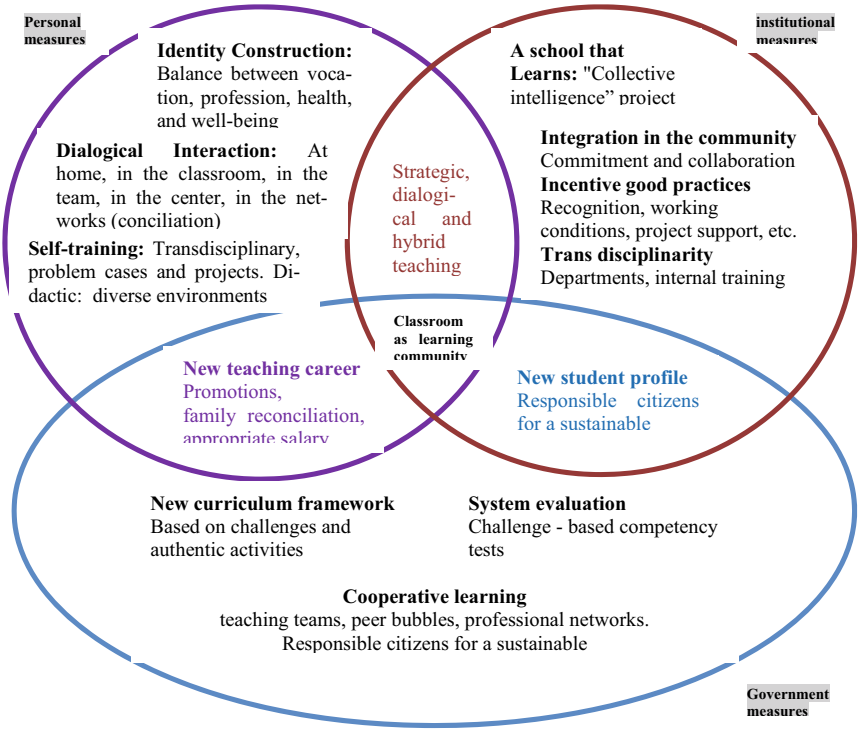

Fig. 2 Measured for the development of a post-pandemic education [5]

Therapy	Tool	Therapeutic robots			
Attention-deficit Hyperactivity Impulsiveness Cerebral palsy Hemiplegia Physical motivating rehabilitation Playful learning	Video games, Animatronics: physical with virtual reality; PITS-glove, Diego, Pablo Amadeo, Nintendo Wii™, stylus attached to PHANTOM, URSUS, InMotion, Haptic, CosmoBot		Smart-home environment to support the ADHD therapies inside the home [40]	Atent@ robot assistant [41]	
			Therapy for children with autism- ASD, attention deficit cerebral palsy sensorimotor Speech and Language Therapy, S. Down, Alzheimer's	SPELTRA: facilitates audiovisual learning [32] Romibo eye-tracking controlled by iPad, iPhone, or Tablet [33], similar to Leka, is programmable [34]	
Administration of drugs and/or surgical intervention	Biohybrid robots: Octo-bot, robot bees Row-bot, rataraya, the cyborg				

Fig. 3 Virtual playful tools: applications that they work on a computer, iPhone, or Tablet [24]

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Evaluating the Effects of Primary User Emulation Attacks on Cognitive Radio Networks

Nomfundo Favourate Manyisa and Mthulisi Velempini

Abstract A Cognitive Radio Network (CRN) is a solution to wireless technology which solves the spectrum scarcity challenge. CRN addresses the underutilization of the spectrum by enabling unlicensed users to coexist with the network's licensed users (primary users). The secondary users are expected to utilize the spectrum only when the primary user is idle. Unfortunately, cognitive radio network is vulnerable to security threats. This study focuses on one of the threats known as the Primary User Emulation Attack (PUEA). A number of mitigation schemes have been designed to combat the PUEA. This study evaluates the Neyman-Pearson Hypothesis Test (NPCHT) and Wald's Sequential Probability Ratio Test (WSPRT) through network simulations. The results show that the NPCHT only outperformed the WSPRT in the probability of false alarm results when the malicious nodes are high. However, the remaining scenarios also yield poor results.

Keywords Cognitive radio network · Primary user emulation attack · Security threats

1 Introduction

The advancement of wireless communication technology increases the need for more bandwidth and spectrum which results in spectrum scarcity. However, Cognitive Radio introduced by Mitola [1] is a new technology which is regarded as the solution to the overcrowding of unlicensed spectrum and the underutilization of licensed spectrum. Unfortunately, the technology is susceptible to security attacks. This chapter focused on Primary User Emulation Attacks (PUEA). This attack degrades the performance of CRNs. Hence there is a need for mitigation techniques to be deployed to improve the performance of CRNs and to counter the effects of PUEA. In a PUEA, malicious users can emulate the primary user and transmit using the idle channels to

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block the secondary users (SUs) or it can report an idle channel as in use to prevent SUs from using a given channel [2]. The PUEA misleads the SUs so that it can either monopolize the idle channels or prevent the SUs from using the idle channels. As a result, the goals of CRNs are not realized.

2 Related Work

The authors in [3] proposed a cooperative belief propagation procedure to detect an attacker by using Received Signal Strength (RSS) measurements and the interactions between neighbouring secondary users. To relate the received power to the distance between the transmitter and receiver, a parametric model is needed for the approach. The drawback of the belief propagation is that it uses RSS-based approximation of the primary user, which could result in fluctuations even in small environments causing obstacles and transmission imperfections. Furthermore, actual values are not used as it relies on estimated values.

In [4], the authors used the location data of the primary user and the Received Signal Strength (RSS). This scheme has three phases in which at least two of the phases must be satisfied. The phases are: (i) verification of signal characteristics, (ii) received signal energy estimation and (iii) localization of the transmitter. It locates the transmitter using RSS measurements collected by a wireless sensor network. The use of RSS is a challenge as estimates and fluctuations may be frequent in small geographical areas.

Authors in [5] proposed a public key cryptography mechanism where a PU will attach a digital signature to the data unit it transmits. The digital signature is generated using the primary user id, current time stamp and private key. The SUs sense that the primary signal (malicious or non-malicious) is transmitted in a specific channel. The digital signal part is sent to the base station through the control channel. The secondary base station with the help of a Certification Authority (CA) verifies if the signal detected is from the PU or not. The challenge of this method is that a base station is susceptible to DoS attacks when an attack continuously transmits fake signals. DoS is an attack where a stream of traffic is sent continuously to the target to overwhelm and make it unavailable to process any request other than the attack. A number of schemes designed to either detect, address or mitigate the effects of primary user emulation attacks are proposed in [6–22]. The techniques show that this attack still require further attention in CRN. In this work, we evaluate the performance of the most promising techniques.

3 Methodology

There are several techniques used to mitigate the PUEA however in this chapter, we focus on two techniques, the Neyman-Pearson Composite Hypothesis Test (NPCHT) and the Wald's Sequential Probability Ratio Test (WSPRT). These two schemes were selected in this study as they are recommended as the best techniques by other researchers. Furthermore, they do not require the knowledge of where PU is located which requires a lot of computation. They however rely on the signal strength of the PU.

The comparative performance of the schemes was evaluated using these metrics:

- The Probability of a False Alarm (PFA)
- The Probability of Missed Detection (PMD)
- The Probability of Detection (PD)

Tools and platforms that were used:

To simulate and perform the analysis, MATLAB was used. It was installed on an HP L45 Desktop computer with 8 GB RAM. Intel®Pentium(D) CPU 2037 @3.19 GHz running on Windows 10 Operating System.

4 Results

The main objective was to evaluate the efficiency of the two selected schemes in detecting the PUE attack. In this study, different network sizes were considered with 20, 50 and 70 nodes with different percentages of attacking nodes such as 15%, 25% and 35% respectively. We evaluated the performance of the schemes based on the following metrics: the PD, the PFA and the PMD. The evaluations were carried out in a grid of 700*700 square metres of network topology. The performance of the selected schemes was evaluated in a MATLAB environment.

5 Analyses of the Results

The scenario in Fig. 1 shows the simulation of the performance of the two selected schemes where both malicious users and secondary users are active in the network. For example, in a network with 20 nodes, 15% of the nodes would be malicious. The network also included a base station. The primary user is located outside the CRN.

Figure 2 results show the PFA. It shows that the WSPRT achieved the least PFA compared to the Neyman-Pearson Composite Hypothesis Test. For WSPRT, when $N = 20$, there are 3 malicious users and the results show a decreasing PFA even when the number of nodes is increased. The PFA of WSPRT is less compared to NPCHT.

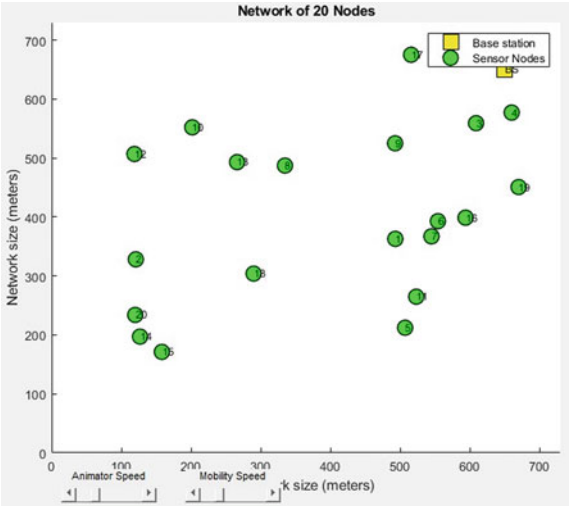

Fig. 1 Cognitive radio environment.

This means that the WSPRT has fewer instances of false alarms in comparison with the NPCHT which shows that it is more efficient.

Figure 3 results show how the two schemes performed when the number of attacking nodes was increased with the number of nodes being constant. The results show that WSPRT has been consistent in reducing the PFA compared to NPCHT which fluctuates between the three scenarios. The WSPRT outperformed the NPCHT as shown in Fig. 3. We also observed that the PFA increases as the attacking nodes are increased.

Figure 4 shows the results with 35% of attacking nodes. We observed that there was an increase in the PFA in WSPRT as the environment was smaller with a higher

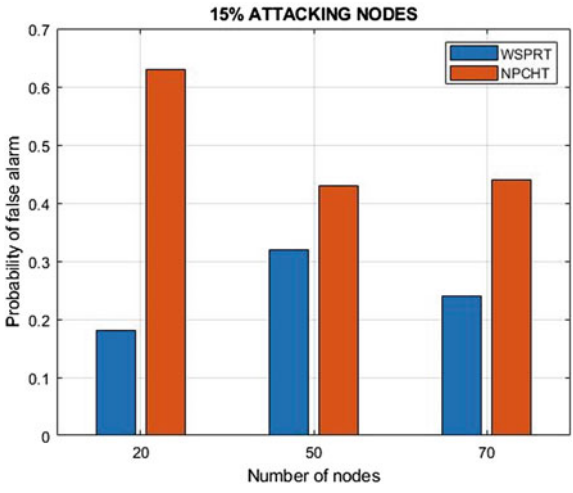

Fig. 2 Probability of false alarm with 15% attacking node.

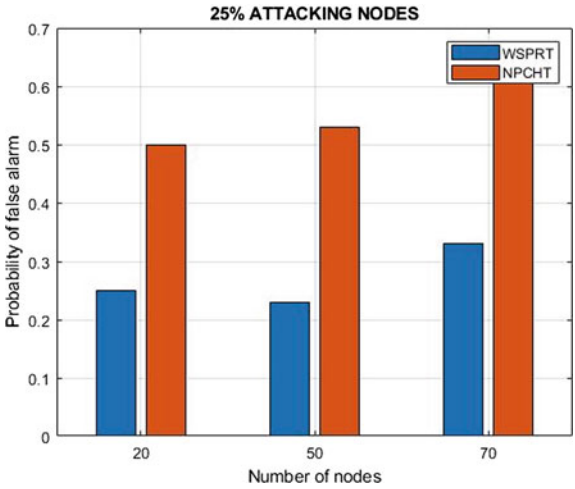

Fig. 3 Probability of false alarm with 25% attacking nodes.

number of attacking nodes. In this scenario, the number of attacking nodes was increased to 35%. The NPCHT performed better than WSPRT in this instance which shows that it is effective in addressing the effects of malicious nodes when more malicious nodes are considered. The results also show how the scheme performs in scenarios where the number of malicious nodes is increasing.

Figure 5 shows that WSPRT reduced the PMD more than the NPCHT scheme. We observed that NPCHT's PMD is much higher which shows that the scheme is unable to reduce the PFA. We also observed that the PFA remains consistent as the number of nodes in the network increases. The performance of WSPRT keeps on reducing the PFA regardless of the change in the number of malicious nodes in a network.

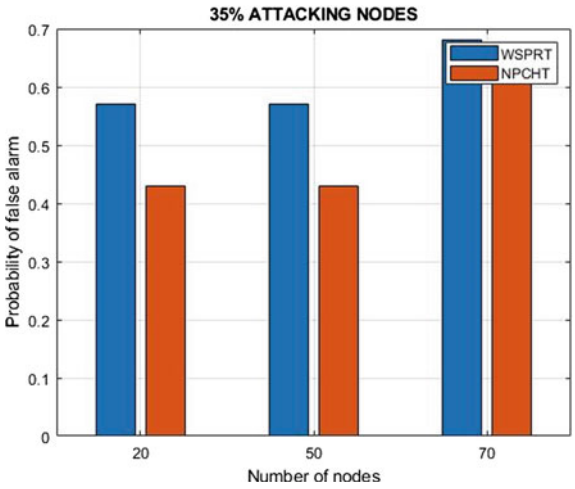

Fig. 4 Probability of false alarm with 35% attacking node.

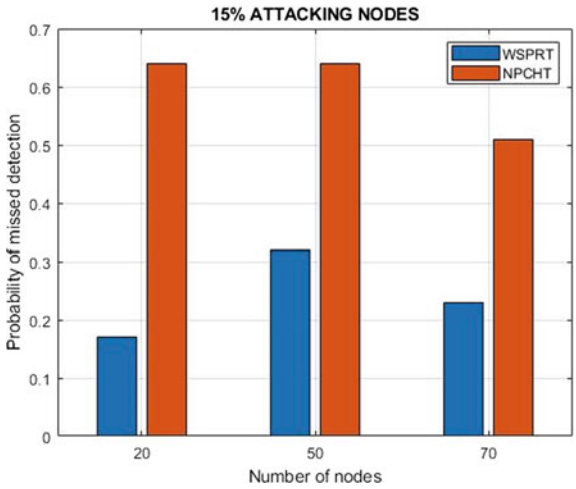

Fig. 5 Probability of missed detection with 15% attacking nodes.

In Fig. 6, through simulations, we can observe the positive results in WSPRT as it is not affected by the change in the increasing number of malicious users in the network compared to NPCHT where the missed probability is still much higher. WSPRT probability is also the same compared to the scenario when the number of attacking nodes was 15% of the total nodes. Nevertheless, the WSPRT still performed better. We then increased the number of attacking nodes from 25 to 35% of the total nodes in Fig. 7.

Figure 7 shows that WSPRT is affected by the missed probability compared to NPCHT. The results show that WSPRT is affected by the increase in malicious nodes in the network. Its performance degraded significantly compared to Fig. 6. However,

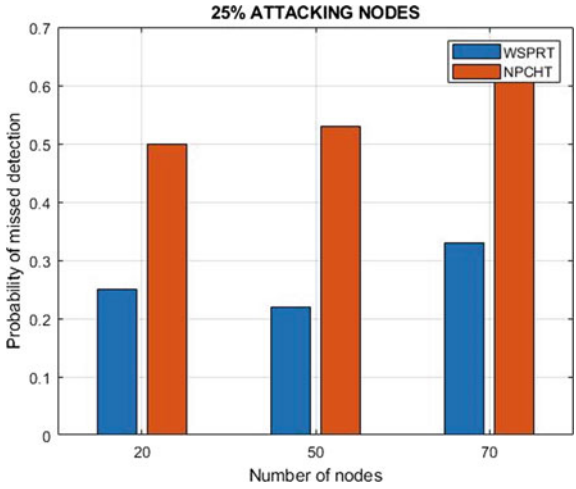

Fig. 6 Probability of missed detection with 25% attacking nodes.

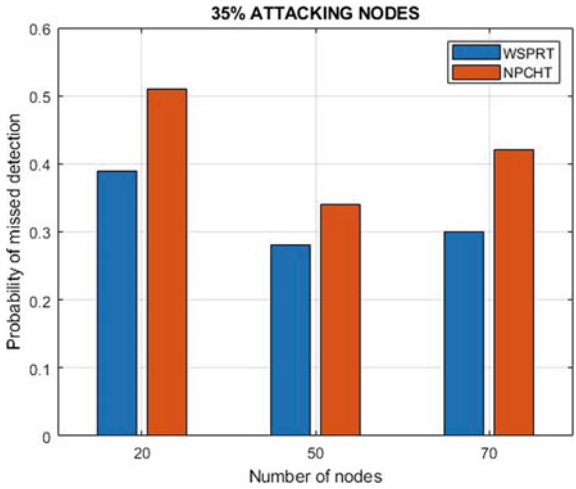

Fig. 7 Probability of missed detection with 35% attacking nodes.

despite the higher percentage of increase in response to the increase in the number of attacks, the WSPRT still outperformed the NPCHT scheme.

In Fig. 8, we observed that the performance of WSPRT is degraded by the increase in the number of attacking nodes. As the percentage of malicious nodes increases, the detection results of WSPRT become poor whilst the results of the NPCHT scheme improves. This shows that the performance of NPCHT improves with the increase in the percentage of malicious nodes. This analysis pertains to how the two schemes respond to the increasing number of nodes. However, in general, the WSPRT scheme is still superior.

In Fig. 9, the WSPRT has a higher probability compared to NPCHT and its probability is somewhat constant as the number of nodes is increased. However, the

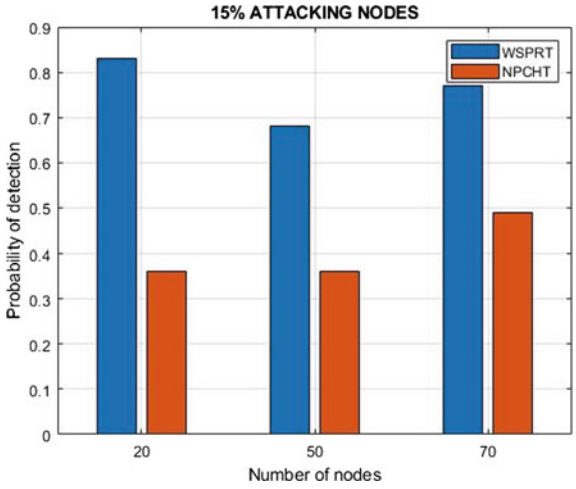

Fig. 8 Probability of detection with 15% attacking nodes.

probability of NPCHT keeps on decreasing as the number of nodes increases. This shows the effect of the increasing number of nodes in scenarios with higher percentages of malicious nodes. The NPCHT scheme was outperformed by the WSPRT scheme.

In Fig. 10, the PD of the WSPRT scheme is lower compared to Fig. 9. Its performance is marginally better than the one for the NPCHT scheme. As the percentage of malicious nodes increases, we observed that the two schemes' probabilities were increasing as the number of nodes increases. The WSPRT is still superior in all the scenarios. This shows that the WSPRT is effective in detecting PUEA.

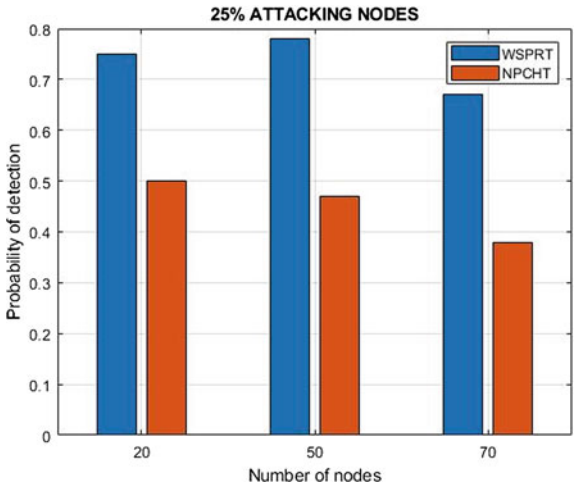

Fig. 9 Probability of detection with 25% attacking nodes.

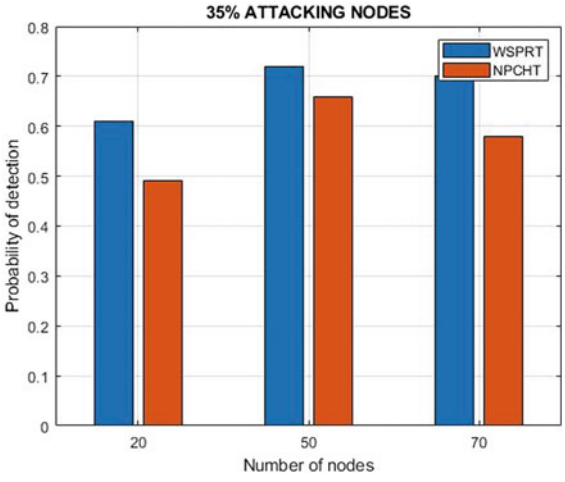

Fig. 10 Probability of detection with 35% attacking nodes.

6 Conclusion

The performance of WSPRT was compared to NPCHT, these two schemes detect and isolated malicious users. The performance results show that WSPRT is superior to NPCHT, especially when the percentage of malicious nodes is 15%. In a network where the number of malicious nodes is higher, NPCHT performs better than WSPRT in the PFA results. This happens to be the only scenario where the NPCHT performs better than WSPRT scheme.

The study can be improved by improving the two schemes. The best features of the two schemes can be integrated into a new hybrid scheme optimized for improved detection efficiency. There are also other security challenges in the cognitive radio, such as the spectrum sensing data falsification (SSDF), which require attention. The combined effects of PUEA and SSDF can be more disruptive. The DOS attacks can also scale the magnitude of the attacks in CRNs.

It is therefore of paramount importance to address the effects of PUEA in CRNs since it negates its goals. As a result, PUEA ensures that the spectrum challenges are not addressed. The overcrowding of unlicensed spectrum and the underutilization of licensed spectrum persist in the presence of the PUEA attacks. It renders the CRN technology ineffective.

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3L-AODV: Three Layer Security Protocol for Grayhole Attack Mitigation in MANET

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Abstract As the mobile ad hoc networks infrastructure has no centralized points of connections, the traffic from a source to a destination passes through number of intermediate nodes. When more than one neighbor node is available, the traffic passes through one of them based on some criteria. If a node behaves maliciously in all of the connections and drops the traffic, it creates a security blackhole, while a malicious node that behaves normally is some of the connections creates a security grayhole. Since the malicious node behaves normally in some connections, mitigating this attack is challenging. In this paper, we proposed 3L-AODV, a security protocol that uses three layers of protection and detection to mitigate the grayhole attack. As it does not require any modification on the AODV protocol, it can be implemented on any network that its routing is based on AODV. The analysis of our results shows that 3L-AODV could mitigate the grayhole attack without affecting the performance of the network.

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Keywords MANET · Grayhole · Security protocol

1 Introduction

A mobile ad hoc network (MANET), also called a wireless ad hoc network or mobile mesh network, is a wireless network without a centralized infrastructure, i.e., the nodes do not need to communicate with a central base station or access point. Thus, the mobile nodes communicate directly among themselves using wireless links. In MANET, the nodes are assumed to have both host and router roles, which allows a node to forward data to other nodes. This way, the information can pass through some nodes in communication between the source and the sink [2]. As the nodes in MANET can be producers and consumers of data without any centralized node, the communication between any two nodes is established either directly or through some intermediate nodes. In case, there is no direct link between the sender and the receiver, the sender passes the traffic to its neighbors to be forwarded toward the destination node [15]. While this infrastructure makes the creation and management of the network more flexible, it adds some challenges, such as security and trustiness, due to its decentralized and mobile nature.

Due to the mentioned infrastructure, the transmission starts from one of the neighbor nodes, and the traffic in indirect links passes through multiple nodes to reach its destination. Choosing which node among the neighbors to send the traffic through depends on the closest and most updated path. The choice considers the path that has the higher sequence number (*Seq*) or, in the case of two equal *Seq* in two different paths, the path with the lower number of hops. In original protocols such as AODV, there is no guarantee that the information of the returned path by a node is reliable. Therefore, a malicious node can pretend to have the most updated path by setting a high *Seq* and shortest path, which leads to being chosen by the sender node. Then, later, the malicious node can drop all the incoming traffic instead of forwarding it to the destination node. This attack is called *Blackhole attack* [7, 14]. The attack will be harder to detect and prevent if the node forwards some of the traffic as any other normal node and drops the rest of the traffic. In this case, the attack is called *Grayhole attack*.

The objective of this research is to detect any suspicious activity in the network that might turn into a grayhole attack without affecting the network performance. As a result, the proposed model has to mitigate the independent malicious detected nodes from having a successful grayhole attack. We propose 3L-AODV, a security protocol that uses three layers of detection and prevention of grayhole attacks. In first layer, an attribute verification protocol [6] is utilized. In the second layer, a bait detection technique has been implemented, while in the third layer, similar to [7], a threshold detection technique has been utilized. The proposed approach uses a *Credit Value* that is affected by the results of all three layers. 3L-AODV does not require

any modification in the original control messages of the AODV protocol. Therefore, it can be implemented on any existing network without a requirement to modify the existing protocol. The contribution of this paper is as follows:

- Three layers of detection and mitigation of grayhole attack.
- Mitigating the grayhole attack without decreasing the efficiency of the network, or any modification or update in the underlying protocol.

2 Grayhole Attack

MANET is a type of network that can be used without requiring specific infrastructure. It is an unsupervised network consisting of mobile devices to communicate with each other within several hops in a distributed approach [11]. The blackhole attack can be considered a type of denial of service attack and is also known as a full packet drop attack [14]. The attacker node tries to attract the communication traffic, positioning itself as the router node by disclosing its *Seq* number as the maximum and its path number as the shortest. Besides disturbing the routing process, it also degrades the network performance. A grayhole attack [12] is a smarter blackhole attack in which the attacker node works appropriately as a normal node in some of the traffic while on the rest of the traffic works as a malicious one, dropping received packets selectively. This attack is also known as a partial packet drop attack [14] since the attacker node works alternatively as normal and malicious and hence does not drop all the packets.

Figure 1 demonstrates how a grayhole attack can happen. An attacker appears as a malicious node among the intermediate nodes responsible for forwarding the communication between the source and destination and tries to convince the sender

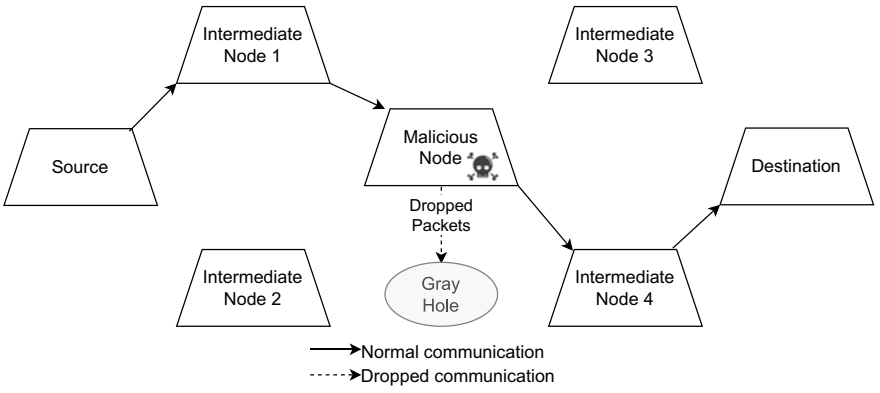


Fig. 1 Grayhole attack

to pass the traffic through the malicious node. Then, sometimes, the malicious node will work adequately, forwarding the packets correctly, and sometimes, it will drop the packets.

3 Related Works

As it has been discussed, grayhole attack as a more complex variant of blackhole attack is a challenge for MANETs security that can cause the destruction of the networks, reducing efficiency, and losing data [4, 16, 19]. Ahamed and Fernando [1] proposed a security mechanism that improves the data communication security between source and destination in a MANET. They also deal with the security issue of a blackhole attack. STAODV proposed by Kamel et al. [7] specifically protects the network against blackhole attack by proposing a model to mitigate the attack through adoption of a threshold technique. Shukla and Joshi [17] proposed trust-based fuzzy AODV technique to handle the blackhole attack using a method of trust-based fuzzy based on energy auditing, neighbor node trusting, node member authenticating, and packet integrity checking. Due to using fuzzy logic, the proposed method suggests that the node is considered to be trusted by evaluating the trust value (greater than or equal to 0.6), then the communication is established between source and destination; otherwise; the node is considered as unsafe. The researchers showed that the results are improved based on factors such as throughput, end-to-end delivery, and delivery ration context.

The blackhole and wormhole attacks were handled by Shukla et al. [18] by using a scalable-dynamic elliptic curve cryptography. They examined two types of scenarios (with and without attack). They found outstanding results according to end-to-end delay and energy consumption. Ramaprasad and Lingareddy [13] introduced a novel scheme to assess the link's legitimacy for detecting the attack of route diversion and counter-measuring the cost-effectiveness of the attack. They concluded that the process of token generation, associated with link legitimacy, will offer more secure routing than other threats' ranges. By using lightweight encryption, there is a balance between security and data transmission.

Gurung and Chauhan [4] proposed a methodology based on NS-2.35 for mitigating the attack of smart grayhole in MANET by implementing an intrusion detection for nodes. The detection nodes are deployed in MANET to prevent smart attack. The proposed mechanism suggests that the nodes overhear their neighboring nodes' transmission and block the node with malicious behavior when it drops data packets at a greater rate than the determined threshold. The nodes then notify the other nodes about the nodes with malicious behavior by broadcasting an ALERT message. Chawhan et al. [3] proposed a model to mitigate the grayhole attack in MANET by introducing a number of intrusion detection system (IDS) nodes, along with the intermediate nodes that are utilized to detect the malicious nodes responsible for grayhole attack. The proposed model works efficiently in terms of throughput and delay. However, it requires a modification to adopted AODV routing protocol.

4 3L-AODV

Lets $\mathcal{N}$ denotes the set of nodes in the network. We assume there is a subset of independent malicious nodes in $\mathcal{N}$ that perform a grayhole attack. A node $i \in \mathcal{N}$ in the network has a set of neighbors $\mathcal{B}_p \subset \mathcal{N}$. Each node in $\mathcal{B}_p$ is associated with a local value by the node p called *credit value (CV)*. Under a node p's point of view, each member $b \in \mathcal{B}_p$ is assigned with a CV_b value. The initial value of CV is fixed during the system setup. Later on, a node $i \in \mathcal{N}$ assigns the default value of CV to each new incoming neighbor node in $\mathcal{B}_p$. 3L-AODV uses three layers of detection: 1—attribute verification, 2—bait detection, and 3—threshold detection. As shown in Fig. 2, the results of these three techniques affect the CV parameter of each node. A zero credit value results in putting the corresponding node in a local table called *black-list table*.

As the first layer of malicious node detection, a node in the network can verify the hop counts of its neighbors and let only those nodes with verified attributes to involve in the process of transferring the traffic as intermediate nodes. We assume the existence of a subset of trusted nodes in $\mathcal{N}$, called *Hop Provers*. The primary duty of these nodes is to provide a proven hop distance ticket to a given node, as illustrated in Fig. 3. A trusted hop prover issues a hop count ticket to a node associated with an expiry. It does not have to be online later during the attribute verification process. Therefore, this layer is performed partially offline.

In order to verify the claimed attributes, specifically the number of node hops in $\mathcal{B}_p$, a node in the network applies the attribute verifier protocol [6] that is based on Attribute-based Encryption (ABE) [20] and is mainly used in the data validation networks [8]. The node utilizes *n-out-of-n* verification mode for a specific set of target attribute verification. In the case of resource-constrained nodes, lightweight protocols for encryption [9, 10] can be integrated into the attribute verification process. The inability to solve a transmitted challenge by the issuer node p and prove the attributes will reduce the corresponding CV value of a node in $\mathcal{B}_p$.

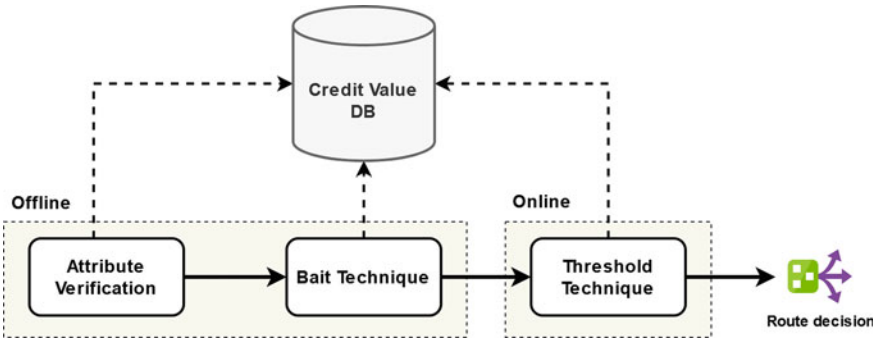


Fig. 2 3L-AODV layers

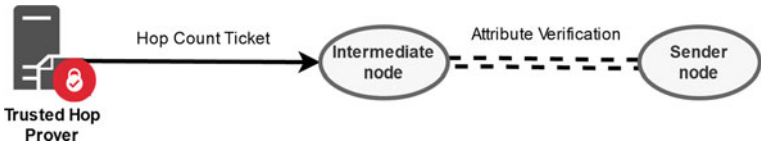


Fig. 3 Attribute verification layer

Before the traffic transmission, the sender can send a request with its address or a non-existed address as the bait address (destination address). In case, a node responds to this packet, it will be detected as malicious, its corresponding CV value is set to zero, and the node is added to the black-list table. This step will filter some of the malicious nodes. Since the malicious nodes in the grayhole attack can work adequately in some periods, this technique will not detect all the malicious nodes during a grayhole attack. Finally, the traffic is sent, and the responses from different nodes are gathered together and examined to detect the safety of each response and any possible grayhole attack.

A network setup can allow the peers to perform end-to-end communication using protocols, such as distributed address table (DAT) [5]. When a node p wants to send a packet to a destination node d, it sends the request RREQ to its neighbors and receives a set of replies (i.e., RREP). Each received RREP includes a *Seq* value and hop counts. The path through the node i that sent a RREP with higher *Seq* is chosen to send the packet to the destination node d. Prior to the path selection, 3L-AODV uses *Seq* values of the received RREPs to calculate the average threshold value as in Eq. 1.

$$\text{threshold} = \frac{1}{N} \sum_{i=1}^{N} Seq_i - Seq_d \tag{1}$$

In which N is the number of nodes in the routing table that sent an RREP, Seq_i is the *Seq* parameter of RREP received from node i, and Seq_d is the available sequence number of the destination node in the node p's routing table. The next step is to check the *RREP Validity* by defining the *Dif* value for each of the received RREPs as in Eq. 2.

$$Dif_i = |Seq_i - \text{threshold}| \tag{2}$$

In which Seq_i is the *Seq* parameter of RREP received from node i. If the Dif_i value is lower than a predefined acceptable range, the RREP is considered *Valid*. Otherwise, if the Dif_i value is higher than the predefined acceptable range, the CV parameter of the node i will be reduced by one. A zero CV parameter result in adding the corresponding node in the *black-list table*.

5 Evaluation

5.1 Simulation Design and Setup

To evaluate the 3L-AODV, we utilized the network simulator NS-2 to conduct experiments considering the implementation of a grayhole attack in an ad hoc network. The purpose of these experiments was to assess how well the proposed 3L-AODV would function in a MANET in the existence of independent malicious nodes performing the grayhole attack.

For the simulation, we configured the parameters accordingly, as described below. We set the simulation time for 100 s and a simulation area of 800 m × 800 m. We configured 25 for the number of nodes and zero to four malicious nodes that performed the grayhole attack. We assumed that the malicious nodes were independent. The routing protocol used the AODV protocol, whereas the MAC protocol employed the IEEE 802.11. The traffic type of simulation was constant bit rate (CBR), with the source and destination being 12. The data payload was 512 bytes. Spoofed route replay generates the details of attributes concerning the malicious nodes by making a path replies PDU. Consequently, the hold count is assigned "1" as a value and the fake destination sequence number via incrementing 30–90 as a random number to arrive. Path discovery relies on path requests' destination sequence number.

To compare the 3L-AODV versus the AODV, the particular setup for the simulation results was the primary point of our research concentration. The first two layers of 3L-AODV, i.e., part of the attribute verification and bait techniques, can be done prior to actual traffic transmission during the idle time. Without loss of generality, we evaluated the third layer of 3L-AODV that is fully executed during the actual data transmission.

5.2 Results and Discussion

The time it takes for a packet to be transferred from source to destination across a network is known as end-to-end delay or one-way delay. The proposed approach of 3L-AODV had fluctuating performance compared to AODV as illustrated in Fig. 4.

3L-AODV experienced an increase in end-to-end delay from 55 s to 97 s according to the appearance of malicious nodes sequentially. The grayhole nodes broadcasted spoofed acknowledgments containing fabricated target node sequence numbers. Utilizing 3L-AODV, these nodes might be detected in the first two layers. Additionally, 3L-AODV detected the malicious node and mitigated the grayhole attack by preventing the malicious nodes from being selected for traffic transmission. Consequently, taking this approach during the third layer of 3L-AODV impacted the end-to-end delay performance.

Fig. 4 Effect of delay

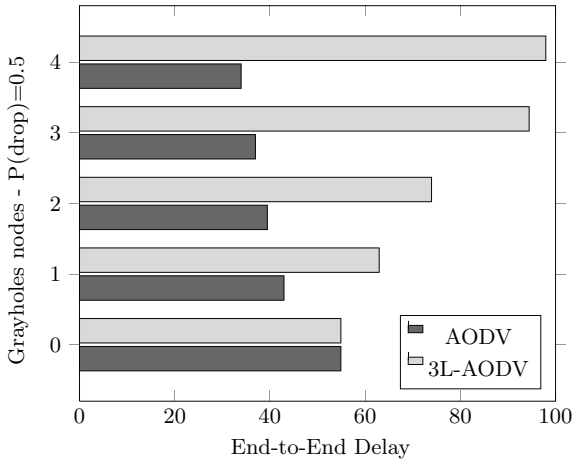
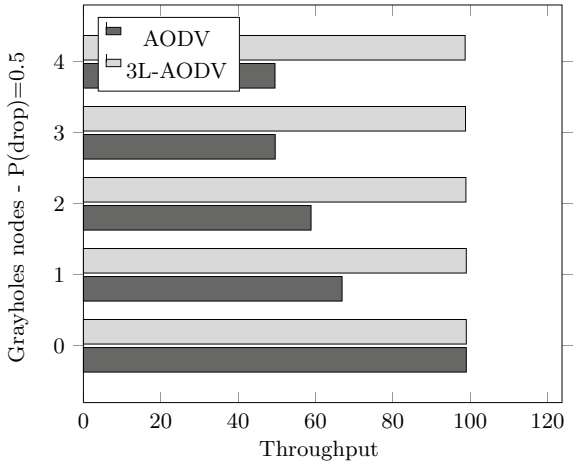


Fig. 5 Effect of throughput



The throughput is recognized as a number of successful delivered packets or bits within a specific period of time. Where throughput performing high with no occurrence of malicious node, i.e., high throughput indicates good performance. The existence of a grayhole node affects the throughput by dropping some of the packets. The 3L-AODV performed 50% better than that of AODV as illustrated in Fig. 5. Both AODV and 3L-AODV performed identical at initiate time. However, the performance of AODV exhibited consistent degradation. Occurrence of malicious node degrade the AODV 49 kbps for instance malicious node 1 appearing throughput preformed 66kbps while throughput scored 58 kbps to 49 kbps when node 2 and node 3 appeared correspondingly. Thus, 3L-AODV outperformed AODV in terms of throughput from the added malicious nodes. 3L-AODV exhibited a high throughput performance ranged between 98 kbps and 99 kbps respectively.

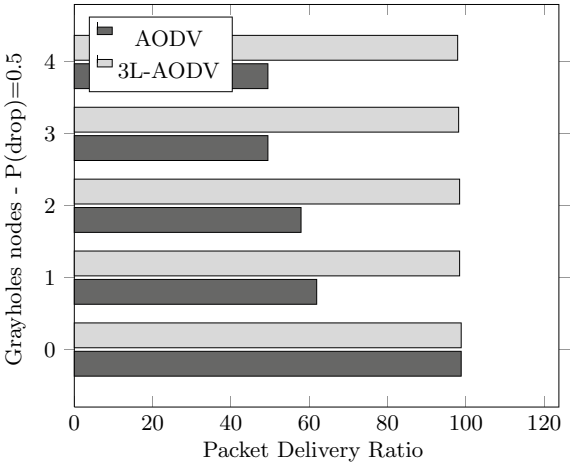


Fig. 6 Effect of packet delivery ratio

The packet delivery rate (PDR) is defined as the ratio of total received packets through destination node to the total sent packets by source. Where PDR performing high with no occurrence of malicious node, i.e., high PDR indicates good performance. The malicious node affected through dropping a packet resulting the total packets sent through source nodes be higher than the total received packets by the destination node. Figure 6 shows that the performance of AODV exhibited consistent degradation during grayhole attack. Both AODV and 3L-AODV performed identical at initiate time, as a result, packet deliveries are unaffected by the calculated safety status. Occurrence of malicious nodes degrades the AODV PDR ratio, which reached to 50% in case of four malicious nodes that performed the grayhole attack. Thus, 3L-AODV outperformed AODV in terms of packet delivery ratio that exhibited a high PDR between 97 and 98%.

6 Conclusion

In this paper, a security protocol to mitigate the grayhole attack has been proposed. The proposed protocol, 3L-AODV, consists of three layers of protection and detection. In the first layer, the node can choose the intermediate nodes based on verified attributes, such as the hop count attribute, and a challenge-response approach to verify the attribute. In the second layer, the node uses bait technique to detect the malicious nodes. In the third layer and using threshold technique, the sender is able to mitigate the grayhole attack. The analysis showed that 3L-AODV is efficient and does not require any modification in the original routing protocol of AODV. The future research directions include further analysis on the layer modification and inte-

gration, as well as the use of various detection techniques in the third layer that choose a valid safe path as long as it receives one, without the need to wait for other replies.

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Implementation of Projects Based on FPGA: Practical Applications

Edisson Coronel-Villavicencio, Luis Serpa-Andrade, Leonardo Bueno-Palomeque, and Roberto Garcia-Velez

Abstract Embedded systems are important in all fields. Among them, FPGA is one of the most powerful. However, their limited usage is due to the complication in their programming. A proposed practice guide has been generated, including the following topics: (1) Combinational Circuits, analyzing VHDL components, data types, and recurrent assignment, (2) Combinational and Sequential Circuits, analyzing relational and arithmetic operators, conditionals, management of constants and generics, (3) Regular Sequential Circuits, using synchronous clock, GALS, CDC, and PWM, (4) FSM Finite State Machines, including ASM diagrams, functions, and procedure, attributes in VHDL, which allow a better understanding of its use.

Keywords Embedded systems · FPGA · Practical applications · VHDL

1 Introduction

Embedded systems play a crucial role in modern applications, since they are the "brain" of today's manufactured electronic systems. FPGAs are the most recent computing technology used in embedded systems since they allow high processing speeds and parallel computing.

There is a growing demand for FPGA-based embedded systems, in particular, for applications that require fast response times. Engineering curricula must be kept up-to-date in this field to respond to the demands of this industry [1, 2].

During the last few years, there have been great changes in the interest of industry and academia for the integration of control systems in real time, Digital Signal Processing (DSP), communications, etc.

To respond to these needs, engineering curricula have been updated to address these problems from the use of microcontrolled systems, but, given the advances in technology, it is necessary to integrate and socialize the use of FPGA as a

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cross-sectional study in all branches engineering. These changes have been latent in previous years in Spanish universities [3], which is why a greater transversal integration of these digital systems is considered necessary in all branches of engineering.

To establish the background of the use of FPGA in academic work in Ecuador, it has been found that the oldest entry among the institutional repositories dates from 2005 at the University of the Armed Forces ESPE, with the work entitled "Analysis and design of two data network interface cards for Power Line—In Home communications (Application for PCI and USB port)," [4] which demonstrates the knowledge of the existence and interest in the development of these devices. Table 1 presents some resources available for the study and learning of FPGA based on practices.

Table 1 Practice-based FPGA books

Year	Book name language	Idioma	Development card	Themes	Cite
2011	**Design of digital systems in VHDL**	ESP	XUPV2P, Nexys 2	VHDL review; sequential circuits; RS-232 transmission; arithmetic circuits; VGA display controller; PS/2 port; memories; digital image processing and video games.	[5]
2008	**FPGA prototyping by VHDL examples XILINX Spar-tan-3**	ENG	Spartan-3 S3, Nexys 2, Basys	Combinational circuits; sequential circuits; finite state machines; UART; PS2 port; SRAM; VGA controller; PICOBLAZE microcontroller.	[6]
2017	**FPGA prototyping by VHDL examples XILINX Microblaze MCS SoC**	ENG	Nexys 4 DDR, Basys 3	Combinational circuits; sequential circuits; finite state machines; memories; embedded SoCs; embedded SoC peripherals; embedded SoC video cores.	[7]
2009	**Introduction to digital design using digilent FPGA boards—block diagram/VHDL examples**	ENG	Basys, Nexys 2	15 examples of basic circuits	[8]

2 State of the Art

During the last decade, a great revolution has taken place in the field of digital design. Today's FPGAs can contain over a million equivalent logic gates and tens of thousands of Flip-Flops. This means that it is no longer possible to use traditional digital logic design methods when the circuit involves thousands of gates. The reality is that currently digital systems are designed by writing software in the form of HDLs [8]. FPGA devices and HDL open doors for designers to quickly design and simulate sophisticated digital circuits, implement them in a prototyping device, and verify the functionality of the physical implementation [7, 9].

2.1 FPGA

FPGA (Field-Programmable Gate Array) or field programmable gate array is a logic device that contains a two-dimensional logic array of generic logic cells and programmable switches [10].

FPGAs fill a need in the digital systems design space, complementary to the role played by microprocessors (uPs). uPs can be used in a wide variety of scenarios, but since they rely on software to implement their functions, they are generally slower and consume more power than ASICs (Application Specific Integrated Circuits) or custom designed chips.

Similarly, FPGAs are not ASICs, so they are not as good at any specific function, they are slower and consume more power than an ASIC; What's more, FPGAs are relatively expensive, which would imply that making an ASIC would be cheaper. However, FPGAs have their compensating advantages, mainly due to the fact that they are standardized parts: there is no waiting time between designing a circuit and getting the chip working, since the design can be immediately downloaded to the device and proven in reality, the same FPGA can be used in many different designs, which reduces the design cost [9–11].

3 Architecture and Configuration

The conceptual structure of an FPGA is presented in Fig. 1. A logic cell can be configured to perform a simple action, and a programmable switch can be modified to provide interconnections between the logic cells. A design can be implemented by specifying the operation of each logic cell and the connections of the programmable switches.

Once the circuit design and synthesis are complete, this configuration can be downloaded to the FPGA device and it starts working as desired. Since this process

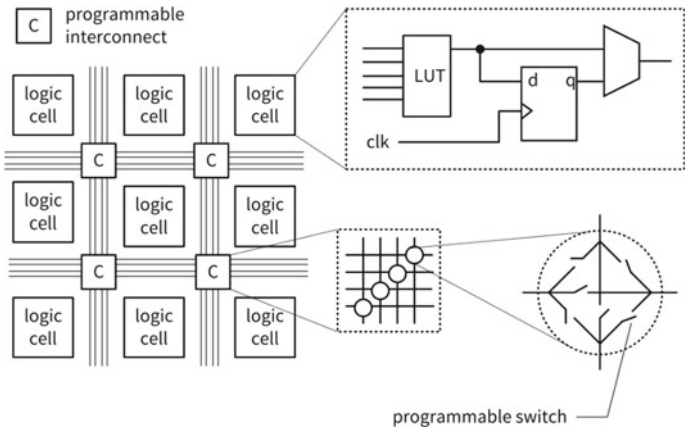

Fig. 1 Conceptual structure of a device FPGA [7]

can be performed "in the field" rather than "in a manufacturing facility (fab)," the device is known as field programmable [7, 9, 10].

A logic cell usually contains a small configurable combinational circuit with a D-type FF (Flip-flop). The most common method of implementing a configurable combinational circuit is through a LUT (Lookup Table). On the other hand, most FPGA devices also include some macrocells or macroblocks. These are designed and manufactured at the transistor level, and their functionalities complement the general logic cells. Some of these macrocells include memory blocks, combinational multipliers, clock drive circuits, and input/output interface circuits. The most advanced FPGA 3 devices can even contain one or more pre-built processor cores [7, 9, 10].

3.1 HDL

HDL (Hardware Description Language) are the most important tools used to describe and model digital systems. While circuit diagrams can present some information very clearly, they are generally less dense than textual description languages. Furthermore, the textual description of an HDL language is much easier to generate than a schematic with pictorial information. There are two widely used HDLs, Verilog and VHDL, both of which are IEEE standards and widely used in the industry. This work will focus only on VHDL [7, 8, 11, 12].

3.2 VHDL

VHDL is an acronym within an acronym, as the "V" stands for "VHSIC," which is the same as "Very High-Speed Integrated Circuit." The "HDL" stands for "Hardware Description Language," so VHDL stands for "Very High-Speed Integrated Circuit Hardware Description Language." It was originally sponsored by the US Department of Defense and later transferred to the IEEE, which formally defines it by the IEEE 1076 standard. VHDL is a true computing language, with its specific syntax and usage rules, but unlike other high-level computing languages such as C and Java, VHDL is mainly concerned with description (or modeling) of hardware [7, 12–15].

There is a tendency for programmers of high-level computing languages like C or Java to view VHDL as just another programming language. This is a common mistake, since when trying to "program" in VHDL, the intention would be to execute instructions sequentially, this is not the case with VHDL (or most HDLs) since they describe digital circuits. Another way of looking at this is that programming languages are used to describe algorithms (inherently running sequentially), while VHDL is used to describe hardware (inherently running parallel), known as concurrent execution [13, 14].

4 Proposal

The present work is a technological research, with a qualitative and experimental approach, where the validity of a manual of practices for the use of the embedded system Nexys 4 DDR for teaching FPGA will be analyzed. The studies that are carried out have characteristics of pre-experiments, being post-test studies, applied to a group of engineering stakeholders made up of students and teachers, who are exposed to the practice manuals in multiple sessions, and a survey is applied to them. That seeks to validate the practices, considering the visual and procedural aspects. In addition, a section is considered where the participating stakeholders can write their criticisms and observations to the manual of practices as feedback to improve its validity. The methodology for the development and validation of the practice manual is described below:

- Analyze the scope of the study of FPGA in the engineering curriculum.
- Design a practice for each topic, using the Nexys 4 DDR embedded system. Structure the practical guides module so that it can be delivered to the test groups. The format is based on the guide established by the academic vice-rectorate of the Salesian Polytechnic University.
- Design validation tools for practices.
- Form focus groups for the application of the practice manuals, the same ones that will respond to the validation instruments of the practices.
- Carry out a satisfaction survey, after the execution of the entire proposed practice manual.

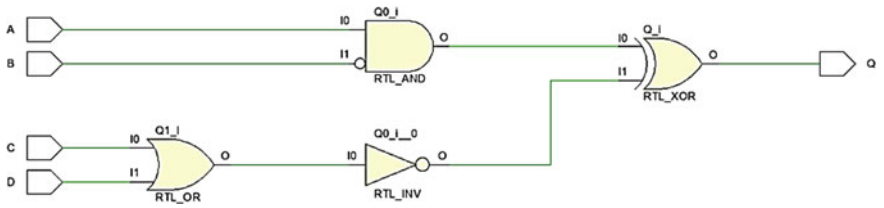

Fig. 2 Circuit to be implemented

- Apply the pertinent corrections and observations to the design of the laboratory practices manual.

5 Development of the Practice Guide

5.1 Combinational Circuits at Gate Level

The proposal of a combinational circuit responds to Eq. (1).

$$\left(A \times \overline{B}\right)\text{XOR}\overline{(C+D)} = Q \tag{1}$$

After the verification of the circuit, we proceed to the implementation and synthesis of the digital logic in Vivado Software, resulting in the circuit described in Fig. 2, which is implemented in the Nexys 4 DDR embedded system.

5.2 Combinational Circuits at Register Level (RT-Level)

The proposed circuit is a 4-bit signed integer adder circuit, which must receive its inputs through the switches available on the development board, and must show the result on the multiplexed displays. This circuit must be built by lower level modules, and encompassed in a higher level entity. The modular guide diagram is presented in Fig. 3, where the summing, decoding, and multiplexing modules for the 7-segment display are planned.

After the verification of the circuit, we proceed to the implementation and synthesis of the digital logic in Vivado, which is implemented in the Nexys 4 DDR

Fig. 3 RT combinational circuit

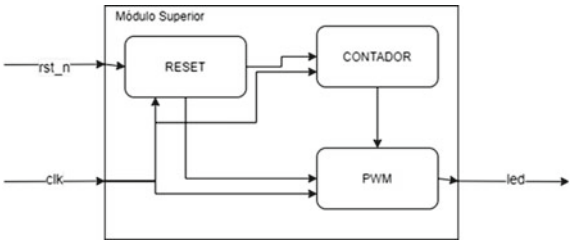

Fig. 4 Sequential circuit

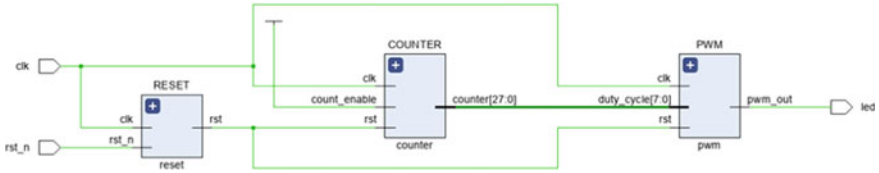

Fig. 5 Sequential circuit implementation

embedded system. This circuit includes the lower level modules for decoding, adder and presentation on the display, according to the programmer's needs.

5.3 Regular Sequential Circuits

The proposed circuit is a circuit that controls the intensity (brightness) of an LED by PWM, with a sawtooth signal. This circuit must be built by lower level modules, and included in a higher level entity, where the PWM, addition, and reset modules are planned; the reset circuit is planned as an independent module since it will have an integrated debounce circuit. The top-level module is coded with component structural description and does not include descriptions of any independent circuits (see Fig. 4).

After the verification of the circuit, we proceed to the implementation and synthesis of the digital logic in Vivado, resulting in the circuit described in Fig. 5, which is implemented in the Nexys 4 DDR embedded system. This circuit includes the modules of lower level of PWM, adder, and reset, according to the need of the programmer.

5.4 Finite State Machines

Here all basic VHDL knowledge is synthesized, presented in a single design, using combinational, sequential, and FSM circuits. A self-enclosing two-digit counter is featured. The circuit needs a block dedicated to decoding (presented in an alternative way than in past practices), a multiplexing circuit, a reset circuit based on shifting

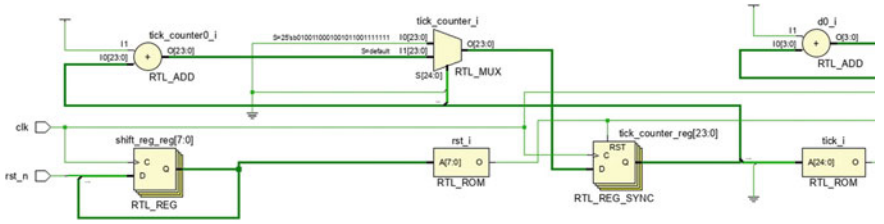

Fig. 6 Finite state machine implementation

registers, a counter based on UNSIGNED, which will serve as a starter. Voltage for the multiplexing of the digits, a counter represented in a procedure, which will be in charge of generating the BCD count, a tick generator (impulses) at the frequency that the user needs, and finally an FSM that allows to represent digital numbers. Figure 6 shows the result of the verification with testbench, checking that the circuit works properly. You can see the change of states between the count of units and tens for the displays.

6 Survey

As a fundamental tool, a survey of the practices has been carried out on a group of 10 students, who are studying the Digital Systems subject, the proposed practices were analyzed, their schedule was organized and then the practices were delivered for later development and implementation to students, the questions asked are listed below:

Q1. Do you think that implementing VDHL practices helps to complement the sessions dictated by the teacher?
Q2. Were the syntax and structure of the practices clearly captured and easy to understand?
Q3. Do you think that the difficulty of the practices increases as the subject develops?
Q4. Do you think the number of practices developed is adequate?
Q5. Does implementing the practices on a development board help to understand VHDL?
Q6. How satisfactory was the handling of the VIVADO software and its simulator?
Q7. Do you think that the practices developed throughout the course will help in the professional application?
Q8. Would you recommend applying practices of this type to related subjects within engineering?
Q9. Is the implementation proposed at the end of each practice related to the theme that is developed in it?

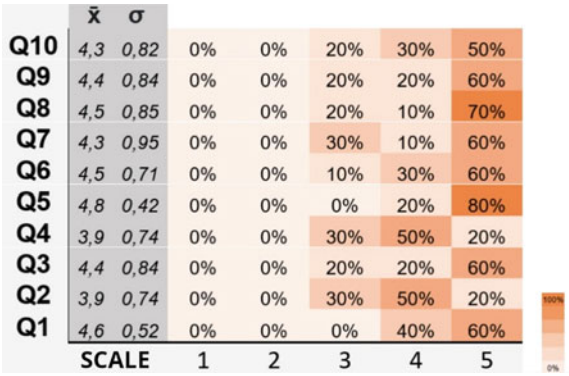

Fig. 7 Student survey results

Q10. Does the use of images, screenshots, simulations, and diagrams satisfy the understanding and development of the practices?

7 Análisis de resultados

In Fig. 7, the results of the survey are represented, where the level of satisfaction reaches expectations, it can be seen that in none of the questions raised about the development of practices does it reach levels higher than 30% in level 3 satisfaction. In addition, at the lowest levels of satisfaction, the values are 0%. It should be noted that since it is the first time that laboratory practices for FPGAs are implemented, the results show averages above 3.9 out of 5 on the satisfaction scale.

8 Conclusions

The practical management and implementation in VIVADO help to understand VHDL, since with the implementation more interest is generated to investigate each topic further, making this complement an ideal way to increase knowledge. As VHDL is a hardware description language, it is a bit complicated to understand it, it is for this reason that there is moderate difficulty in understanding syntax and how each one of the practices is described, for this it is necessary in subsequent developments to polish said description. The methodology applied to the learning of VHDL was developed following a scheme of progressive advancement of knowledge, which is why for the majority of respondents this type of advancement is satisfactory, perhaps it should be taken into account that 20% are moderately of agreement, and as a solution, topics or doubts should be reinforced opportunely, while each one of them is developed.

For later developments, the expansion in a number of 1 or 2 additional practices should be taken into account, with which the progressive progress is slower, guaranteeing the understanding of all the topics, thus obtaining an ideal chronological learning. By using the embedded system, the student goes through all the stages from the creation of a project to the recording in the FPGA, making each one of the participants have ingenuity and develop their logical intelligence, because the study of VHDL will do so requires.

Lived together with its simulator, it is initially difficult to learn, however, only 1 out of 10 respondents finds this software moderately satisfactory, making it a top tool in the development of FPGA applications. As the future professional outlook is broad, more than half of those surveyed understand that VHDL can be used for applications and solutions to problems in the workplace, which is why teaching this language in engineering is essential.

By having the versatility of an FPGA with its parallel processing of instructions, the pilot group of students understands that VHDL can be used in various subjects and with these practices they help learning to be carried out in a better way. It is important that the person who implements the practice, after carrying out this process, acquires capacities, with which he can solve proposals of any kind, with these results more than half of the respondents can obtain said sufficiency satisfactorily. It could be taken into account for subsequent developments, in the implementation of the practices, reinforce with 10% more visual representations, which support the understanding of the practices and generally of VHDL.

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Mobile Game of the Generals 3D: An Original Filipino Board Game Going Mobile

Allen Jhon C. Muyot, Karlo Jose E. Nabablit, Jervin R. Macalawa, and John Dominique C. Reyes

Abstract Board games are used for entertainment and pastime for people. Game of the Generals also known as “Salpakan,” is one of these games that are widely played during the 1990s and is slowly being forgotten because of the developing culture of converting everything into a mobile application including board games. This chapter aims to develop a mobile-based Game of the Generals 3D (GOG 3D). Specifically, the chapter aimed to create a mobile application based on the Filipino board game called "Game of the Generals;" Design the overall look of the game that resembles the board game in 3D with two players playing on their mobile phones connected through a hotspot and artificial intelligence to serve as the arbiter; and conduct alpha testing using test cases and evaluate the application using ISO/IEC 25010 game evaluation instrument. The GOG 3D is compatible with the android Operating System (OS) and can be played using a hotspot even without an internet connection. The Iterative model was used as the framework for the development of the application. GOG 3D was designed using adobe photoshop and developed using the Unity game engine and Blender.

Keywords Game of the generals · Salpakan · Mobile board game · Filipino board game · 3D mobile game

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1 Introduction

Game of the Generals (GoG) is a board game made by Ronnie Pasola Jr., a Filipino citizen, and was invented in Barrio Palanan, Makati, in August 1976 after winning a chess tournament. The board game was made out of cartolina cut-outs marked with soldiers' ranks, applying the concept from mahjong and experimentation with his father. It requires an arbiter, a third person who observes and decides which piece wins or loses when they collide in one board cell. Iking Gonzales, a journalist, introduced the game. The arbiter was replaced then, by an electronic arbiter that causes the GoG to win 3rd most outstanding electronic invention of the year 1978 in the Philippines Inventor's Festival [1]. It was introduced to 33 different countries, which sparked the formation of 2500 GG clubs and 28 new Filipino game inventions. GoG still lives in the culture of the Philippines. However, with the transition from manual to electronic, computer games derived from physical games and sports were invented, such as the NBA 2 k series, table tennis, etc. As the technology evolved, it carried the ideas and put games into mobile phones such as Chess, PubG, hearstones, and Minecraft [2]. With the big opportunity presented, led to the development of the Mobile GOG 3D, a mobile-based board game that can be played by two players connected via a hotspot without relying on the internet connection that runs on an android OS. The output of the research is useful for board game enthusiasts, particularly in the case of GOG, to revive the board game hence, to introduce it to the new generation of Filipino.

2 Literature Review

2.1 Strategic Board Games

There are a large number of strategic board games (strategy games played on a game board) on the market today. Each of these offers its own unique strategy and manner of playing. Many of these have a vast and long history such as chess, checkers, and Go [3]. Some examples of board games played worldwide are chess, shogi, go, abalone, game of the generals, etc. [4].

2.2 Game of the Generals Aka "Salpakan"

Game of the Generals is an original board game developed by a Filipino to test its players' strategical and tactical skills using modern-day pieces as their pawns for war. It was known as "Salpakan" or literally, "to clash" in English [5]. It was a chess game of the Filipino where players strategize from the setting up of the pieces to the tactics to be used to win the game. The game is played on a rectangular board with squares arranged by eight rows and nine columns as shown in Fig. 1. This will serve

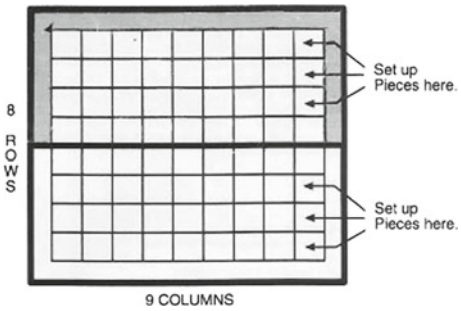

Fig. 1 GOG board

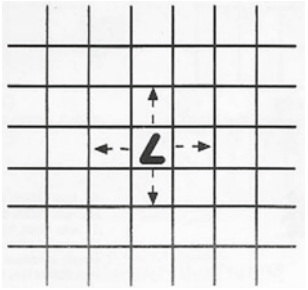

Fig. 2 Piece movement

as the battlefield of the game. There are 21 pieces for each player to be arranged according to their tactic and be placed on the first 3 rows of the board.

The game is commonly played by 3 people, the two opposing sides and the arbiter who is referred to as the judge of the game. Its task is to judge the colliding pieces and remove the piece that has a lower rank than the other. The player that will go first will be determined by rock-paper-scissors or a coin toss. Each piece can move one cell up, down left, or right only as shown in Fig. 2.

The ranks of the pieces will determine who will win the clash. Table 1 represents the hierarchy of ranks of each piece of players. There are 3 ways to win the game, (1) one player catches the flag of the opposing player, (2) a player reached the farthest row on the opposing player, and (3) one of the players forfeits. There will be a draw if both players agreed to [6].

3 Methodology

The process of development is called the iterative model of the System Development Life Cycle (SDLC) where the researchers developed a working version early in the process and make iterations throughout the development cycle [7]. The researchers have gone through the initial planning and cycles through requirement planning, analysis and design, development and testing until the last step, deployment. This

Table 1 Power ranking of each piece in the GOG

Name of the piece and hierarchy (highest to lowest)	Pieces per player	Power/description
Spy	2	**Eliminates all lower ranking officers and the flag, but can only be eliminated by the private**
5-star general	1	Eliminates any lower-ranking officer, the private, and the flag
4-star general	1	Eliminates any lower-ranking officer, the private, and the flag
3-star general	1	Eliminates any lower-ranking officer, the private, and the flag
2-star general	1	Eliminates any lower-ranking officer, the private, and the flag
1-star general	1	Eliminates any lower-ranking officer, the private, and the flag
Colonel	1	Eliminates any lower-ranking officer, the private, and the flag
Lt. Colonel	1	Eliminates any lower-ranking officer, the private, and the flag
Major	1	Eliminates any lower-ranking officer, the private, and the flag
Captain	1	Eliminates any lower-ranking officer, the private, and the flag
1st Lieutenant	1	Eliminates any lower-ranking officer, the private, and the flag
2nd Lieutenant	1	Eliminates any lower-ranking officer, the private, and the flag
Sergeant	1	Eliminates the private and the flag
Private	6	**Eliminates the flag and is the only piece that can eliminate the spy**
Flag	1	**Can eliminate the enemy's flag when challenged by the player. Any piece can eliminate this piece once it has been successfully challenged**

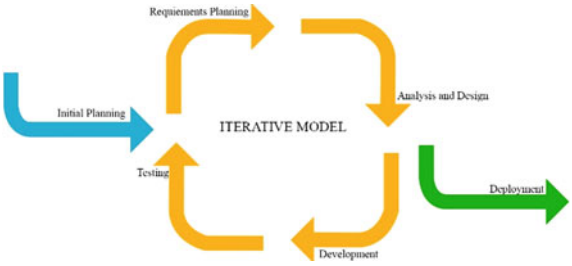

Fig. 3 Iterative model (SDLC)

model eliminates bugs and errors and experienced improvements every cycle [8] (Fig. 3).

3.1 Data Gathering

The first step in the research process is the initial planning where articles and related studies and journals from the internet and library are read and studied to acquire

all the needed information that was needed in the development of the game such as the history of the GOG and the game rules. As part of the research, interviews with board game enthusiasts and GOG players are conducted to have a cross reference of information. The data collected was stored and processed to develop the idea for the design and development of the game.

3.2 System Analysis and Design

After data was collected, analyzed, and processed, the needed assets for the game were designed such as the 3D level battlefield, board, and game pieces shown in Fig. 4. These assets are created using Blender, an open-source software for creating 2D and 3D assets that support 3D pipeline, modeling, rigging, animation, simulation, rendering, compositing, and motion tracking [9]. The skins and materials of the asset were designed in adobe photoshop. The assets were transferred to Unity 3D (Fig. 5), a game engine used for game development, architectural designs, automotive, films, etc. [10].

This software was used to put all the assets together to create the design and programming.

Fig. 4 Battlefield

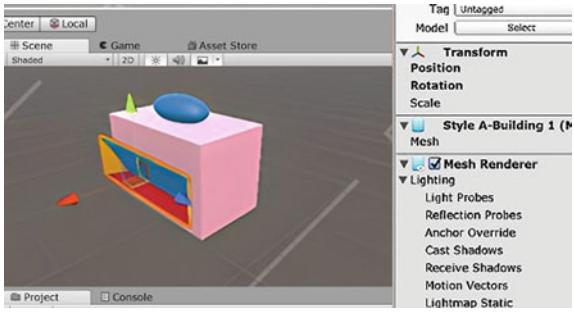

Fig. 5 Unity 3D IDE

3.3 Development

The development phase mainly focused on adding the system's functionalities. Functions include phone connectivity, counting of wins and losses, and the in-game characteristics of the pieces and the arbiter's perspective. C# programming language was used in coding all of the modules of the game.

3.4 Testing

The testing was conducted using two android smartphones. Functionalities of the game were listed on a test case which includes various steps on how the test for each function will be conducted. The results of the test are listed together with the test case ID, the number of times debugged, and the details of errors. The cycle of these tests made sure that all of the functionalities of the game are running smoothly without bugs.

3.5 Deployment

Upon the design, development, and testing cycles eliminating all the errors in the test cases, the game was deployed on several android smartphones and was used by GOG enthusiasts, information technology people, and students.

4 Results and Discussion

4.1 Description of the Game

GoG 3D is a mobile board game that runs on an android OS. It was based on a classical Filipino board game called Games of the General, primarily known in the Tagalog term "Salpakan." Two players play the game with their mobile phones, connected via a hotspot and an automated arbiter to judge the clashes of pieces. It is played in an 8×9 celled battlefield along with a set of 21 pieces of different ranks distributed evenly on each player. The application was created using Unity Game Engine, Blender for the assets, and Adobe Photoshop for the graphic design.

4.2 Game Design

GOG 3D is a mobile game capable of connecting two players on each android smartphone. Figure 5 shows the main menu upon opening the game. It shows three different options (1) Start, (2) How, and (3) Profile (Fig. 6). The "How page" shows the instructions on how the game can be played while the "Profile page" shows the statistics of wins and losses of the player. The in-game interface in Fig. 7 shows that the user that serves as the creator of the game will be assigned the color blue while the other player is red. It has a disconnect button located at the top-right side of the screen. Also, the zoom-in and zoom-out buttons are located at both corners of the screen, and a green label signifies the player's turn.

The game starts upon pressing the "Start" button, the player will be directed to the lobby page where are two buttons, "Create Lobby," which automatically creates a match when pressed, and "Join Lobby," which is accompanied by a textbox. The purpose of the textbox is to enter the opponent's IP address to allow the user to join that existing match shown in Fig. 8.

The mechanics of the game are as follows:

1. Once the game mode has been selected, freely set up your piece's positions.

Fig. 6 GOG 3D home page

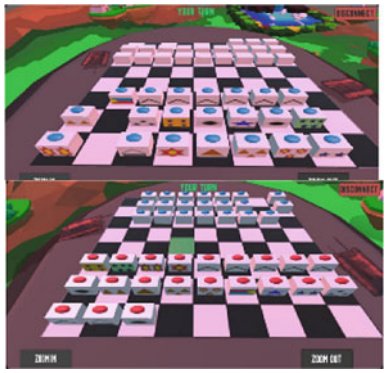

Fig. 7 Player's perspective

Fig. 8 Lobby page

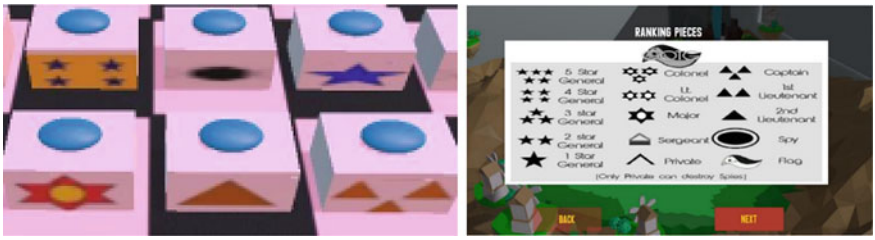

Fig. 9 Piece's ranks and rankings

2. Press and hold the screen for three seconds to lock in your arrangement.
3. Once both players are ready, the game commences.

The pieces' rankings are located at the back of each piece. Figure 9 shows the ranking hierarchy.

4.3 Test Results

The testing of the game was done for each function to ensure that all modules are error- and bug-free and of top quality. The functions to be tested are listed with test case ID. Upon testing the functionalities, the developers recorded the details if the game encounters an error and will debug it after. Table 2 shows the testing procedures done for the game. These procedures are done using 2 mobile phones connected via a hotspot. The test includes major functionalities from compatibility, game navigation buttons, connectivity, and scoring. Upon testing, one of the major problems encountered was connectivity where the mobile phones disconnected due to the limited range of the hotspot. After disconnection, the game was halted and there was no score update since the game was not finished. Overall, the testing ensured that the game can be played assuming that the 2 mobile phones are in reachable positions via hotspot.

Table 2 Summary of testing results

No.	Functionality	Testcase ID	Times debugged	Details
1	Compatibility	CMP-001	0	N/A
2	Button navigation	BTN-001	1	The piece moved in the red player but did not move in the blue player screen
3	Button navigation	BTN-003	0	N/A
4	Button navigation	BTN-004	0	N/A
5	Connectivity	CNNT-001	2	An error in the proximity of the two mobile phones/connection was lost
6	Timer	TMR-001	0	N/A
7	Timer	TMR-002	0	N/A
8	Flag function	FLG-001	0	N/A
9	Flag function	FLG-002	0	N/A
10	Score	SCR-001	0	The player score was reset after uninstalling and reinstalling the game
11	Score	SCR-002	0	N/A

5 Conclusions and Recommendations

The digital era is in commence and now engulfing manual processes. Mobile phones are also getting powerful, to the point that they can be used as a personal digital assistant and serve as a mini personal computer. Through the years, most board games are digitized, and creating a tangible and physical board and pieces are slowly getting off the line. With the development of this study, the board game industry can still grow and be utilized in mobile platforms and will not meet its end. With the use of development tools for designing and programming, every board game can survive and still be played and enjoyed by enthusiasts on the go. The game is recommended to be uploaded and connected online with an internet connection to reach more players to achieve maximum utilization.

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Investigating the Role of E-Satisfaction on E-Loyalty Toward Packed Health Food Products

Amarnath Gupta and Pradnya Chitrao

Abstract With 50% of FMCG sales in household and private care, the FMCG (Fast Movement Consumer Goods) sector is the fourth biggest sector in the Indian economy. Increasing consumer awareness, easier online access, and dynamic lifestyles are the key growth drivers for the FMCG category in India. The urban market segment is leading with a revenue share of around 55%. Technological advancements and globalization have resulted in shifting the main target of marketers to online promoting due to its wide reach among customers. Packaged health foods are one among the leading segments within the Fast-Moving Consumer Goods (FMCG) categories that have witnessed exponential growth in the Indian market in recent decades. "Around 72% of Indian consumers are most likely to shop online locally for premium products," according to the IBEF Report 2021. The connection between loyalty and satisfaction is the main field of research in the marketing discipline. Today, online shopping is rapidly increasing as technology is improving and the Internet is rapidly spreading. E-satisfaction and E-loyalty are critical components of online business success. The objective of this chapter is to detect and develop a conceptual framework for connecting e-satisfaction to e-loyalty. This chapter analyzes the link between consumer satisfaction and corresponding loyalty while shopping online. Finally, a conceptual framework is proposed in the chapter. This chapter further investigates the various constructs for online marketing and focuses on how to determine and measure the effectiveness of online marketing methods for packed food brands.

Keywords Healthy · FMCG · Online marketing · Satisfaction · Loyalty

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1 Introduction

The Fast-Moving Consumer Goods (FMCG) sector is the Indian economy's fourth biggest industry with 50% of FMCG sales accounting for the household and private care segment. "The Indian processed food market is projected to expand to US$ 470 billion by 2025, up from US$ 263 billion in 2019–2020," according to the IBEF Report 2021. As there is an ascent in livelihoods, top level salary customers in metropolitan regions are buying premium brands of packed healthy food items rather than fundamental items. Shoppers are jumping at the chance to purchase packed healthy food products that are of high quality and from the trusted brands. Today, individuals need everything speedy, which has fueled the web-based shopping. It turned out to be exceptionally simpler and quicker. During the COVID-19 pandemic, many FMCG brands collaborated with e-commerce platforms such as Amazon, Flipkart, Grofers, and Bigbasket to deliver products to consumers' homes. The industry was largely unaffected by the pandemic, and organized players saw growth, while a lot of conversion from unbranded to branded food products occurred during this time period. Since FMCG shopping is very time taking and less fascinating shopping action, web- based shopping turned into a solution to overwhelm. During the pandemic, digital commerce more than doubled. As a result, it is now considered a must-have rather than a nice-to-have. The effect of internet shopping on the purchaser is exceptionally high because of this occupied and serious world. The consumer market's key growth drivers are increased awareness, easier access, and changing lifestyles. India's growing internet penetration and digital maturity, as well as its developing infrastructure, have all contributed to an increase in online transactions. "Around 72% of Indian consumers are most likely to shop online locally for premium products," according to the IBEF Report 2021. Consumers in India are highly adaptable to new and innovative products. For example, immunity boosters and health supplement food products such as sugar free chyawanprash, health drinks, nutrition supplement like appetizers and snacks such as digestive biscuits, corn flakes, muesli, and so on have found widespread acceptance. This chapter examines the impact of satisfaction on the loyalty of the customers.

2 Literature Review

For marketers everywhere, especially in the FMCG sector, digital media is changing the landscape. Campaigns for each of the FMCG products traditionally depend on determining the appropriate 4 P marketing mix (product, price, location, and promotion), which would best influence the purchase decisions of the target audience. Today, however, consumers make different buying choices, and strategies to influence this process also need to be developed. Covid-19 has only further stepped up this trend with purchases through markets, apps, and consumer brands. For FMCG companies, digital marketing involves manipulating FMCG products' marketing mix to bring

them into the present age. Digital marketing trends in FMCG allow marketers not only at the final shopping stage to capture consumers, but also to build relationships with them from the beginning, which had not been possible previously. This requires marketers to develop a complete digital FMCG strategy that not only influences but also engages with their consumers.

Literary reviews and expert opinions show that the success of packaged health food brands depends on online marketing. According to Perry [1], online marketing helps to develop brand awareness and helps to position the brand. The sales performance of companies and the implementation of effective marketing strategies are positively and significantly related. The survey also found that marketers utilize internet marketing to enhance brand recognition and develop brand commitment via tailor-made online communication.

By customizing email marketing. Sahni et al. [2] discovered that the likelihood of an email recipient being read was boosted by 20%. Videos accounted for over 80% of internet traffic in 2019, according to Abuyounes (2019). More than 77% of companies that utilize social video marketing have direct beneficial effects on their web KPIs [3]. Camilleri et al. [4] described how the efficiency and success rates of online marketing can be measured by internet marketers. They have raised awareness of the limits of online marketing methods by delineating the links between various online marketing terms. The factors that are important to Internet transactions and affect channel decisions have been examined by Kiang et al. [5]. Logistics, therefore, has the prevailing effect on the decision-making process for channel selection, especially for digital products that utilize the Internet for both transaction processes and delivery. A study was carried out by McMahan et al. [6] on the various contributions and implications of online marketing in the field of interactivity and gender differences. The results of the research demonstrated that men and women spent varying degrees of time on different types of interactive features on business websites, especially interactions between people and computers. Online marketing generates three times as many leads as conventional outbound marketing, but costs 62% less than traditional outbound. The study done by Schwarzl et al. [7] showed that all websites are full of different kinds of ads and offers that make it difficult for companies to "lose" potential buyers to a specific website by using the Internet. The study carried out by Kushwaha et al. [8] showed that Indian consumers remain very price-conscious and are affected while shopping online by branded products and the high standard of service. However, both e-satisfaction and e-loyalty have a direct and positive impact on service quality. Gefen [9] says that creating online customer loyalty is a requirement for online sellers to retain existing customers.

The definition of e-satisfaction as "customer satisfaction with the previous experience of purchasing from an online business organization" was given by Anderson and Srinvasan [10].

Table 1 Items in the scale and its reference

Construct	Scale/references	No. items in the scale
E-satisfaction	Zeithaml et al. [11]	4
E-loyalty	Zeithaml et al. [11]	4
Online marketing Strategies	Szymanski et al. [12] and Van Riel et al. [13]	6

3 Research Methodology

Identified Research Gaps: The following research gaps were identified based on the literature review and suggestions made by the experts:

1. Notably, fewer recent literature examines the role of e-Satisfaction in e-Loyalty for packed health foods.
2. Very small number of studies are available to examine the correlation between e-Satisfaction and e-Loyalty.

The consumers of FMCG products who purchased them online and were above 18 years of age were the population of the study. The study was based on a descriptive research design. The primary data for the study was gathered from 391 online customers. The Structured Questionnaire was the tool for primary data collection. The opinions were assessed on a 5-point Likert scale. The Cronbach's Alpha test was performed to check if the questionnaire items used for the survey were reliable and consistent. Research data was collected between July 2021 and November 2021. The purposive sampling method was used for the study. Secondary data was gathered from published print and electronic media sources (Table 1).

4 Hypothesis Development

In general, satisfaction is regarded as a major driver of loyalty and customer satisfaction with an online retailer will be more significant than with an offline retailer [14, 15]. That is why it is anticipated:

H1: **The impact of online marketing strategies on E-Satisfaction is direct and positive**.

H2: **The impact of E-satisfaction on E-loyalty is direct and positive**.

5 Conceptual Model

The conceptual model proposed is shown in Fig. 1. The model suggests that online marketing strategies i.e., Search Engine Optimization (SEO), Search Engine Marketing (SEM), Social Media Marketing (SMM), Email Marketing (EM), and

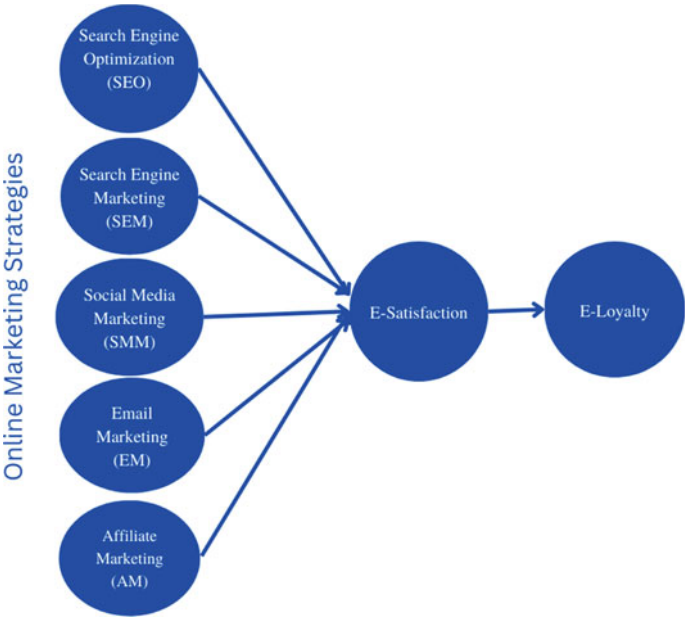

Fig. 1 Conceptual model

Affiliate Marketing (AM) have a significant impact on consumer e-satisfaction that affects consumers buying packaged food online. Consumers' e-satisfaction influences their e-loyalty.

6 Hypothesis Testing

Scale reliability test: The Cronbach's alpha test is performed for each variable to evaluate the reliability of the Likert scale used in the questionnaire. Cronbach's alpha test results are displayed in Table 2.

7 Test of Normality

The researchers conducted the Kolmogorov–Smirnov Test and Shapiro–Wilk Test to determine if a data set contains a normal distribution pattern. "It was found that the data collected were not normally distributed as the calculated sig. value was less than 0.05."

Table 2 Results of Cronbach's alpha test

Variable name	Number of questions	Cronbach's alpha value	Result of test
Online marketing strategies	9	0.889	Accepted
E-satisfaction of consumers	4	0.926	Accepted
Customer's online purchase decision	12	0.846	Accepted
Advantages of online shopping	9	0.874	Accepted
E-loyalty	4	0.861	Accepted

8 Data Analysis and Interpretation

The data analysis was based on Structural Equation Modeling (SEM) which simultaneously indicates the relationships between several independent and dependent constructs through the model. SEM is also known as the technique of the second generation, which shows the relationship between different constructions in a model. The results have been interpreted using the Partially Least Square (PLS) based Smart PLS 2.0 software. The researchers have developed a measurement model to further link the latent variable with its indicators, and a structural model has been developed to investigate the causal relations between exogenous and endogenous variables indicated by the path diagram.

The variables have been measured and presented with a mean and standard deviation for data capture. The outer loading has been calculated and for further analysis using the Smart PLS. Based on the results obtained from the analysis, convergent validity and internal consistency were assessed. The value of the Extracted Average Variance (AVE) was above 0.5. As a thumb rule, for the model to be reliable and valid The Composite Reliability should be more than 0.6. On the basis of the analytical findings, therefore, the model was found to be reliable since all composite reliability values exceeded 0.6. The effectiveness of an Average variance extracted (AVE) and Discriminant Value (DV) model was evaluated. "DV was found to be greater than the corresponding correlation values of the constructs, which indicated that the model was valid. It was determined that the model was reliable because all of the Composite Reliability (CR) values were greater than 0.6" (Fig. 2).

From the model above, the calculated *R* square value was 0.832 for E-Satisfaction, and for the E-Loyalty, it was 0.769. The level of confidence assumed while running the model was 95% and thus, the level of significance was 5%. For interpretation, the *t*-critical value at a 5% level of significance (1.96) was chosen. Based on the given information and statistical analysis, we can interpret the results as follows:

H1: The impact of online marketing strategies on E-Satisfaction is direct and positive. The path coefficient for H1 was calculated as 0.2587, and the t-value exceeded the threshold of 1.96, indicating statistical significance. Therefore,

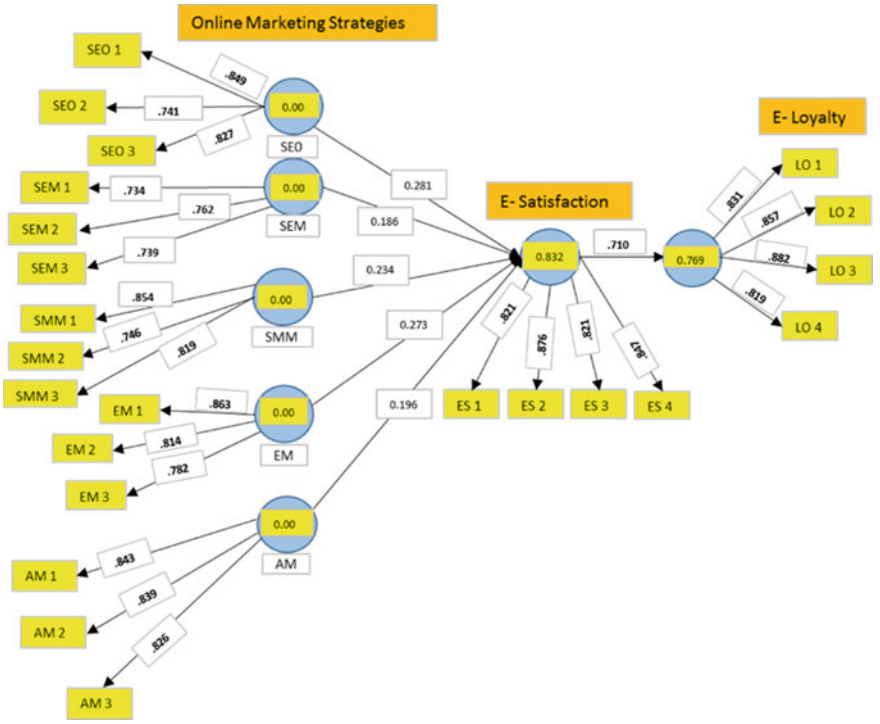

Fig. 2 Measurement model results

we can conclude that online marketing strategies have a significant and positive impact on E-Satisfaction. This suggests that effective online marketing efforts positively influence customers' satisfaction with the electronic platform or website.

H2: The impact of E-satisfaction on E-loyalty is direct and positive. The path coefficient for H2 was calculated as 0.2726, and the t-value exceeded the threshold of 1.96, indicating statistical significance. Thus, we can interpret that E-satisfaction has a significant and positive effect on E-loyalty. This implies that when customers are satisfied with their online experience, they are more likely to exhibit loyalty towards the electronic platform or website. In summary, both hypotheses H1 and H2 have been supported by the analysis. The results indicate that online marketing strategies positively influence E-Satisfaction, and E-Satisfaction, in turn, has a positive impact on E-loyalty. These findings highlight the importance of effective online marketing practices in enhancing customer satisfaction and fostering customer loyalty in the electronic environment.

Table 3 Calculation of path coefficient for hypothesis H1 and H2

Hypothesis	Path coefficient	*t*-value	*t*-critical	Conclusion	
H1	0.2587	**8.9310**	1.96	**Accepted**	
H2	0.2726	**9.4578**	1.96	**Accepted**	

9 Findings

The research study found that online promotions and pricing have a significant impact on consumer purchasing intentions for packaged health food products. Online marketing methods were found to have a direct and positive effect on e-satisfaction, which in turn had a direct and positive effect on e-loyalty. Branding was found to be an essential criterion for shopping for packaged goods online, with over 97% of customers stating it was important. A substantial and positive correlation was found between customers' online purchase intentions and online promotional offers on packaged health food products. Payment methods were also found to be a significant criterion for shopping for packaged food products online, with more than 87% of customers citing it as important. The study also found that high-income consumers prefer online shopping due to the ease of comparison and purchasing. Additionally, the study found that even small adjustments in customer satisfaction can have a major impact on customer loyalty. Furthermore, the study found that working respondents had a significantly positive attitude toward buying packaged food products online compared to student respondents. Lastly, the study concluded that there is a substantial link between customer contentment and consumer loyalty, with 96% of shoppers stating that safety and privacy during online transactions were the primary criteria in their decision to remain loyal to an online retailer. The convenience of comparing packed food products online and the perceived value of the brands creates trust among the customers, and customer loyalty is significantly and positively a customer satisfaction function.

10 Conclusion and Discussion

The substantial increase in online purchasing has strengthened the rivalry in the FMCG segment. Customer loyalty is one of the key determinants for the survival of companies and for growth. The purpose of this study is to test the function of e-satisfaction in the online purchase process and to investigate the influence of e-marketing tactics on consumer e-satisfaction.

It was concluded that the constant updating of websites by e- marketers will lead to greater traffic, better Search Engine Optimization (SEO), higher conversion rates, stronger brand loyalty, and much more with the appropriate Social Media Marketing (SMM) approach.

Customers are notified about promotional activity and marketing opportunities via social media sites. Social networking provides fantastic customer service 24 hours a day. Social networking may be an excellent tool for customer service. Once online consumers believe that their packed food companies offer excellent products at competitive prices and promote offers that have a better overall value than competition, the association between e-satisfaction and e-loyalty becomes stronger and stronger. It was concluded that consumers who spend more time on the Internet are between the 18 and 45 age group. It was further concluded that more than 70% of consumers prefer to see the reviews and ratings of packed food products online on social media and other websites before making a purchase decision. It was also concluded that the price and promotional offers significantly influence the purchase intentions of consumers shopping online. It was also concluded that more than 90% of consumers preferred the feedback from other consumers available on social media over brand advertisements for making purchase decisions. It was revealed that more than 70% of the consumers who shop for packed food products online prefer trustworthy brands and the celebrity endorsements of such brands. The study further revealed that more than 82% of consumers preferred online shopping over offline shopping for packed food products due to the online assurance, brand value, and the online price-promotional offers by the marketers. The easy customization and check out options are the key to the success of online shopping.

The internet marketing strategies can lead to overall profitability and a reduction in organization share of business failures. Satisfied consumers show loyalty to packaged food brands and a higher online buyback rate, whereas loyal users often buy the packaged food online and recommend it to others.

The overall results of this study reveal a connection between the aspects of loyalty, the intent to repurchase/purchase and the satisfaction.

11 Scope for Further Research

The study could be expanded to include a wider range of packaged food products to understand how the findings apply to other product categories. Further research could be conducted to explore the impact of other online marketing strategies, such as social media marketing and influencer marketing, on e-satisfaction and e-loyalty. The study could be expanded to include different segments of consumers, such as older adults, to understand how their purchasing behavior differs in the context of online shopping for packaged food products.

12 Managerial Implications

The findings of the study suggest that online promotions and pricing can have a significant impact on consumer purchasing intentions for packaged health food products. Marketers should therefore use online promotions and pricing strategies to drive sales and increase customer loyalty. The study highlights the importance of online branding in the context of shopping for packaged goods online. Retailers should therefore focus on building and maintaining a strong online brand to attract and retain customers. The study also suggests that online payment methods are a significant criterion for shopping for packaged food products online. Retailers should therefore ensure that they provide a wide range of secure and convenient online payment options to customers.

The study indicates that customer satisfaction is a key driver of customer loyalty in the context of online shopping for packaged food products. Marketers should therefore focus on providing high-quality customer service and support to ensure customer satisfaction and retain customers over time.

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On the Use of Low-Cost IoT Devices to Perpetrate Slow DoS Attacks

Enrico Cambiaso

Abstract Internet of Things security is a crucial topic, due to the characteristics of these networks and the sensitivity of exchanged data. In this paper, we focus on the execution of cyber-attacks from low-cost IoT devices. Particularly, our aim is to evaluate if the ESP8266 module is able to successfully perpetrate a denial of service attack against a widely adopted web service daemon. Results show that the performance of the IoT component is similar to conventional attacking nodes, although memory overflow issues are experienced when targeting some specific configurations of the server. Hence, by measuring the behavior of the ESP8266 for different attack instances, we found that, by targeting a server configured to serve the maximum number of clients possible, a single-node attack is able to establish 66% of the server's resources without experiencing any client-side malfunctioning. Instead, a distributed attack involving malicious IoT nodes is perpetrated correctly.

Keyword Cyber-security · Internet of Things · Denial of service · Slow DoS attack · ESP8266

1 Introduction

The introduction of new technologies has always attracted cyber-criminals [1] and to address cyber-security aspects in both Information Technology (IT) and Operational Technology (OT) contexts is a crucial aspect. Internet of Things (IoT) is a growing technology implemented for both IT and OT environments [2]. The IoT phenomenon is quickly gaining popularity and it is projected that the number of IoT devices in 2024 will reach 83 billion [3]. Thanks to IoT, common objects gain the ability to store, elaborate and exchange information among themselves or with external components. Regarding IoT environments, cyber-security assumes a crucial

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role, as nodes are typically demanded to accomplish critical activities or to collect and manage sensitive information (e.g., health parameters, environmental sensors, industrial activities, smart cities operations, etc.).

Although it is important to protect IoT devices appropriately [4], in this paper we consider instead the adoption of low-cost ESP8266 IoT devices for malicious purposes, targeting Internet services. This concept is not new: the most important threat in this context is represented by Mirai [5], a distributed denial of service (DDoS) [6] IoT botnet which, during 2016, infected more than four thousands IoT devices per hour to perpetrate cyber-attacks against a common target. The total amount of attack bandwidth generated by Mirai was around 1.1 Tbps, with more than 148,000 IoT devices infected, including CCTV cameras, DVRs and routers [7, 8].

By following the concept to exploit IoT nodes for malevolent goals, we evaluate if a low-cost IoT device is able to perpetrate a cyber-attack against an Internet service. The rationale behind our work derives from the increasing diffusion of IoT devices and their potential exposure to adversaries. By focusing on low-cost devices, we consider the possibility for a malicious user to set up a botnet potentially distributed around the globe, by exploiting cheap and easy-to-hide attacking devices. Our focus is on Wi-Fi networks, which potentially allow a malicious node to directly communicate on the Internet by exploiting the TCP/IP stack and by avoiding the need of a "physical" connection on the network. Although such connectivity may enable IoT hosts to perpetrate attacks on the global network, such devices are typically characterized by a limited amount of resources. Therefore, while attacks such as targeted exploits [9] may require low resources to the attacker, in terms of execution time, memory and network capabilities in particular, other threats, such as volumetric attacks [10], remote control [11] or data exfiltration [12], may require continuous communication with the target and considerable amounts of attack resources.

Particularly, we aim to execute a denial of service (DoS) attack against a web service. While it is widely known that attacks such as flooding DoS require huge amounts of attack resources [10], other DoS threats, known as slow DoS attacks [13], make use of limited amounts of attack resources, as they directly target the listening application daemon, instead of the transport or network layer. Previous works demonstrated how mobile devices [14] can be suitable for such purpose. Instead, we focus on the adoption of the ESP8266 low-cost[1] IoT device. Such module provides Wi-Fi connectivity to an embedded micro-controller, and it is composed by a L106 32-bit RISC microprocessor with 32 KiB instruction RAM, 32 KiB instruction cache RAM, 80 KiB user-data RAM and 16 KiB ETS system-data RAM.

By following such direction, the contribution of this paper is twofold: (i) to evaluate if low-cost IoT devices such as ESP8266 are able to successfully lead a denial of service on an Apache web server, and (ii) to define parameters useful to evaluate if an attack has reached the goal of the adversary (which may not always coincide with the DoS, e.g., for stealthy reasons). This work provides therefore the possibility to address in advance potential implementation of cyber-attacks involving low-cost devices, a threat which may assume great relevance in the next future. We focus

[1] The cost of an ESP8266 module is approximated to around 2 EUR (updated on Januray 18, 2023).

on the point of view of the attacker, in order to evaluate the effective possibility to successfully perpetrate a denial of service on the target.

The remaining of the paper is organized as follows: Sect. 2 presents an overview of the literature on the topic. Instead, Sect. 3 reports the adopted approach to evaluate the possibility to perpetrate cyber-attacks through low-cost IoT devices and the adopted choices. Section 4 introduces novel parameters useful to evaluate the success of an attack, while Sect. 5 describes in detail the executed tests and discusses obtained results. Finally, Sect. 6 concludes the paper and reports further work on the topic.

2 Related Work

Literature works concerning Internet of Things security mainly focus on attacks targeting IoT networks and sensors, with consequent protection [15–17]. Nevertheless, as mentioned above, our interest is instead on the use of IoT devices for malicious purposes. In this context, many works focus on IoT botnets: we already introduced Mirai [5], a massive threat which affected huge portions of the Internet network, compromising availability of services like Amazon, Twitter, The Guardian, Netflix, Reddit, Github and CNN [18]. Several works [19–23] investigate in detail such threat and propose adequate protection solutions.

By following the IoT botnet trend, Wazzan et al. [24] address the problem by proposing a survey of scientific works, including IoT botnet detection systems. Similar works focus on detection of IoT botnets through different approaches, such as machine learning [25–27], network flow [28] or forensics [29] analysis. Instead, Dange and Chatterjee [30] focus on IoT attack vectors, by investigating recent attacks aimed to infect or retrieve sensitive information from IoT devices, also discussing the IoT botnet phenomenon. Soltan et al. [31] consider instead distributed IoT attacks executed in power grid environments, while [32] analyzes Hajime, an IoT botnet similar to Mirai, but using a different architecture, based on the concept of peer-to-peer nodes. A relevant malware connected to Hajime [32] is represented by Storm [33], sharing with Hajime the command-and-control information propagation methodology.

Considering instead the different types of IoT devices, it is important to consider that the IoT context is composed by a wide set of devices, such as industrial devices, smart home sensors, Raspberry PIs and smart cameras. Such devices have relatively limited cost and performance similar to mobile device's ones. To the best of our knowledge, previous works investigating the use of limited devices to carry out DoS attacks focus on the adoption of mobile devices. Instead, we make use of the ESP8266 device, a very cheap module with extremely limited resources, not comparable to the resources of a mobile device. To consider a device with reduced cost allows us to address a new potential threat where a malicious user with a limited budget is potentially able to build and distribute a botnet [6] of low-cost IoT devices.

Considering instead the category of attacks executed during our work, as previously mentioned, as flooding-based DoS threats typically require large attack resources [34], we focused on slow DoS attacks [13], a specific type of denial of service attacks aiming at compromising the availability of a network service, by using minimum amounts of network bandwidth. In this scenario, while [13] exhaustively describes the threat, its functioning and the attack approaches, Cambiaso et al. [14, 35] focus on the evaluation of the possibility to carry out a successful attack from a mobile device. Even if nowadays the performance of last generation mobile devices may be similar to a desktop computer, in terms of network connectivity, processing power and memory allocation, back in 2014, Cambiaso et al. [35] demonstrates, for the first time, that it is possible to carry out a successful DoS attack against an Internet service, by using a single mobile attacking device. By following the same approach, the aim of this paper is to push the limit further, by evaluating the possibility to perpetrate a slow DoS attack through a single low-cost ESP8266 IoT device. Although the use of ESP8266 modules to perpetrate denial of service attacks is found in literature [36], to the best of our knowledge, previous works focus on Wi-Fi deauthentication attacks [37] or on targeting the ESP8266 module itself [38]. Differently, although [39] includes tests on the use of ESP8266 devices for executing malicious DoS attacks, considered tests are limited to a single scenario. Therefore, as our work focuses on the adoption of ESP8266 devices to perpetrate and optimize DoS attacks to Internet services, to the best of our knowledge, no similar works are found in literature.

3 The Attack Approach

During our work, we implemented a denial of service attack on the ESP8266 module. The aim of our attacker is to make a network service unavailable to its intended users, by using an attacking ESP8266 IoT node. As anticipated above, conventional denial of service attacks (e.g., flooding [10]) require a large amount of resources to the attacker. Such characteristic is in contrast with the capabilities of the ESP8266 module, equipped with limited resources. Because of this, we decided to implement a slow DoS attacks [13, 40], as such threats are characterized by limited requirements, in terms of bandwidth and memory in particular. Our aim is to demonstrate the possibility to adopt low-cost and computationally limited IoT modules to carry out potentially relevant cyber-attacks against conventional network services. For the context of this work, we target an Apache web server.

Particularly, slow DoS attacks reduce the attack bandwidth by directly communicating with the application daemon (instead of working at the transport layer, like traditional flooding-based threats). At the application layer, the number of connections the attacker has to establish and maintain is particularly low (typically, just a few hundreds [41]), compared to transport layer attacks, where several thousands of connections are usually involved. In addition, slow DoS attacks make use of the so-called *Wait Timeout* [13] to alternate active data send periods to inactivity periods,

where no packets are sent to the victim, at the application layer. Such characteristics lead to a reduced attack bandwidth. In particular, our attack ports the SlowComm threat [40] to the ESP8266 module.

In detail, as soon as all the connections the listening daemon is able to simultaneously manage are established (by the attacker), any additional connection would not be accepted by the daemon,[2] hence experiencing a denial of service. While many different categories of slow DoS attacks exist [13], we focused on SlowComm due to its behavior, as it requires minimum amounts of network bandwidth. Particularly, as mentioned, the goal of the attack is to concurrently initiate all connections the server is able to manage. Such connections are kept alive by the attacker, by periodically sending a size-limited payload (composed by a single space character, hence, by a single byte payload) to the victim. As mentioned above, such period is identified as the *Wait Timeout* and it may assume even relatively high values, in the order of minutes [13]. Hence, considering a single connection with the daemon, as a single byte is sent at each round, we have that, potentially, just a single byte is sent every a few minutes. In addition, during a SlowComm attack, the server is induced to wait for the end of the client message/request: as the characters identifying the end of the request are never sent, the server is forced to an endless wait. Because of this, from one side, the connection is kept alive; from the other one, the server is never allowed to send data to the client (at the application layer). Such characteristics allow us to reduce at minimum the network resources required from the attacker.

If we compare SlowComm to the well-known SYN flood attack [34], the approach used by the two attacks may appear similar. Nevertheless, while the SYN flood attack targets the transport layer, by flooding the victim with huge amounts of SYN packets, SlowComm (as other slow DoS attacks) targets the application layer, hence, the listening daemon. Also in this case, a large amount of packets is sent, but in the order of a few hundreds, compared to the tens of thousands sent during a flooding attack. In addition, while flooding attacks never interrupt the sending of packets to the victim, the use of the Wait Timeout makes SlowComm able to temporarily interrupt the packet sending, hence reducing both the attack bandwidth and the computation effort of the attacker.

Our aim is to evaluate if cheap IoT devices are able to perpetrate such kind of attack. In order to verify it, we need first to define some parameters able to evaluate the efficacy of an attack, from the point of view of the adversary.

4 Introduced Parameters

In order to evaluate the efficacy of a slow DoS attack, in this paper we extend the metrics reported in [40], by providing additional metrics based on the already available ones. Particularly, referring to [40], we make use in particular of the *maximum attack*

[2] Please note that the connection may still be established at the transport layer, while the daemon will not be able to manage it [13].

peak M_{peak} parameter, defined as the maximum number of simultaneous connections the adversary established on the server during the attack.

By focusing instead on the definition of the *DoS percentage* P_{DoS} parameter reported in [40], such parameter refers to the percentage of time the victim is in the denial of service state, during an ongoing attack. Hence, for instance, if the DoS on the server is experienced only half of the time of the duration of the attack, we will obtain $P_{\text{DoS}} = 0.5$. By extending such concept, we introduce in this paper an additional parameter related to the P_{DoS}, called *desired DoS percentage* P_{desired}. Particularly, the introduced parameters identify the percentage of time the victim is in the state desired by the attacker: let us suppose the server is able to manage at most N_s simultaneous connections. In this case, if N_s connections are established by the attacker, the $(N_s + 1)$th connection will not be accepted by the application daemon, as the server is experiencing a denial of service attack. Nevertheless, the aim of the attacker may be (e.g., for limits of the attacking node, for stealthy reasons, etc.) to reduce the number of connections simultaneously established by the malicious node (N_a in the following), hence, in this case, to establish and maintain $N_a < N_s$ connections with the target. It is clear that, under such conditions (except in case of some additional legitimate connections, or when a distributed attack is perpetrated), the denial of service state will not be reached on the server, although the attack influence may even approach its maximum value 1. Also, in this case, the P_{DoS} parameter will assume a 0 value, as the DoS will never be reached.

Nevertheless, it may be important to evaluate the success of an attack, in relationship with the initial goal of the attacker. To do so, assuming T is the attack duration and $f(t)$ the function representing the number of connections established with the victim at a certain time during the attack, we define $F_{N_a}(t)$ as reported in Eq. 1.

$$F_{N_a}(t) = N_a \;\forall\; f(t) > N_a \tag{1}$$

Hence, assuming $k \in [1, T]$, we introduce the $P^k_{\text{desired}} \in [0, 1)$ parameter, defined as reported in Eq. 2.

$$P^k_{\text{desired}} = \frac{\sum_{t=k}^{T} F_{N_a}(t)}{N_a \cdot T} \tag{2}$$

At this point, we define k' the instant where N_a simultaneous connections are measured for the first time, for the current attack. According to Eq. 2, we define $P_{\text{desired}} = P^{k'}_{\text{desired}} \in [0, 1]$ as the percentage of time $n \geq N_a$ connections are simultaneously established on the server, over the entire attack duration. Finally, we consider $P_{\text{desired}} = P_{\text{DoS}}$ in case $N_a = N_s$. Such parameter allows us to analyze, if and how the attack is successful, from the point of view of the attacker, by providing a quantitative value to the amount of time the goal defined by the attacker has been reached.

Similarly to our discussion on the P_{DoS} parameter [40], also define the *attack influence* η, as the integral of the number of simultaneous connections established by the attacker during the attack execution time, over the maximum number of connec-

tions the victim is able to simultaneously manage during the attack execution time. By exploiting the definition of such parameter, we define in this paper the *desired attack influence* η_{desired} as the integral of the number of simultaneous connections established by the attacker during the attack execution time, over the N_a connections the attacker aims to simultaneously maintain with the server.

Hence, according to Eq. 3, we define the desired attack influence η_{desired} as follows:

$$\eta_{\text{desired}} = \frac{1}{N_a \cdot T} \int_0^T F_{N_a}(t)\, \mathrm{d}t \tag{3}$$

Similarly to the P_{desired} parameter, we consider $\eta_{\text{desired}} = \eta$ in case $N_a = N_s$.

Such parameter provides us the possibility to evaluate the impact of the attack on the server, compared to the initial goal defined by the attacker.

5 Executed Tests

In this section, we detail the tests we have executed to evaluate if the ESP8266 module is able to successfully carry out a denial of service attack against a web service. We first describe the adopted testbed; hence, we present the executed tests and the obtained results.

5.1 Testbed

Our testbed is composed by an USB-powered ESP8266 module acting as the attacker and connected to a wireless access point.

The network also includes the victim host, represented by a virtual machine host equipped 4 vCPUs, 4 GB of RAM memory and running Apache web server version 2.4.52 (built 2022-06-14T12:30:21) on an Ubuntu Server 22.04.1 LTS operating system. Such version represents the latest version avable for the adopted OS (to September 2022), on its default settings.

All our tests have been executed by adopting an attack *Wait Timeout* equal to 60 s (lower than the 300 s configured on the server by default [13]) and for a duration of 600 s. In addition, during the attack, network traffic was captured on the victim host, hence, on the targeted server, for post-attack analysis. Also, during the attack, the number of connections established with the server and managed by the daemon application was monitored every second, to analyze the attack performance from the victim itself. In particular, by periodically monitoring such number of connections, the P_{desired} parameter is computed, by assuming that the DoS state is reached if and only if the number of connections established with the daemon at a certain period is equal or higher to the maximum number of connections the server is able to concurrently manage (as defined by the *MaxRequestWorkers* directive).

5.2 Tests Against the Default Server Configuration

As a first test, we executed the attack from a single ESP8266 node, by targeting a default configuration of our Apache2 instance. In this case, as mentioned, we have $N_s = 150$, configured as the default *MaxRequestWorkers* value of the *mpm_common* module [42]. Hence, our victim is able to manage at most 150 concurrent connections. Therefore, in case our attacker would establish all of them, any additional request would not be accepted by the application daemon, hence leading to a denial of service. The results of this first test are reported in Fig. 1, where we adopted $N_a = 150$. Hence, we have in this case $P_{\text{desired}} = P_{\text{DoS}}$ and $\eta_{\text{desired}} = \eta$.

As it is possible to notice, the victim is able to establish all the $N_s = N_a = 150$ connections (M_{peak}). In addition, such number of connections is established almost immediately, just after a few seconds since the beginning of the attack. Nevertheless, such connections are not maintained over time. This is due to the enabling by default of the *reqtimeout* module, an Apache plug-in able to limit the impact of slow DoS attacks, by applying minimum bandwidth requirements for clients connections [40]. Particularly, under such circumstances, we found $P_{\text{desired}} = 0.575$ and $\eta_{\text{desired}} = 0.9743555555555555$. Hence, while the impact on the server is relevant, the DoS state is not maintained over time. As similar results are also found for other more powerful devices running SlowComm [40], we can state that such result does not depend on the limited processing capabilities of our IoT node. In addition, as we executed preliminary results executed against a different host (a Raspberry PI 4 running running Apache web server version 2.4), leading to similar results, we can state that the result we obtained does not depend on the targeted system. To evaluate the presence of such potential limits related to the characteristics of the ESP8266 module, we will now analyze the effects of the attack by disabling the *reqtimeout* module.

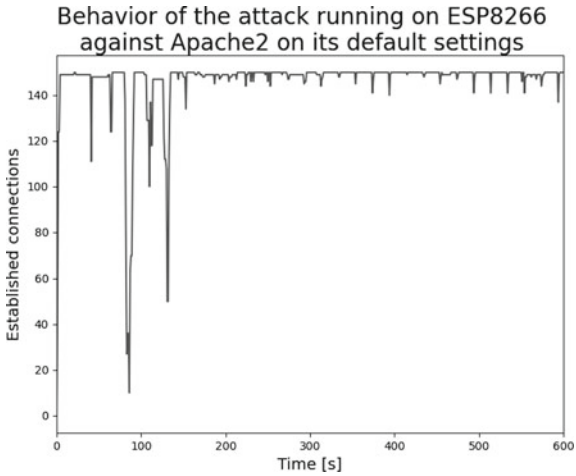

Fig. 1 Results of a SlowComm attack perpetrated by an ESP8266 attacking node by adopting $N_a = 150$, targeting an Apache 2.4 web service on its default settings

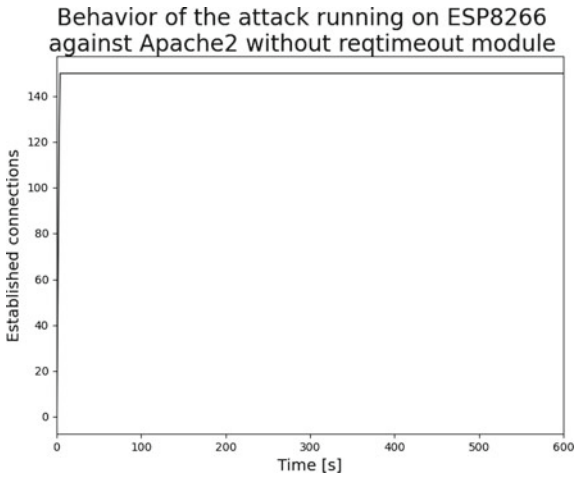

Fig. 2 Results of a SlowComm attack perpetrated by an ESP8266 attacking node by adopting $N_a = 150$, targeting an Apache 2.4 web service not loading the *reqtimeout* module

5.3 *Tests Against a Server Without the* reqtimeout module in execution

As the performance of the previous attack were influenced by the presence of the *reqtimeout* module on the server, in this set of tests, we target a victim which is not loading such module. In particular, as for the previous test, we have $N_s = N_a = 150$. Results are reported in Fig. 2.

Results clearly show that the ESP8266 node is able to manage and maintain all the N_a connections. In fact, in this case, we found $P_{\text{desired}} = 0.9933333333333333$ and $\eta_{\text{desired}} = 0.9960222222222223$. Hence, the attack performs very good in this case.

As additional tests, we want to push the limits of the ESP8266 module, by evaluating if it is able to perpetrate an attack against a server with higher N_s values.

5.4 *Tests on ESP8266 Attacker Establishing the Maximum Number of Connections Available*

In the previous tests, we have considered a server able to manage at most $N_s = 150$ connections, the default value of the *MaxRequestWorkers* module. In this new set of tests, we configured the victim host to manage at most $N_s = 256$ connections, which represents the maximum value supported by the *MaxRequestWorkers* module.[3] Also, we consider the presence of the *reqtimeout* module, previously disabled as reported

[3] More information can be found at the following address: https://www.woktron.com/secure/knowledgebase/133/How-to-optimize-Apache-performance.html (accessed on September 2, 2022).

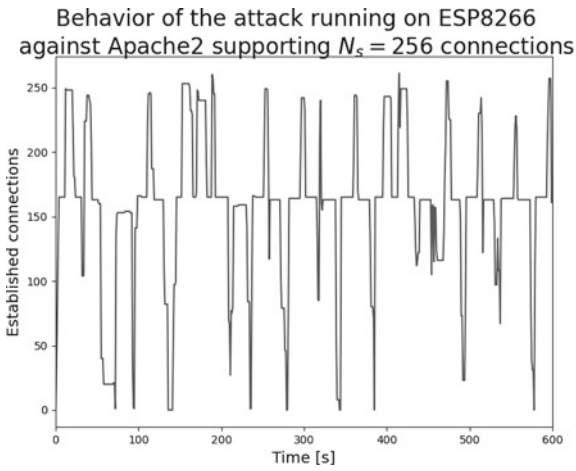

Fig. 3 Results of a SlowComm attack perpetrated by an ESP8266 attacking node by adopting $N_a = 256$, targeting an Apache 2.4 web service supporting $N_s = 256$ concurrent connections

in Sect. 5.3. Our aim is, on one side, to analyze the effects of the attack on the server; on the other side, to evaluate if our IoT attacking node is still able to successfully perpetrate the attack. Obtained results are depicted in Fig. 3.

For such test, we found $P_{\text{desired}} = 0.01$. Such value may seem low, but, by considering the results discussed in Sect. 5.2, we did not obtained a high P_{desired} value due to the repeated connection closures executed thanks to the *reqtimeout* module.

Instead, considering the desired attack influence parameter, we found $\eta_{\text{desired}} = 0.6169921875$. Such value is low, compared to the value obtained for the tests reported in Sect. 5.2. In addition, the figure shows how the $f(t)$ value repeatedly approaches 0, hence, no active connections are established with the server.

By deeply analyzing such behavior, we measured that the ESP8266 device repeatedly crashes and (automatically) reboots. Such crashes were certainly unexpected. By looking at the ESP8266 console logs, an exception is periodically raised (`Exception (29)`), forcing the reboot of the device. Particularly, exception code `29` refers to a *StoreProhibitedCause*, occurring when "*a store referenced a page mapped with an attribute that does not permit stores*".[4] Hence, the error is raised because of the high number of connections the IoT node has to manage, with a memory allocation which exceeds the available memory. Therefore, even if in such conditions it is still possible to carry out denial of service attacks from a single low-cost IoT attacking node, we experienced some limits of our ESP8266 attacking node. Particularly, the malfunctioning of the attacking node, in terms of overload of the embedded memory, leads us to conduce additional tests. As a next step, our focus is to execute a set of measurements of the performance of the ESP8266 module, to evaluatae its limits, by analyzing the attack performance in function of the adopted N_a parameter.

[4] More information are available at the following address: https://links2004.github.io/Arduino/dc/deb/md_esp8266_doc_exception_causes.html (accessed on September 1, 2022).

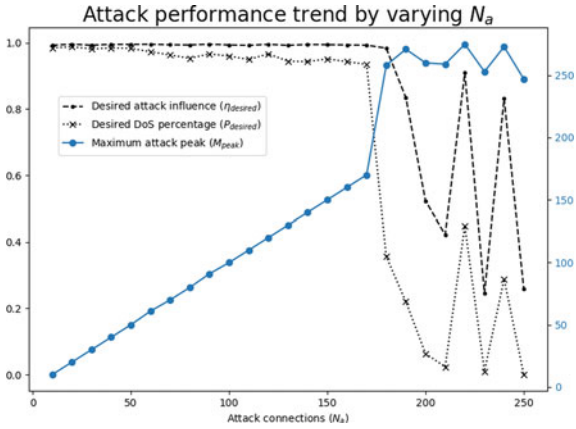

Fig. 4 Results of a set of attacks perpetrated by the ESP8266 module against an Apache 2.4 web service with *reqtimeout* enabled, by varying the N_a parameter

5.5 *Performance Trends by Varying the Number of Connections Established*

As previously anticipated, our aim is to identify the limits of the ESP8266 device, in terms of capability to initiate and maintain a specific number N_a of connections with the victim. In particular, we executed tests for $N_a \in [10, 250]$, with N_a multiple of 10; hence, $N_a \bmod 10 = 0$. Figure 4 reports obtained results.

As reported in the figure, we found that, for $N_a \geq 180$, $M_{\text{peak}} > N_a$. This was not expected. Nevertheless, as we have observed and detailed in Sect. 5.4 related to $N_a = 256$, we noticed that, for $N_a \geq 180$, the ESP8266 module crashes and reboots. On the contrary, for all the other low values of N_a, no crash was experienced. Hence, the adopted IoT attacking node is able to establish around 66% of the connections the server is able to manage without experiencing any malfunctioning. Particularly, being each boot of the IoT module independent on the previous one, more than N_a connections may be established at a specific time, hence resulting with $M_{\text{peak}} > N_a$, as those connections refer to both the current (after crash and restart) and the previous (referring to the previous boot) execution of the software from the ESP8266 module. In a similar way, we founded that, under such circumstances, both the desired attack influence and desired DoS percentage parameters assume low values, also related to a higher variance, compared to the cases with lower N_a.

Instead, if we consider $N_a < 180$ tests, we found a stability of all the parameters: in particular, we obtained $M_{\text{peak}} = N_a$ for all the cases and a desired attack influence near to 1. Regarding the desired DoS percentage, under such circumstances, the value slightly decreases with the increase of N_a, with $P_{\text{desired}} = 0.935$ for $N_a = 170$. Nevertheless, the reduction of such value depends on the *reqtimeout* behavior, closing low-bandwidth (hence, all) connections: as it is needed to the attacker to establish an increasing number of connections, with the increase of N_a, the time required to establish them increases as well, hence resulting in a decrease of the P_{desired} parameter value.

Therefore, we found that, for our tests, the best choice for the attacker would be to adopt $N_a = 170$. Although such value does not provide the possibility to reach a DoS on a victim supporting $N_s = 256$ concurrent connections, it allows a single IoT attacking node to establish 66% of the connections the server can manage, without experiencing any malfunctioning, from the attacker's point of view. Particularly, although such approach would not lead to a DoS on the server, a distributed attack [6], involving just two attacking low-cost IoT nodes, would be able to make the service unavailable.

5.6 *Performance of Distributed Attacks*

As reported in the previous tests, although, by default, our Apache2 service was configured to manage at most $N_s = 150$ simultaneous connections, in case the server is configured to manage a higher value, equal to $N_s = 256$ (the maximum value of the *MaxRequestWorkers* parameter), a single attacking ESP8266 node would not be able to perpetrate the attack successfully.

In this set of tests, we are going to overcome the limits of our IoT node, by executing a distributed attack. In this case, a coordinated attack is perpetrated by all the nodes of the botnet. For our scenario, we adopted $N_c = 2$ different ESP8266 attacking devices/clients. Equation 4 reports the approach adopted to identify the N_a value to use.

$$N_a = \left\lceil \frac{N_s}{N_c} \right\rceil \tag{4}$$

Particularly, according to Eq. 4, we configured each one to manage at most $N_a = 128$ concurrent connections, a value lower than the limit discussed on Sect. 5.5. Results are reported in Fig. 5.

Obtained result reported a desired attack influence value equal to 0.9649544270833333 and an M_{peak} value equal to $N_s = N_a = 256$. Nevertheless, we found a very low P_{desired} value, equal to 0.023333333333333334. This was not expected, as we would expected a value approaching 1. Such behavior is also visible in figure, showing a peak of 256 connections just after the beginning of the attack. Hence, once connections are closed, not all of them are re-established by the client.

Therefore, it is important to understand if such behavior derives from the client(s) or the server itself. As a first step, by evaluating the potential limits of the attacking nodes, we increased the number of connections simultaneously managed by each client to $N_a = 170$, the maximum value obtained in Sect. 5.5. Obtained results include $M_{\text{peak}} = 253$, $\eta_{\text{desired}} = 0.9676171875$ and $P_{\text{desired}} = 0$. Hence, considering that the P_{desired} value depends on the M_{peak} value, approaching N_s, we can state that the effects of this attack, compared to the previous one, are similar.

At this point, we decided to analyze if the unexpected behavior depends on the server. At first, we decided to increase the number of vCPUs allocated to the virtual

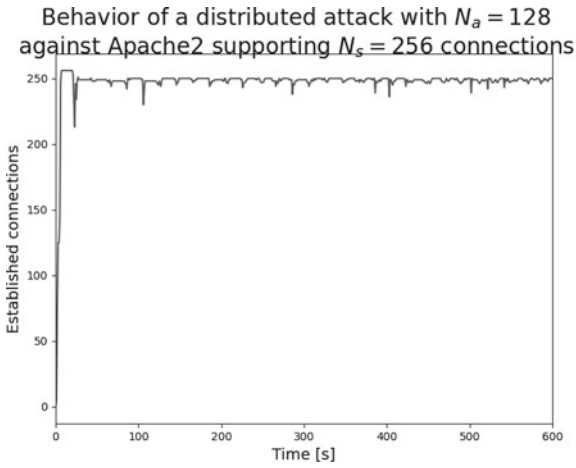

Fig. 5 Results of a distributed SlowComm attack perpetrated by $N_c = 2$ ESP8266 attacking nodes by adopting $N_a = 128$, targeting an Apache 2.4 web service supporting $N_s = 256$ concurrent connections

machine running the service. We doubled such number, from 4 vCPUs to 8 vCPUs. Hence, we executed a distributed attack with $N_c = 2$ and $N_a = 170$. We found results similar to the previous tests: $M_{\text{peak}} = 251$, $\eta_{\text{desired}} = 0.9671940104166666$, $P_{\text{desired}} = 0.0$.

Similarly, we increased RAM memory allocated to the attacked virtual host to 8 GB. Hence, we doubled it, compared to the previous tests. Under such circumstances, by executing a distributed attack with $N_c = 2$ and $N_a = 170$, we found, again, results similar to the previous tests: $M_{\text{peak}} = 252$, $\eta_{\text{desired}} = 0.9682682291666667$, $P_{\text{desired}} = 0$. Therefore, we can state that the unexpected behavior does not depend on the memory allocated to our server. By executing additional tests against a 4 vCPUs and 4 GB RAM server, disabling the *reqtimeout* module, we found, again, similar results: $M_{\text{peak}} = 246$, $\eta_{\text{desired}} = 0.9535091145833333$, $P_{\text{desired}} = 0$.

With the aim to identify the cause of the unexpected behavior, as our previous tests failed from such perspective, we decided to analyze the effects of the attack on the server from another point of view. Particularly, we executed additional tests against our Apache2 service supporting $N_s = 256$ simultaneous connections. In this case, the *reqtimeout* module is enabled. Also, we adopted $N_c = 2$ attacking ESP8266 nodes making use of $N_a = 128$. In addition, compared to the previous tests, we evaluate the effective denial of service state through a different approach. In detail, we include an additional HTTP client (implemented on the server itself) periodically checking the effective possibility to communicate with the application daemon. Hence, we are introducing an additional client which may have an impact on the targeted server, as it is behaving actively. Our aim is to evaluate if the *MaxRequestWorkers* directive of *mpm_common* is reliable enough or not, by introducing a legitimate client verifying over time if the DoS is led on the server or not. Results are depicted in Fig. 6.

Obtained results, in terms of connections established, are similar to the ones reported in Fig. 5, although, in this case, our attack does not establish all N_s con-

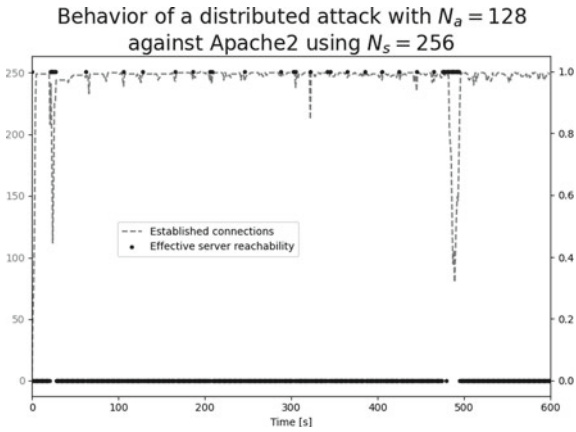

Fig. 6 Results of a distributed SlowComm attack perpetrated by $N_c = 2$ ESP8266 attacking nodes by adopting $N_a = 128$, targeting an Apache 2.4 web service supporting $N_s = 256$ concurrent connections, with results on the effective reachability of the server

nections, hence retrieving $P_{\text{desired}} = 0$. Indeed, we found in this case $M_{\text{peak}} = 251$, while $\eta_{\text{desired}} = 0.9536848958333334$ is in line with our previous results. Instead, if we consider the results of our checking service, we found that the system is not reachable (value equal to 0) for almost the entire the duration of the attack, with limited availability (value equal to 1) in line with the connection closures executed by the *reqtimeout* module. Considering such aspect, we found in particular that the DoS state is affecting the service for 91% of the time.

Hence, by summarizing obtained results we can state that: (i) the distributed attack is able to lead a DoS on the victim and (ii) the *MaxRequestWorkers* parameter seems not to perfectly match the N_s parameter, especially when the maximum value is configured. Regarding the latter point, further work may be directed to execute additional tests aimed to verify how it is possible to improve the accuracy of such parameter and/or to identify the causes of such unexpected behavior, also analyzing the implementation code of the module.

6 Conclusions and Further Works

In this paper, we addressed the execution of denial of service attacks from low-cost IoT devices, by focusing on the adoption of the ESP8266 hardware. By implementing a slow DoS attack [13] on the device, we evaluated if the attack is successful or not, when executed from a node with extremely limited capabilities.

Results executed against an Apache 2.4 web server on its default settings show that it is possible to carry out a successful attack. Hence, we found that the ESP8266 device is able to successfully lead a denial of service. Instead, by targeting a server configured to simultaneously serve the maximum number of connections possible (as defined in the *MaxRequestWorkers* directive of the *mpm-common* Apache module), we noticed that the attack is still successful, but the device experiences some crashes and reboots,

due to an exceed of the available memory. Therefore, additional works on the topic may address such limits, by considering the use of more powerful IoT devices, such as ESP32. A potential extension of the work may also focus on improving the attack behavior/approach, for instance by analyzing if the malfunctions are related to the adopted Wait Timeout, by optimizing the attack behavior or by designing a new threat aimed to reduce required attack resources.

We also focused on the identification of the optimal solution, in terms of effects on the server, in relationship with the capability of the IoT node to perpetrate the attack without experiencing malfunctions. We found that a single IoT device is able to allocate and manage around 66% of the resources of the server without experiencing any crash. Such value should be considered particularly high, considering the adopted hardware. As a further test, we involved two coordinated nodes executing a distributed attack [6] against our victim. In this case, although the attack is successful and no malfunctioning is observed, we found that the number of connections the attacker needs to effectively establish with the victim in order to lead a DoS may be lower than the value configured on the server (through the *MaxRequestWorkers* directive). The analysis of such unexpected behavior and further investigation on the *MaxRequestWorkers* directive and its implementation is in the scope of further work on the topic.

Similarly, as we focused on the HTTP protocol, by targeting an Apache 2.4 web server, the exploitation of other protocols and services may be scope of further works. For instance, it is known that slow DoS attacks can target other TCP-based protocols such as SMTP, SSH and FTP [40]. Hence, further works may focus to analyze the performance of (even different) cheap IoT nodes against other communication protocols.

Finally, an extension of the work may be focused on providing adequate protection. In literature, different protection systems able to identify and protect from slow DoS attacks are available [41, 43, 44]. However, additional studies may focus on protection from IoT botnets, for instance, by investigating how to induce issues (e.g., crashes) on the clients, e.g., to reduce their attacking power.

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EEG Signals Variation Under Stroboscope and Binaural Sound Stimulations

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Abstract Electrical activity on the temporal and occipital lobes (alpha waves) is associated with physical and mental rest (8–12 Hz). In this study, alpha waves were stimulated by two methods: the first one involved the generation and implementation of a binaural sound, and the second method was a frequency-controlled strobe light. The electrical changes caused by arousal were recorded by the EPOC Emotiv headset and the OpenViBe software. An audiovisual device was built, in order to isolate the person from external disturbances, to obtain a higher concentration in the light that flashes from a screen and in the binaural stimulation applied through headphones. The results obtained in this study showed a change in the measurements on the temporal and occipital lobes. It increased from 0.44 ± 0.13 to 0.55 ± 0.15 in alpha waves, and beta waves showed a decrement from 0.61 ± 0.11 to 0.436 ± 0.19. This study presents the analysis of the electrical brain's variation of a person under audiovisual stimulation.

Keywords Alpha band · Binaural · EEG · Strobe light · Wavelet

1 Introduction

Stress is a disease caused by various reasons such as physical trauma, psychological problems, and work pressure[1]. One way to counteract this pathology is the scientific treatments based on biofeedback, in which the electrical signals from the

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brain are analyzed and interpreted in response to external stimulus such as: visual, auditory, somestesic, and cognitive evoked potentials [2–4]. These stimuli can alter the frequency of the electrical activity in defined bands known as: delta (1–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz), depending on the individual sensory stimulation applied [5].

The alpha waves are a state whose main characteristics are: physical and mental rest, which are especially evident in the frontal and occipital lobes [6]. Among the different stimuli associated to this frequency band, several studies have demonstrated the influence of binaural beats in relaxing people and confirm that these sounds have the potential to reduce stress or pre-surgery anxiety in patients with negative effect of analgesics consumption [5, 7, 8]. The binaural sound is obtained from the difference in frequencies that are applied in each ear independently, without interference or possible frequencies combinations. These different sound frequencies are perceived by the brain generating the binaural fusion [4].

This research presents the quantification of the electrical variation registered in the EEG of a person under audiovisual stimulation (AS). An AS system was developed, with binaural sound and stroboscopic light to induce a person into a relaxed state without external disturbance. EEG waves were recorded with and without stimulation to compare and quantify them. With the development of this work, a tool that allows to perceive the degree of brain stimulation of the individual is presented.

2 Materials and Methods

In order to capture the EEG signal, sixteen electrodes were placed in the front, occipital, and parietal segment of the skull according to the international system of positioning electrodes 10/20 [9]. Additionally, a device was built to insulate people from outside to study sensory stimulation. Two programming blocks were developed in LabVIEW to stimulate the patients. The first block generated the binaural sound by dividing the audio card in two parts to apply a pure tone of 500 Hz in the right ear and a pure tone of 510 Hz in the left ear. The second block generated a 10Hz strobe light. EEG activity was monitored with EPOC Emotiv headset and recorded with OpenViBe free software.

Fifty healthy and fully informed volunteers participated in the study: twenty-eight men and twenty-two women (mean age 25 years). The electrodes for acquiring EEG signals were placed, giving priority to four electrodes: two occipital and two temporary. Contact electrodes were checked to guaranty correct signal acquisition before the storage of data. Subsequently, a first test without stimulation by fifteen minutes long was performed. The next test consisted in applying the AS on the volunteers during fifteen minutes each, thus creating a database of four hundred and eighty samples (Fig. 1).

Using the wavelet transform, the original EEG signal (sample rate 128 Hz) was decomposed into two signals: the first one with A1 approximation, and the other one with D1 details, then A1 signal was subdivided again, staying with an approximation

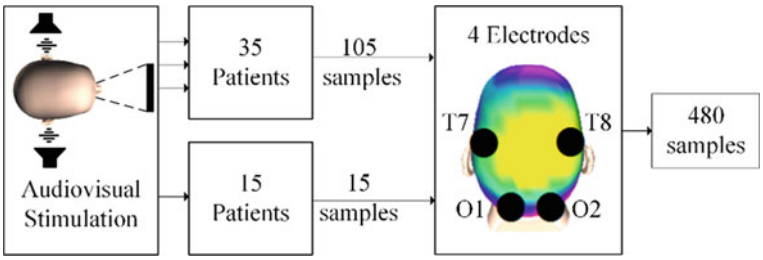

Fig. 1 Audiovisual stimulation and samples obtained

A2 and D2 detail. This process was performed five times to reach the four frequency bands: delta, theta, alpha, and beta.

For better appreciation of the four bands division, fast Fourier transform (FFT) of each subsignals was obtained to observe the frequency range of each group (Fig. 2).

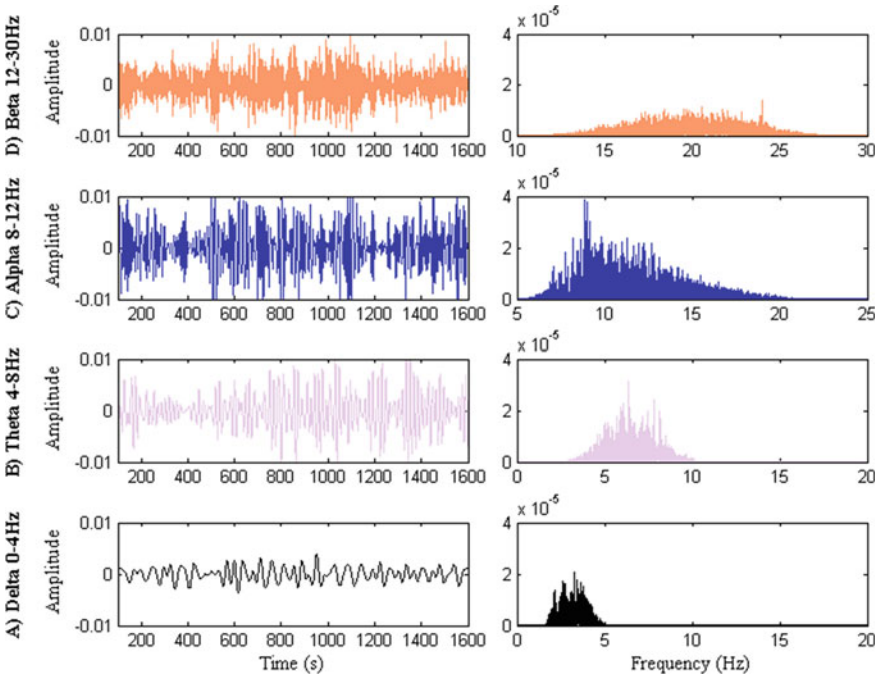

Fig. 2 Subdivision EEG waves and FFT on each subsignals

3 Results and Discussion

The results in each of the audiovisual tests were presented according to frequency bands: beta, alpha, theta, and delta, both in frequency and in time. The results were normalized considering 1 the maximum level of stimulation and 0 a null stimulation.

Figure 3b shows the maximum FFT amplitudes of the four bands before stimulation. It is possible to observe that the normalized mean of the beta waves is predominating with 0.61 ± 0.11. Figure 3a graphics the maximum FFT amplitudes of the four bands after stimulation, predominating the normalized mean alpha waves: 0.55 ± 0.15. The results obtained are summarized in Table 1.

EEG samples were taken before and after of the stimulation. The stimulation results perceived by the temporal and occipital lobes are interpreted according to Fig. 4. It is observed that lobes having higher activity on alpha waves are occipitals O1 and O2 followed by temporal lobes T7 and T8. Beta wave's highest activity is in lobe T8, followed by O2, O1 and T7. Theta waves in the O2 lobe appear followed by T8, T7, and O1, and delta waves lobe predominant O2, T8, O1, and T7.

The data registered before stimulation shows that the value of the beta band was 0.61 ± 0.11 and alpha was 0.44 ± 0.13. Those were prevalent before theta and delta that is consistent with previous studies [10, 11]. Data collected during stimulation

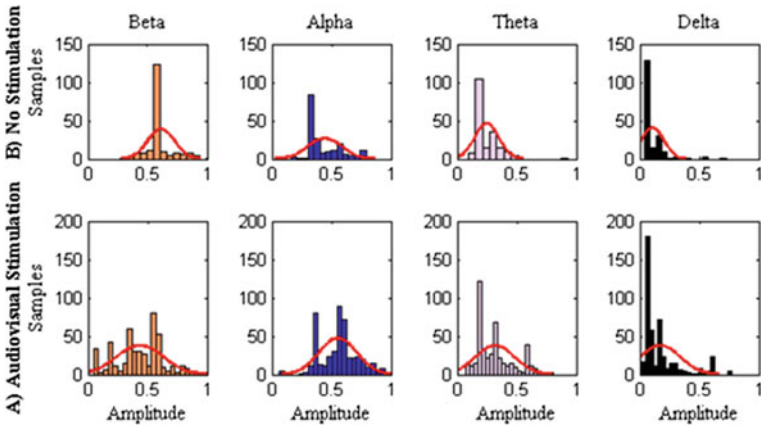

Fig. 3 Histograms of the EEG waves registered on the two temporal and two occipital lobes with: **a** audiovisual stimulation, **b** no stimulation

Table 1 Normalized mean of EEG subdivision waves

EEG waves	No stimulation	Audiovisual stimulation
Beta	0.61 ± 0.11	0.43 ± 0.19
Alpha	0.44 ± 0.13	0.55 ± 0.15
Theta	0.24 ± 0.09	0.31 ± 0.16
Delta	0.10 ± 0.09	0.16 ± 0.16

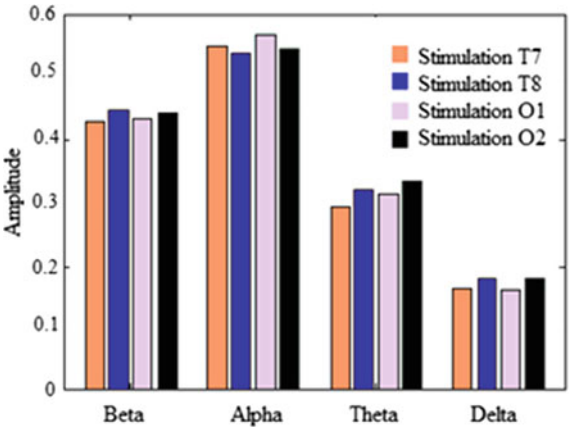

Fig. 4 Arithmetic means of the temporal and occipital stimulations

showed a value of 0.43 ± 0.19 in beta waves and 0.55 ± 0.15 in alpha waves. Beta value is attenuated, and the alpha value increases, but does not exceed the initial value of beta.

The estimation obtained in our study shows an agreement with previously published EEG studies where the brain activity registered while applying a 10 Hz binaural wave attenuates the group of alpha waves, but an increase was seen in the narrow band of 10 ± 0.1 Hz [10, 11].

Analyzing the group of alpha waves and brain regions during stimulation, it observed an electrical activity of 0.55 ± 0.09 at the left temporal and 0.53 ± 0.07 at the right one. Similarly, the left occipital showed electrical activity of 0.57 ± 0.06 and its counterpart, the right occipital showed an activity of 0.54 ± 0.07. From this, it can be seen that the left temporal and occipital give greater brain activity. Observing the arithmetic mean of temporal and occipital areas, it was shown that the occipital had major activity than the temporal one (Fig. 3), taking into account that the occipital area was associated with vision, and in the temporal with ear [10], we can say that strobe light showed a higher stimulation than binaural waves.

The results of this study can also be influenced by the type of wavelet transform used and the cooperation of the participants as it has been previously shown [12]. It is important to note that this is a numerical interpretation and not a psychological interpretation, and it can be said that stimulation causes changes in brain activity, but an analysis was not performed on the behavior of volunteers.

4 Conclusions

The aim of this study was to quantify the change that occurs in the brain activity and analyze alpha waves by applying binaural sound and visual stimulation.

The respective statistical analyses showed that it is possible to influence brain activity using different external stimulations. Additionally, the individual behavior in each of the lobes is shown and appreciated that the occipital and left temporal predominate with a little variation from their counterparts in alpha waves. Among the visual evoked potentials and auditory evoked potentials, we can say that the visual produces greater influence. It should be noted that in every temporal and occipital lobes, one electrode is used by area. In reviewing the behavior of the EEG waves before stimulation, it is observed that the beta waves are more active, followed by alpha, while theta and delta waves presented a lower activity. After stimulation, alpha waves predominate followed by beta waves. Theta waves showed a small increase, and delta is kept constant. All these assertions are based solely on mathematical observation without any professional help from neurologists or psychologists for deeper interpretation of the results as the change in mood. This study opens new research opportunities, as the search for stimuli that will be able to characterize certain brain activity, so they could be applied in different tasks on daily basis.

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Digital Platform for Teachers' Professional Development

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Abstract An essential challenge is to provide an effective digital support tool for the processes of career advising, training, and teaching staff employment in the educational system. One of Kazan Federal University's major development goals is the building of a complex of evidence-based technologies and platform solutions to boost human potential in the face of emerging socioeconomic difficulties. A laboratory "Research-oriented teacher education" was established within the framework of this project, with one of its tasks being to develop an effective tool for career guidance, training, and employment of teaching staff. This platform might be dubbed the Digital Platform for Teachers' Professional Development. The platform's goal is to automate the processes of support for a unified system of activities in educational institutions of various levels for the selection, career guidance, training, employment, and support for teaching staff career growth, as well as the creation of a single database of personnel reserve. The article gives an overview of the fundamental ideas behind the digital platform that supports teachers' professional careers and provides a quick study of some existing digital tools for hiring and job searching in the education sector.

Keywords Teacher career · Aspiring teacher · Career planning · Digital platform · Career support

1 Introduction

Digital platforms have grown rapidly in practically all areas of life during the past ten years. As a result, several researches on the reasons behind, characteristics of, and potential for the growth of digital platforms have been published. Due to their dispersed nature and interdependence with institutions, markets, and technology, digital platforms are widely acknowledged as a complicated subject of research

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[1–4]. Digital platforms have significantly altered how individuals engage with one another while they are at work, conducting business, socializing, studying, or moving about, among other activities.

There is still no widely agreed meaning of the phrase "digital platform", according to an examination of scientific and practical literature. For instance, Mark de Reuver [4] draws attention to the difficulty in precisely defining what digital platforms are, what their key traits are, and how they add value. Digital platforms are currently viewed as a collection of digital resources, including services and content, which encourage interaction among its users [5].

Furthermore, it is still unclear whether digital platforms can be solely social or whether they must include technological elements. For instance, Mark de Reuver contends that digital platforms should not include those that only serve as a conduit between various user groups and do not provide an extendable codebase [4].

Digital platforms often have three key features: They are technologically mediated, they allow for user group interaction, and they enable these user groups to carry out certain activities [6, 7].

The technological and digital aspects of digital platform components, such as their layered architecture and modularity, have been the subject of research [8].

At the same time, digital solutions (apps) are typically categorized into applications, platforms, and infrastructures based on the complexity of architectural design and administration [9]. Platforms are defined in this group as having a medium level of architectural and design expertise.

According to their primary function, transaction platforms and innovation platforms are the two major categories into which most scholars split digital platforms [1, 4, 6]. Such a divide, in our opinion, is somewhat arbitrary. Modern digital platforms are equally concerned with developing new features and attributes and lowering transaction costs in participant interactions.

Digital platforms, according to Bonina, are a sociotechnical phenomenon that must be carefully considered in a social context [1]. The idea of Xiaolan Fu to investigate the transformational and disruptive impacts of digital platforms on conventional organizations and business models is also intriguing [4].

There are several instances of digital infrastructure being successfully organized to support teachers' professional careers worldwide. There are several systems available for seeking, hiring, and recruiting educators as well as doing other tasks.

We researched the existing digital solutions available globally in the fields of recruitment and job search in education before beginning work on building our own platform that would broadly fulfill the needs of the regional education system. Table 1 provides a quick examination of these systems. Every service offered was examined for its country of origin, primary objective, and user demographic.

The most well-known platforms are given; however, the list of platforms in the table is by no means complete. All of them are in demand by school administrators and instructors, have a sizable user base, and are well built. However, they solely work toward the search and publication of job openings. We have not yet come across any digital solutions that could provide a thorough fix for issues with staff development in education.

Table 1 Existing digital solutions available globally in the fields of recruitment and job search in education

No.	Platform (Name and URL)	Country	Primary goal	Target user
1	SchoolSpring https://www.schoolspring.com/	USA	Search, job posting	Teachers, employers
2	TeachingJobs.com https://www.teachingjobs.com/	USA	Search, job posting	Teachers, employers
3	The International Educator (TIE) https://www.tieonline.com/	Worldwide	Search, job posting	Teachers, employers
4	Education Week TopSchoolJobs https://www.topschooljobs.org/	USA	Search, job posting	Teachers, employers
5	Nimble https://www.hirenimble.com/	USA	Search for teachers	Employers
6	Eteach https://www.eteach.com/	UK	Search, job posting	Teachers, employers
7	Selected https://getselected.com/	USA	Search, job posting	Teachers, employers
8	Teacher's Job World https://teachersjobworld.com/	Thailand, South East Asia	Search, job posting	Teachers, employers
9	Education Canada Network https://www.educationcanada.com/	Canada	Search, job posting	Teachers, employers
10	Teach4life https://teach4-life.eu/	European Union	Make the STEM teaching career more appealing	STEM teachers, both aspiring and currently employed

A person's professional development includes stages such as professional orientation, vocational training, and professional growth. The state wants this process to be linear and continuous since it will be most successful in this configuration. The linearity of the professional growth process is dependent on the system of organizational, managerial, and methodological support at all phases of implementation. In turn, activities that assist an individual's professional growth should be well-organized and mentored.

In this regard, the construction of a system for supporting a teacher's professional growth based on a mentoring approach would address the state problem of boosting the efficacy of a person's professional development. Furthermore, the idea and technology of a person's professional growth, as created in the teaching profession, may

be applied to boost the efficacy of professional development in other fields of professional activity. The concept's technological foundation is the construction of a digital platform as an integrated multi-level infrastructure solution, combining all levels and stages of teaching staff professional development.

The Kazan Federal University Platform's central concept is digital assistance for educator training and support. The system is made to offer ongoing assistance to a young individual interested in professional advancement in the teaching industry. The platform-building project's main objective is to develop innovative technology and administrative approaches to engaging brilliant young people in the teaching profession, supporting their professional and pedagogical development, and fostering career advancement.

The platform's purpose is to automate the processes of organizational and methodological support of a unified system of activities in educational institutions of various levels for the selection, vocational guidance, training, employment, and career growth support of teaching staff, as well as the creation of a single database of personnel reserve for the regional education system.

The platform is created to offer automatic assistance for the following processes:

Creation and support of the activities of pedagogical classes in schools;

Career aspirations of high school pupils interested in becoming teachers;

Enabling entry to training programs for teachers, notably through contracts for specialized training;

Creating and maintaining students' portfolios;

Organization and management of students' teaching practice;

Encouraging university and college graduates to work in educational institutions;

Methodological support for young teachers' activities and professional development;

Tracking teaching staff mobility, vacancy availability, and predicting staffing needs.

The primary functionality and technology aspects of the platform's software implementation will be covered in order.

2 The Platform's Functional Architecture

Python, Django, PostgreSQL, Docker, HTML, CSS, JavaScript, Cypress, and Gulp technologies are used in the platform's development. All of the information arrays of the system are stored using a single database management system (DBMS). You may distinguish between various user types' access privileges to data using the DBMS, which offers strong security against unwanted access.

According to the following requirements, the platform uses client–server technologies: access to real data; data access and modification operations must be based on the data itself in the server, and not on the procedures for loading or unloading data files; client software should not be resource intensive.

The platform has tools for creating requests and setting screen forms. The platform's modular design makes it simple to add and modify functionality. The system offers each user their own username and password along with authentication and independent access to the data. All required reporting forms are set up, along with the structure and presentation of the data that may be seen or modified.

The platform is a collection of online tools and services that complies with the following criteria in order to fulfill the stated requirements:

The system must provide the ability to store data for an unlimited time;

The system must support the work of users located at geographically distributed facilities;

It should be possible to increase the number of concurrent users;

Both productivity and the functional makeup of the system should be increased gradually;

The idea of an open architecture should be used while creating a system, allowing for the integration and communication with any other systems.

The modules that make up the system are as follows: Registration, Designer, and Administrative.

The registration module is designed to ensure the entry of participants into the system. The personal account is the main function of the web platform, because it is through it that most users interact with the system.

The system offers two methods for registering users: one that ensures identity verification, such as the use of authorization from other third-party services, and another that involves the System Administrator establishing a new user and providing a special link to the designated email. It is possible to export registration data from the current systems.

The main template has been developed, on the basis of which you can create services in the constructor for different categories of users. In the constructor, you can select the desired fields from the main template, if you need to give them a mandatory property, and give these fields names.

The administration module is necessary for accessing the DBMS and administering services. The module has to offer analytical features, such as reporting on various indicators.

Figure 1 illustrates the general operating scheme.

The process of creating the platform is divided into several stages.

The following users fit the primary roles played by platform users throughout the early stage of creation: pedagogical class participant, teacher-mentor (class head), and platform administrator.

A student with an interest in becoming a teacher gets access to specialized reading, extra work, an overview of the teaching profession, and details about universities on his profile. He can also update his portfolio, watch open lectures, and participate in webinars. He can communicate with his mentor and view the scheduling of additional lessons on his profile.

A student portfolio is created with the intention of tracking and assessing the stages of the development of cultural and professional competencies in the area of

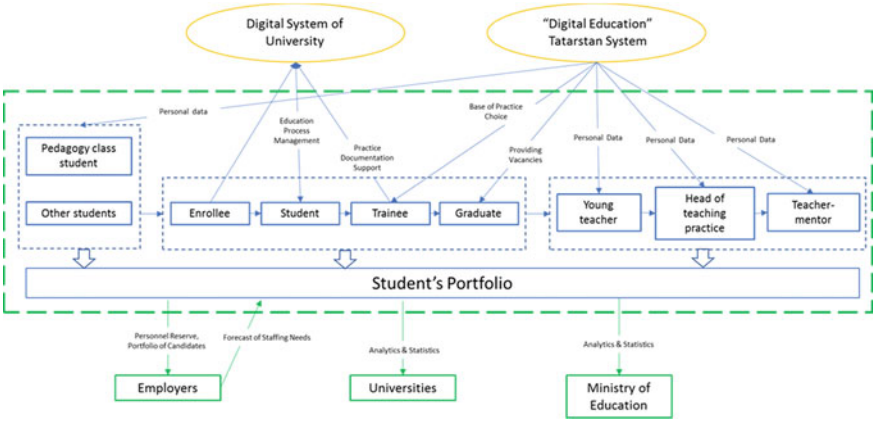

Fig. 1 General operating scheme

pedagogical activity, the dynamics of individual development and personal growth, as well as support for the student's independent academic and professional activity.

The tasks of creating a student portfolio include taking into account the developed competencies and evaluating the unique accomplishments of students; supporting the student's high level of learning motivation, his activity, and independence; developing the students' abilities to set goals and objectives; planning their own personal growth, development, and self-realization; and enhancing the future graduate's competitiveness in the educational labor market.

The purpose of the prospective teacher's portfolio is to record and compile each student's specific accomplishments, allowing for professional assessment of the student's growth in various educational activities.

When a student enrolls in higher education institutions for pedagogical training or in any other situation that calls for the student's qualities, the information in the portfolio is taken into consideration. A graduate CV may be built using the student's portfolio as a starting point.

The portfolio is divided into three sections: "Personal information", "Achievements", and "Reviews". Personal data includes last name, first name, date of birth, school, and class. The "Successes" section collects information regarding academic achievements, volunteering, creativity, and athletic achievements. Thanks, testimonials, and letters of recommendation may be found in the "Reviews" section.

Beginning with the time of platform registration, students have the option to create their portfolios manually or automatically using the platform "Electronic education of the Republic of Tatarstan" (https://edu.tatar.ru). The portfolio can be edited by the student, the instructor, and the platform administrator. The student has the right to create a printed copy of his portfolio at any time for personal use, using the relevant module option, and to certify the portfolio with the school administration.

A mentor or the class teacher of a pedagogical class has the chance to regulate and post notifications and instructional resources for the pupils. In relation to the actions

of specialist pedagogical courses and the specialized training of aspiring teachers, he sees all the governing, methodological, and other important papers. The instructor can create reports and upload them to his page.

A dashboard that shows all the information and the present status of all the procedures that go along with supporting the professional careers of teachers in a certain region is an integral feature of the platform. These statistics cover all user and teacher classes in the area, university admissions in pedagogical fields of study, staffing requirements, university graduation rates, and the "fixation" of new teachers.

It is intended to create the pages of a student-trainee, a future teacher, as well as his head of university practice at school, throughout the second and succeeding stages of building the platform. Additionally, the regional Ministry of Education official and the school principal's personal accounts will be made.

3 Conclusion

The future teachers' digital career support environment is intended to be a dynamic informational space. The functional requirements for software implementation and the system requirements for the infrastructure have been established, and the architecture has been constructed. The digital platform's experimental use demonstrates that the chosen technologies enable the tasks to be solved in an efficient manner.

The main beneficiaries of using the platform should be

A student of the pedagogical class through the accumulation of a portfolio and a deeper immersion in the profession;

Students who will become teachers in the future will benefit from improved classroom management and expanded job options;

A novice teacher, receiving methodological and psychological support with feedback;

Educational institution with great opportunities for finding, recruiting, and hiring teachers;

A university that has the opportunity to improve its educational process by making decisions based on data from the platform;

A local education system that can more efficiently keep track of, foresee, and address the staff issue.

The digital career assistance platform for aspiring teachers is the first customized Russian platform that enables you to handle a variety of duties, from recruitment and job searching to forecasting the growth of human resources in the local educational system.

In summary, it can be said that a digital platform is essential in the rapidly evolving world of today to make the process of assisting future teachers flexible and their job more in line with the conditions of the present.

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Mental State-Based Dialogue System for Mental Health Care by Using GPT-3

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Abstract Mental health disorders are conditions of the mind that cause changes in emotion, thought, and behavior. It can be connected with distress and problems functioning in social, professional, or family activities. This study tries to address this issue and improve the user's mental health situation by using the proposed artificial intelligence dialogue system model. Moreover, this research aims to determine the user's current situation through text-based conversation and provide suggestions to improve his mental health problem. The proposed methodology is divided into three parts: Dialogue analyzer or Natural language understanding (NLU), Dialogue manager, and Dialogue generation. The NLU is responsible for understanding user utterances and the dialogue manager is responsible for defining the policy. Finally, the dialogue generation module generates the response for the user. In the result section, we have tried to calculate every module's training and validation accuracy, automatic evaluation by using embedding similarity and BLEU, ROUGE score. We got 0.66 and 0.93 testing accuracy for the NLU and dialogue manager modules, respectively. Finally, this study got a 0.63 task success rate by using a combined method of correct intent detection and human evaluation.

Keywords Mental health care · Dialogue system · GPT-3 · LSTM · Dialogue policy

1 Introduction

One of the most significant public health issues is mental illnesses, often known as mental health problems, which are extremely common around the world [1]. It is consistently related to distress or difficulty in significant functional domains. Now,

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in this world has numerous mental illnesses, such as depression, suicidal behavior, bipolar disorder, autism spectrum disorder (ASD), anxiety disorders, schizophrenia, can negatively affect a person's physical health and well-being, with the issue being made worse by COVID-19 [2]. There are several causes for mental illness such as abuse from others, neglect from a family member, and experience discrimination and stigma. Mental disorder is so important for human life because it's affected human personal, and family life [3]. Moreover, it is linked with crime, victimization, productivity, financial stability, and societal factor. [3] The precision of the diagnosis is crucial for the choice of medication and prognosis prediction, making the differential diagnosis of mental diseases very significant.

To address this mental disorder, researchers are studying and they offer customized dialogue services for mental counseling in their [4] proposal. Additionally, they employed approaches that allow for delicate ongoing monitoring of users' changing emotional states, such as multi-modal emotion identification from user utterances. However, they didn't focus on the goal achievement of the conversation. They [5, 6] present a chatbot system for mental health care and they also show an emotion identification system but they didn't focus on mental state identification by emotion and sentiment. They [7] used 354 user's connections with the Tess depression modules for examination but didn't focus on others' mental states like sadness. This study provided a favorable perspective on the function of TCV in the context of psychological health chatbot usage, despite the fact that [8] theory of Purchase Behavior has been utilized more frequently to examine the utilization of AI-based public services and they do not show mental state-based any dialogue action.

The main goal of this mental health care study is to resolve those issues and support humans who are affected by mental illness by chatting. Additionally, this system will be providing appropriate recommendations for certain tasks for the user to overcome their mental disease. The proposed methodology is divided into three parts: Dialogue analyzer or Natural language understanding (NLU), Dialogue manager, and Dialogue generation. The NLU is responsible for understanding user utterances and the dialogue manager is responsible for defining the policy. Finally, the dialogue generation module generates the response for the user. And the following contributions can be found in the proposed research:

- As per the user's mental situation specific task recommendations to improve the mental situation.
- This study has shown a separate process in the pipeline for each module.

This research study is divided into five sections, and every section is appropriately interconnected. The literature review result is shown in the Sect. 2. The overall research methodology and recommended system analysis are shown in Sect. 3. The study outcome is presented in Sect. 4. Finally, the conclusion of this study is finally discussed in Sect. 5.

2 Literature Review

To detect mental illness [1] researcher show which neural architectures are used in this current world and which futures are also important too in the future. Here, [2] Human and AI conversation is based on clinical public service and this study discovers the probabilistic action with sharing practice experience, learning from literature, and sense-giving. Five hundred [3] medical patient's imbalance records select for this study and the researcher used different kinds of the model (Bert, DistilBERT, ALBERT, etc.) to detect major/minor depression, bipolar disorder, schizophrenia, and dementia. They [4] propose a dialogue service for mental consulting that is customized techniques to grasp counseling materials based on high-level natural language understanding (NLU), and emotion recognition based on multi-modal techniques. An intelligent social therapeutic bot was introduced by the [5], and it divides the text into the emotions of happiness, joy, anger, sadness, fear, and others. Additionally, based on the emotion label, it may be determined from users' chats whether they are worried or depressed. They [6] show how a natural language model can be used to collect the most important men's health care symptoms. Thus, they extract 46 symptoms with an F1 score of 0.88, and other symptoms also performed very poorly. To [7] comprehend chatbot usage across and within modules, 354 user's connections with the Tess depression modules were examined. Characters per message, completion rates, and time spent on each depression module were all examined using descriptive statistics to examine participant flow. While [8] theory of Purchase Behavior has been used more and more to analyze the utilization of AI-based public services, this study established a constructive viewpoint on the role of TCV in the context of psychological health chatbot usage. [9] Studies employing chatbots in mental health settings with a focus on those who have or are at high risk of getting depression, anxiety, schizophrenia, bipolar disorder, and drug abuse disorders are also included. To [10] improve the course's usability and keep users motivated to use it frequently, they suggest a brand-new edition that uses chatbots and cell phones. The benefits of a safe and effective manner and motivation preservation were recognized. This study [11] offers three types of models to identify slots and intend the first one is the independent model second one is a joint model and the final one is the transfer learning model. They suggest [12] a hybrid intent classification and slot-filling model based on BERT in this work. With regard to intent classification accuracy, slot filling F1, and sentence-level semantic frame accuracy, experimental results are shown by this model. They [13] develop Machine Interaction Dialog Act Scheme (MIDAS), which focuses on open-domain human–machine dialogues. MIDAS was created to aid machines in comprehending text patterns. A [14] dual attention hierarchical recurrent neural network for DA categorization is suggested in this research. Dialogue utterances are typically linked to both a DA and a topic, which is one of the observations that helped shape the model. To [15] determine the correlation between numerous linguistic features of dialogues and conversation consequences, they propose a set of unique computational dialogue evaluation methods.

Finally, this research study implemented a customized self-attention mechanism-based LSTM dialogue manager policy system with a GPT-3 fine-tune-based NLU system and response generation.

3 Methodology

In this research study, the proposed design architecture is divided into a dialogue analyzer, dialogue manager, and dialogue generation. Every part has a special specific task and subtask. The dialogue analyzer part is responsible for key information extraction by slot filling and emotion and sentiment detection of user-inputted text. On the other hand, the dialogue manager is responsible for dialogue act detection or policy-making, generated response analysis, confiding, and life-logging user activity. Finally, dialogue generation is responsible for generating responses as per the user's mental state and intent. Figure 1 shows the proposed architecture of this study.

3.1 Research Datasets

In this research study, three types of datasets were used which are sentiment datasets, emotion datasets, and mental health conversational datasets. For sentiment analysis [16, 17] data are used with positive and negative sentiment. On the other hand, [18] datasets are used for emotion analysis with different kinds of emotions such as anger, sadness, happiness, and others. Finally, we have made 300 customized conversational datasets for this study. Moreover, To develop our customized dataset we took help from [19, 20]. Table 1 shows a single conversation of our customize dataset. The mental health care dataset has some special dialogue act which is written down

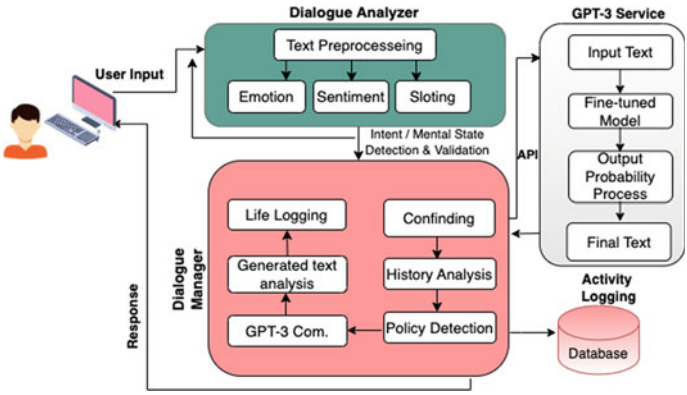

Fig. 1 Architecture diagram of the proposed study

Table 1 This is a table showing a single conversation

Dialogue example	Dialogue act
U: Hi	Greeting_act
S: Hello	
U: I am facing bullying words at college. I can't study so well	Issues_sharing_act
S: Oh, I understand	
S: You should talk with discipline committee. Why you scared?	
U: This is tough time for me and I am little bit nervous to talk with them	
S: Do you feel any depression and sadness?	History_act
U: Yes, and It's so hard to tell you	
S: How long you have been facing this?	
U: After enter my college	
S: Oh, I understood. I think you should go mental health counselor to improve your current thought and feelings	Recommendation_act
U: Thanks for your suggestion	End_greeting_act
S: Welcome	

below: Greeting_act,Issues_sharing_act, History_act, Recommendation_act, End_greeting_act, question_act, facing_feeling_act, duration_feeling_act,suggestion_greet_act, situation_level_act, sympathy_act, motivation_act, suicide_act, carefull_act, mental_health_treatment_act,doctor_checkup_act, therapist treatment, depression_opinion_act, concentrate_act, eating_regular_act, congrat_act,mental_health_council_act, take_care_act, skill_improve_act, Enough_answer_act.

3.2 Dialogue Analyzer

The dialogue analyzer is responsible for: slot filling, sentiment detection, and emotion detection. The slots filling describes below.

Slot Filling: Firstly, the filling of slots has been done by using a few shot learning-based fine-tuned GPT3 model [21]. User-provided text is used as an input prompt in this research study's training datasets, and many slots—including intent, activity, entities, when, where, and others—are used as completions. During the model training some parameters were key factors for this slot-filling model, such as batch size: 0.2% learning rate: 0.01, and prompt loss weight: 0.1. To find appropriate slots during the slot prediction, this gpt3 model uses a few parameters. For example, the temperature parameter value between 0 and 1, and used for the degree of randomness and originality of the text. During the inference time, the sampling threshold is specified by the top-p parameter. For this model, we have used 0.7 as a temperature parameter and 1 as a P value, and a Max token size 70, frequency penalty 0.

3.3 Dialogue Manager

This part discusses the dialogue manager module. After slot filling and intent categorization, the dialogue manager suggests the following appropriate action that should be carried out by a bot. In our work, the slot values are used as an input prompt of the dialogue manager model such as {intent: sleeping@time, activity: sleeping, emotion: neutral, sentiment: negative, when: last few days, where: null, severity: null, previous action: question_act}and it's also taken bot previous action. To predict appropriate bot action long short-term memory-based model policy [14, 22] is used in this proposed dialogue manager where the self-attention mechanism is also applied. The policy-based model is one of the efficient dialogue management methods. The advantage of this policy is that it can be used in modular and end-to-end-based chatbot systems. Figure 2 illustrates the dialogue act detection.

At first input, examples are put to the embedding layer for transforming the text into the input vector with a fixed length. After that neural network is initialized to take the embedding layer output as input. In this neural network layer, Bi-directional long short-term memory (LSTM) is used with 32 units. After that, to highlight relevant features the attention mechanism is used. Additionally, dropout, dense layers, Adam optimizer, and are categorical cross entropy used to more accurate the proposed model. On the other hand, the dialogue manager is also responsible for life logging in MySQL with the structural data format by the life-logging sub-module. There is more sub-module: API service to communicate with the GPT-3 model, history analysis sub-module responsible for historical analysis, confiding responsible for the seriousness of the issue, and policy analysis detection for policy. The conversation-ending process must be after the task recommendation and finding the recommendation. Here, the conversation-ending process depends on user intent and ending greetings such as thanks, thank you, and others.

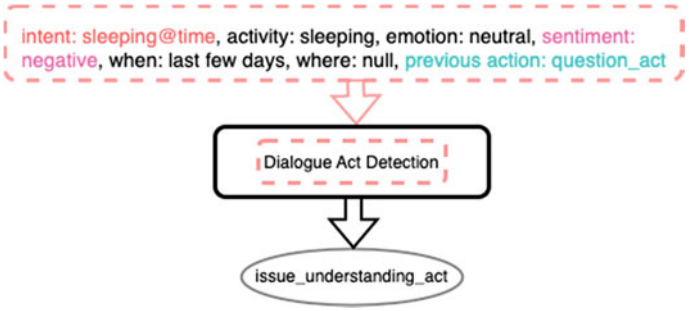

Fig. 2 Block diagram of dialogue act detection

Table 2 Natural language understanding model accuracy

Training Token accuracy	Validation token accuracy	Training sequence accuracy	Validation sequence accuracy
0.97	0.95	0.67	0.66

3.4 Response Generation

The response generation is an important part of this research study. This part is responsible for response generation as per user intent and mental state. In the previous section, we detected dialogue act or dialogue policy which depends on user intent, emotional sentiment, and other slots or entities. In this dialogue, the generation module generates a response based on that dialogue act or policy. The GPT-3 [21] fine-tune model is used to generate the dialogue response. During the training, the batch size, learning rate, and weight prompt loss parameters play a vital role in this fine-tuned model.

4 Results

This section is divided into some sub-sections: Natural Language Understanding, Dialogue management, Embedding-based analysis, BLEU and ROUGE score analysis, and Task success rate analysis.

4.1 Natural Language Understanding

In this part, we already know that this study has used a few shot learning-based GPT-3 model. This research study has used different slots to identify user intent, activities, and others entities. The validation or training token accuracy is the proportion of tokens in the validation batch that the model accurately predicted. On the other hand, the validation or training sequence accuracy is the proportion of completions in the validation batch for which the model's predicted tokens perfectly matched the real completion tokens. All of the outcomes can be seen in Table 2.

4.2 Dialogue Manager

This dialogue management is responsible for predicting accurate dialogue acts. For this module, we have used an attention mechanism-based LSTM custom model. The slots data from user messages is used as a training dataset for this model. As a test, we

Table 3 Dialogue manager model accuracy

Precession	Recall	F1 score	Accuracy
0.95	0.94	0.92	0.93

Table 4 This is a table showing the embedding-based analysis outcome

Embedding	Cosine similarity	Pearson correlation	Spearman correlation
Word2Vec	0.69	0.70	0.59
BERT	0.71	0.72	0.65

used 81 single-turn user messages and got 0.93% accuracy, which has an important impact on task success rate. All of the outcomes can be seen in Table 3.

4.3 Embedding-Based Response Analysis

In this subsection, actual and expected responses are compared by using different embedding methods with cosine similarity. In addition, the correlation was analyzed by using an embedding vector has been with Pearson and Spearman correlation. This study has used word2vec as static embeddings trained on around 100 billion words from Google News Corpus. Table 4 shows the embedding-based analysis.

4.4 BLEU and ROUGE Score Analysis

In this analysis, we have tried to find out comparatively better BLEU and ROUGE scores based on emotion and sentiment slots by using actual and generated response text. This study has utilized different temperature (GPT-3 Parameter) values to find out better scores. All of the outcomes can be seen in Table 5.

4.5 Task Success Analysis

The task success rate measures how well a user's criteria are met by the dialogue system. For example, the generated response is acceptable or not for the user and it's shown in a special matrix or graph. For this research, the objective evaluation strategy is a combined method with human evaluation. Firstly, a human evaluation is conducted with participants interacting with the dialogue system. Secondly, a model evaluates the single-turn response based on user intents. The intents are then used as target labels to fit a model based on attributes that can be measured objectively with

Table 5 This is a table showing BLEU & ROUGE score

Slots	Temperature	BLEU score (%)	ROUGE score (%)
Intent + Sentiment + Emotion	0.70	46.75	57.00
Intent + Sentiment	0.70	46.55	53.00
Intent + Emotion	0.70	45.01	57.06
Intent + Sentiment + Emotion	**0.60**	**53.24**	**61.00**
Intent + Sentiment	0.60	50.18	51.64
Intent + Emotion	0.60	46.83	55.93
Intent + Sentiment + Emotion	0.50	52.6	60.00
Intent + Sentiment	0.50	49.17	50.00
Intent + Emotion	0.50	46.88	63.03

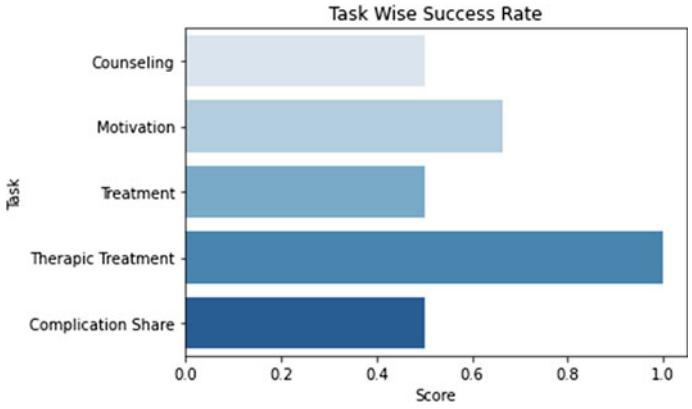

Fig. 3 The task-wise success rate of dialogue

human evaluation. This research study shows five specific tasks and the average task success rate is 0.63. Figure 3 illustrates the task success rate of the model.

5 Conclusion

Mental health problem is a vital problem all over the world and people can't concentrate on their personal and professional life due to this problem. This research aims to find out the user's current situation through text-based conversation and provide some suggestions to improve his mental health. This research study has three main modules or components and every module has some specific task. The first module is the

natural language understanding module which is responsible for understanding the user intent, emotion, sentiment, and other information. This natural language understanding module is being developed by GPT-3-based custom few shot learning fine-tuned model, which has 0.66 accuracies of validation token sequence. The second module is the dialogue manager module which is responsible for detecting dialogue actions for users. The dialogue manager module implements by using long short-term memory and a self-attention mechanism. This module has achieved comparatively better accuracy 0.93. The third module is dialogue generation, which is implemented by using a GPT-3-based custom fine-tuned model based on dialogue management output.

Though the proposed research work has comparatively better accuracy in the mental health dialogue model, the model also has a set of drawbacks: the training datasets have only 300 conversational data which is not enough for a big model and needs more data processing changes to improve model accuracy. Secondly, this study is implemented for the English language which is not usable for other languages native speaker. As future scopes are anticipated to use a larger dataset with various input attributes and model selections. Moreover, we also try to develop other languages for people to improve their mental state. Additionally, we will try to develop a dialogue breakdown system to stop unnecessary text generation. However, this research aim is achieved, and the proposed methodology can be adjustable in the daily activities of a mental health patient.

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Addictive Detection of Gadgets Using Artificial Intelligence

Akif Khilmiyah and Giri Wiyono

Abstract The purpose of this study was to discover the addictive influence of gadgets on the emotional and social intelligence of elementary school students. This type of research is a survey, with a quantitative approach to correlational models. The sample of this study was 150 students from 4 elementary schools in Bantul. Data collection techniques through questionnaires using the P-KES-SD application. Data analysis using descriptive statistics and linear regression. The results of the study showed that: (1) The addictive level of student gadgets belongs to a high category on the aspect of having an effect on the physical. (2) The emotional and social intelligence of students is high in the psychomotor aspect, and the lowest in the cognitive aspect, this indicates a lack of understanding of the student's reasons for doing good deeds. (3) There is an addictive influence of gadgets on the emotional and social intelligence of Islamic elementary school students with a coefficient of determination (*R* Square) of 19.7% and the remaining 80.3% is influenced by other factors. This proves that artificial intelligent is able to detect addictive gadgets of elementary school students.

Keywords Artificial intelligent · Addictive gadget · Primary school

1 Introduction

One of the latest technologies that can be applied to the world of education is artificial intelligence technology or often referred to as artificial intelligence. Artificial intelligence (AI) is a technology that can be used by humans as mobile assistants like robots but its existence is in the form of a virtual display in a computer system. AI can be likened to the brain of a robot. Some experts have difficulty defining AI because of

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its association with several interdisciplinary sciences such as anthropology, biology, computer science, linguistics, philosophy, psychology, and neuroscience.

Overall, the discussion about AI is quite broad and diverse because the elements that build an AI technology are not studied using one point of view, but from multiple points of view. For example, in a city, AI technology will be applied to water plants in the square and surrounding area. When viewed from the point of view of computer science, it is very innovative, but when clashed with elements of sociology and economics. The presence of AI technology will cause a lot of unemployment because the role of janitors is decreasing. If we review the development of AI and its use abroad, of course we will be stunned after seeing it. Sufficient facilities and facilities have made several European and American countries have started research on AI to be applied in various sectors ranging from education, economy, and the field of national defense. Countries that do research on AI quite often are the United States and China.

Several studies present the use of AI in the world of education [1] by involving various levels of education from elementary school to college. Visible uses include AI as a digital assistant in displaying learning tutorials, as a system in evaluating students, as a system in student chat services, and other examples. The expansion of AI technology implementation in Indonesia is still rarely encountered. The complex problems in the world of education in Indonesia are one of the reasons why this technology is difficult to adopt in our country, even though in fact this technology has long been discovered and developed widely abroad. In this study, what was studied was the effectiveness of the application of AI technology with the SD PKES application to detect addictive gadgets in elementary school students. All schools, especially elementary schools, can download applications from this system by implementing a Local Area Network (LAN) type network and if you want to synchronize with data on the central server, just turn on the Internet and then synchronize the local data at each school. The hope is that the presence of this technology will make it easier for students, teachers, parents, and related parties to carry out early detection of gadget addiction and improve children's character education.

2 Research Methods

The type of research is survey research, with a quantitative approach using a correlational model. This research focuses on the addictive influence of gadgets on the emotional and social intelligence of elementary school students using artificial intelligence in the form of PKES applications. SD. The type of research used is field research, which is research that is directly carried out in the field or to respondents, by directly plunging into the research site, researchers will be able to find, collect data, and information about the addictive influence of gadgets on the emotional and social intelligence of elementary school students.

The collection technique in this study goes through the following stages; The first is the observation stage, which is the stage of working only based on data. Second,

the stage of filling out the questionnaire or instruments on the questionnaire in the form of hardfile questionnaires and questionnaires in the P-KES-SD application. Third, the interview stage is by conducting an interview. Furthermore, the last is a document, at this stage of the document such as notes, events that are already in force, can take the form of writings, drawings, or works. The sampling technique used in this study was Purposive Random Sampling. The subjects studied in this study were students of grades V and VI. This research was conducted in four elementary schools in Kasihan, Bantul, Yogyakarta. The instrument in this study used a scale questionnaire in the form of a P-KES-SD application, then in data analysis using a Simple Linear Regression Test and Normality Test.

The statistical analysis technique used to test the hypothesis in this study is linear regression analysis. Before the hypothesis test is carried out, an assumption test or pre-requisite test is first carried out which includes a normality test, a linearity test, and a multicollinearity test. Hypothesis testing is carried out with the help of the SPSS 25 (Statistical Product and Service Solution) application or program for windows. The results of this study are expected to contribute thoughts to related parties and can add insight, contribution of thoughts, information and knowledge in testing the addictive influence of gadgets on the emotional and social intelligence of elementary school level students using artificial intelligence.

3 Theoretical Frameworks

3.1 Artificial Intelligence

AI technology is still very broad in scope so that its use also varies in various fields. The world of education is one of the fields that can adopt the existence of AI technology. Some opinions expressed by experts on AI technology [2] argue that AI as a computer system designed to interact with the world through certain capabilities and intelligence behaviors that we realize like humans in general. Artificial intelligence is an underlying theory about the mechanism of an intelligence as well as empirical methods for building and testing possible models in support of a theory. Artificial intelligence is a way for computers to be able to perform a series of thinking tests owned by humans and animals [3]. Technology is also adopted in the world of games (games). Different from previous opinions, divides the notion of AI into four categories; The first, namely thinking humanly, states that AI technology reflects human thinking in daily activities such as solving problems, making decisions, and other actions. Second, acting humanly which means that AI is a machine that is able to display usefulness by involving intelligence capabilities when displayed by humans, as well as being able to do something today that has better quality than humans. Third, thinking rationally which means that AI is able to coordinate mental abilities through computational models. Fourth, acting rationally shows that AI is designed to create intelligent agents through creation using sophisticated systems.

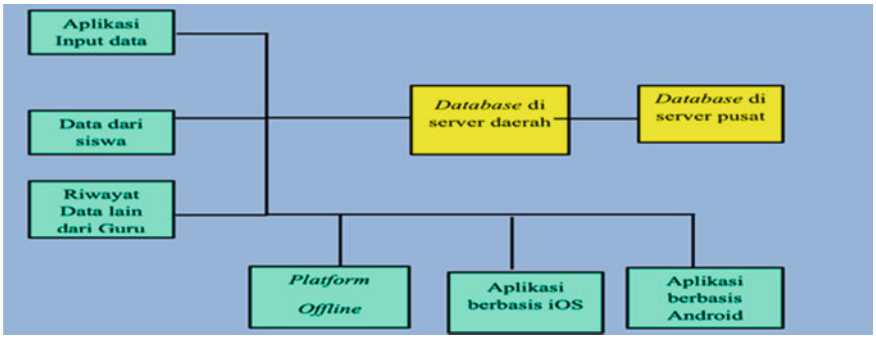

Fig. 1 Network design on offline platforms

Based on several opinions from these experts, it can be drawn that AI technology is a technology that creates a system and allows computers as one of the mediums in order to carry out interaction processes and make it easier for humans to carry out daily activities. Artificial intelligence provides convenience to humans when their existence is maximized for positive things.

AI technology requires the right facilities and infrastructure. This is also a consideration for the selection of research samples conducted at elementary schools in Bantul City, Yogyakarta. In schools in the city area, it is felt that the facilities and infrastructure have been good and qualified to apply this technology. The network scheme that will be applied in this AI technology is as follows (Fig. 1).

Database on Data center server of student Application Input data History Other data of Database Teacher in regional server Offline Platform iOS-based application Android-based application. The display on the offline platform gives a clear picture to everyone who needs information on the integration of this technology.

3.2 Gadget Addiction and Emotional and Social Intelligence

Technology is a work created by human thought with the aim of making human life easier. With technology, everything can be solved in practical, fast and seemingly distance-free ways. The addition of current technological functions and facilities, shows that the development of technology and information is very fast and increasingly sophisticated, with these additions, it will spoil humans more in their daily lives and have many positive impacts. One of the advanced facilities that technology offers today is gadgets [4]. Gadget is a term derived from English, which is an electronic device that has a specific purpose and function on each device. The functions and benefits of gadgets include as a tool to communicate, socialize, and become a supporting device in education or learning, as it is known that the use of technology as a medium to support learning is a characteristic in this era of the industrial revolution 4.0 [5].

In 2020 as the presence of Coronavirus Disease 2019 is known. The pandemic initially had a major impact on the global economic sector, but the impact began to penetrate the education sector, ranging from the elementary school level to the college or university level [5]. Therefore, to prevent and reduce the spread of the virus, the government stipulates through the Ministry of Education and Culture (Kemendikbud) in the Circular Letter of the Ministry of Education and Culture of the Republic of Indonesia number 3 of 2020 concerning the prevention of Corona Virus Disease (COVID-19) for education units, and the Letter of the Secretary General of the Minister of Education and Culture number 35492/A.A5/HK/2020 dated March 12, 2020 concerning Prevention of the Spread of Corona Virus Disease (COVID-19), explaining the regulations that education in Indonesia, namely learning and teaching activities, is carried out online or study from home [6].

The online or distance learning is indirectly requiring children to continue to use gadgets during learning. As for the use and utilization of technology for education or what is called e-learning it can be in the form of podcasts, e-books, educational games or access to documents and libraries that are carried out online [7]. One of them is adaptive hypermedia and moodle which is the development of e-learning-based education that supports technology-based learning. The use of advances in technology in the form of gadgets has two impacts, namely positive impacts and negative impacts, this can also apply to children who are in their growth and development period and at that time have been given gadgets. Examples of positive impacts in the use of gadgets, one of which is being able to hone children's abilities in terms of strategizing, speed in games in the gadget, and also the right brain which is always trained when under good supervision of either parents or family. However, compared to the positive impacts, the negative impacts have more impacts. Among other things, it can interfere with children's growth and development, both brain growth and development, behavior, emotional, and socialization with other humans. The negative impact is caused by excessive use, so that excessive behavior has an impact on the child's communication, social, emotional, and physical ability [8].

This interesting phenomenon stems from current technological advances and has increased, one of which is after the implementation of learning from home during the COVID-19 pandemic. Distance or online learning requires gadget technology to support learning media. This can cause the onset of negative impacts or symptoms such as addictive gadgets, namely the behavior of children who prefer to play gadgets compared to their friends, easy emotions when their gadgets are taken away and so on. All of these things happen, one of which can be caused by learning from home, which is mostly gadgets [9]. This can indirectly affect the emotional and social intelligence of the child as previously described. This would certainly contradict the definition of education, namely the conscious effort of adults in guiding or providing assistance to the development of physical and spiritual personality, intelligence, self-control, development of potential in children realized by the learning process [10].

Emotional and social intelligence is very important, this is important because emotional intelligence will give humans the ability to be able to regulate their attitudes, problems faced, motivation for themselves, social relationships with other humans, and so on. Social intelligence is as important as emotional intelligence,

namely as the ability of a person to interact with others, behave with others, participate in society, be responsible and so on. Related to the explanation above that there is an opportunity for the influence of addictive gadgets on emotional and social intelligence, that addictive gadgets can occur in everyone including children, and have an impact on emotional intelligence, namely in regulating the emotions that occur in oneself as well as other impacts, later in the that there is an opportunity for the addictive influence of gadgets on children's emotional and social intelligence, such as growing attitudes of lack of interaction with others, egocentric. As for this, it is one of the impacts caused by addictive gadgets [11, 12].

4 Results and Discussion

4.1 Addictive Levels of Elementary School Students' Gadgets

Addictive gadgets of elementary school students can be assessed through three indicators, namely (a) dependence on something and done repeatedly, (b) having an effect on the psychological, (c) having an effect on the physical. The results of the overall indicators of all primary school students can be seen in the histogram image below (Fig. 2).

Looking at the histogram table above, which shows an overview of the addictive level of gadgets of elementary school students. As for the table above, it can be seen that there are 3 indicators, namely dependence on something and done repeatedly, giving an effect on the psychological and having an effect on the physical. As for the aspect of giving an effect on the physique, it is the highest aspect of 4800 points. This proves that the addictive level of student gadgets is generally caused by physical effects, such as impaired eye health due to staring at the gadget layer too often, sitting too often so that the pingga is often aching, body fitness decreases due to infrequent exercise as a result of playing gadgets too often, and so on.

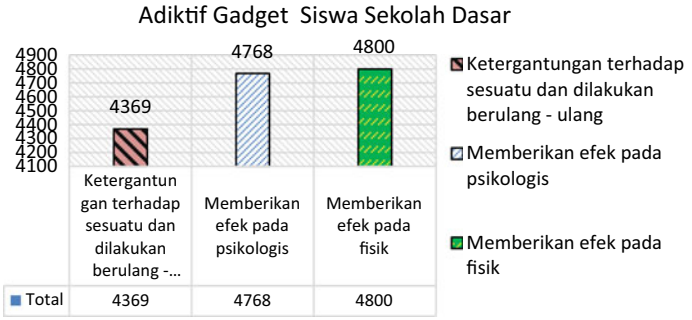

Fig. 2 Addictive gadgets for elementary school students

As for the aspects that show psychological effects, they also have points that are not much different from the highest points, which are 4786 points. This shows and at the same time also proves that this aspect can also be a picture of students who experience addictive gadgets, these behaviors will certainly affect the student's psychology, especially can also be seen from their emotional and social intelligence.

However, it can also be seen in the table above, in the aspect of dependence on something actually has a point below the other two indicators, even if the value of each indicator is not far from higher, this shows that the indicator of dependence on something is also owned by most students. In quantity, it can be said that students rarely use their gadgets, but if once, twice, even three times they have the opportunity to use their gadgets, it is certain that they use them for a very long period of time, causing the effects mentioned above. Because a person can be said to be addictive to gadgets not only measured in their dependence, but also in the effects caused. Like when at a predetermined time they can use their gadgets and they are disturbed they will be much more emotional or have the opportunity to use their gadgets longer they will show attitudes that indicate the addictiveness of the gadget such as wanting to linger longer with the gadget than interacting directly with other friends.

4.2 The Addictive Influence of Gadgets on Students' Emotional and Social Intelligence

After knowing the addictive level of gadgets, emotional and social intelligence in Islamic elementary school students, furthermore, to measure the addictive influence of gadgets on the emotional and social intelligence of elementary school students, before conducting a regression test, it is necessary to test the normality of the data with the help of the SPSS program. In this study, the normality test used the Kolmogorov–Smirnov nonparametric statistical test with SPSS. The results of the data normality test that have been carried out resulted in an addictive significance (p) value of 0.202, and a significance value of emotional and social intelligence of 0.353. The terms of the data can be assumed to be normally distributed on the normality test, if the significance value (p) $\geq$ 0.05. Next is the multicollinearity test, after conducting a multicollinearity test on the existing one, it produces a tolerance value of 1.000 > of 0.1 and a VIF value of 1.00. The figure means that all the variables studied meet the multicollinearity test. Then conducting a heteroskedasticity test on the data that produces an image of a point on spreading scatterplot, it means that all the variables studied meet the heteroskedasticities.

After it is known that the data is normally distributed, meets the requirements of the multicollinearity test and the heteroskedasticity test, then the research data enters the data analysis using a simple linear regression test. The presentation is as follows (Table 1).

Based on the above output, the signification value is 0.000 < 0.05, which means that there is a significant influence between the addictive variables of gadgets on emotional and social intelligence (Table 2).

As for the cause of the least addictive influence of gadgets on the emotional and social intelligence of students as stated by the religious teacher at the school.

"As in general, in this school, there are children whose parents do not enforce children to hold cellphones, some apply but with conditions such as the period of use. For example, all task groups have their parents, all go back to their parents, but if they ask the children if they all play cellphones and so on, they say yes, but all go back to their parents at home" (Interview with Ibu Marwanti, religious teacher, in Yogyakarta, May 22, 2022).

Likewise, Yuni Hastarningsih's mother, a religious teacher, stated in Yogyakarta on May 24, 2022).

> For the use of cellphones, there are indeed some children in this school who are one cellphone for one family, so their use is limited, but there are also parents who allow their children to play without being given mas conditions.

The results of the interview above show that the cause of the little addictive influence of gadgets on students' emotional and social intelligence is due to restrictions on the use and ownership of gadgets in the four schools studied.

Another factor of 80.3% that also affects the level of gadget addiction in students is the parenting factor, explained [13, 14], that proses the interaction between parent and child to support physical, emotional, social, intellectual, and spiritual development lasts from a child in the womb to adulthood. In addition, another factor that contributes to emotional and social intelligence is the religiosity factor. Religiusitas contributes to the development of a person's emotional intelligence. Emotional intelligence that paradigma religiosity is able to give rise to a harmonious synergy between emotional and religiosity. That is, the whole form of emotion deployed will never escape the values embodied in relgiusity itself [15].

Then also found environmental and peer factors [16]. The environment and peers are one of the places for students to get mutual help, attention, acceptance, affection, protection, and so on. So that from such it can influence the development of emotional and social intelligence of students. Such as in making choices, accepting and rejecting input, ways to deal with problems and so on.

5 Conclusion

The addictive level of gadgets of elementary school students has a high category. The highest indicator is that the indicator has an effect on the physical, while the indicator has an effect on the psychological category and the lowest indicator is dependence on something and is done repeatedly. The level of emotional and social intelligence of primary school students has a high category in psychomotor aspects, followed by affective aspects, and the lowest in cognitive aspects. In all indicators in

Table 1 Regression test output

ANOVA[a]						
Model		Sum of squares	df	Mean square	*F*	Sig
1	Regression	13,309.115	1	13,309.115	36.265	0.000[b]
	Residual	54,314.779	148	366.992		
	Total	67,623.893	149			

[a]Dependent Variable: Kecerdasan Emosional dan Sosial
[b]Predictors: (Constant), Adiktif Gadget

Table 2 Linear regression test output

Model summary[b]				
Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the estimate
1	0.444[a]	0.197	0.191	19.157

[a]Predictors: (constant), addictive gadgets
[b]Dependent variable: emotional and social intelligence

social intelligence include: respect for others, responsibility, cooperation, tolerance, effective communicative with others. This shows that elementary school students when doing good to others are only as a habituation, even if empathy exists, but understanding the reasons why they do so they do not know this.

The addictive influence of gadgets on the emotional and social intelligence of Islamic elementary school students has an influence of 19.7%. While 80.3% is influenced by other factors such as peers, parenting, religiosity, and others.

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Digital Resilience in the Millennial Generation According to the Islamic Paradigm in Southeast Asia

Fitriah M. Suud, Kana Safrina Rouzi, and Faisal bin Huesin Ismail

Abstract Covid-19 has required students to interact more intensely with digital due to distance learning. This condition has formed a new habit in adolescents, especially millennial adolescents in interacting with online media. They face risks, negative effects, dangers but also great opportunities with digital activities. How their resilience and self-control skills in choosing the benefits or harms of digital activities are important to note. This study aims to find the resilience of millennial teenagers in digital activities that are excluded from the Islamic dimension by using resilient digital attributes. The research data was collected qualitatively, namely by interviews and observations on adolescents in two countries. The teenagers who were used as informants were students who were involved for a long time in online learning in Indonesia and Malaysia. The results of the study found that adolescents found great challenges in managing themselves to be skilled in interacting with digital media. Religiosity is found to be a tool of self-control of Muslim adolescents in digital behavior. Adolescents also need social and environmental support to strengthen their resilience.

Keywords Digital resilience · Millennial generation · Islamic paradigm · Self-control

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1 Introduction

Digital activities during this disruption period showed a very significant increase compared to the pre-pandemic period [1] which occurred around the world and changed world activities from paper-based to internet-based. This simultaneous and significant disruption makes the world community to adapt to all situations and conditions such as visit does not have to be face to face [2], learning new skills in maximizing the functioning of devices [3], entrepreneurship [4], shopping [5], online learning systems including learning the Quran [6].

During the pandemic when all activities are carried out from home, the millennial generation is the most sophisticated generation in terms of digital activities such as: digging for information on various applications and platforms, interacting with friends and relatives through various social media, and being exposed to various news that is circulating. This information can be valid or invalid and even hoaxes that are used as sources and learning media [7]. This is because this millennial generation comes from a different era of technology and media which is expected to have new developments in learning that is more interactive, experimenting, collaborating, and connecting with technology [8]. Digital activities that spend most of their time cause psychological problems for millennials in the world such as insomnia [9], emotional problems, social development and dependence in their use [10], internet fraud, browsing porn sites, and privacy intrusion which are negative effects of the internet [11]. This psychological impact not only affects users in Indonesia but also users around the world, especially in Southeast Asia. Positive consequences are sought to be developed and negative consequences need serious attention [12].

This digital activity begins with digital literacy which means being able to understand and use technology [13]. It has to do with the ability to find, use, and create information online in a useful way. It also means knowing the limitations of technology and understanding the dangers and precautions required by the use of technology [14]. These skills are needed to live, learn, and work in a society where communication and access to information are increasing through digital technologies such as internet platforms, social media, and mobile devices. This capability allows citizens of the world to interact and bond together for a common goal. This also means that distinguishing authentic content becomes more difficult to do [15]. Having good digital literacy skills will benefit from sharing ideas efficiently and filtering content well. Digital literacy plays an important role in determining an individual's ability to succeed both in school and throughout an individual's life. This is an inherent aspect of twenty-first century education, which is the backbone of educational pedagogy at the *World Academy* [16, 17]. Because all activities are carried out digitally, it is necessary to pay attention to digital resilience because the effects arising from digital activities can be handled with an attitude of resilience [18].

Resilience to all trials, from a psychological point of view, is the ability or flexibility of recovering from a downturn, trauma, or stress due to a problem experienced. There are individuals who can survive and rise from negative situations. However, not a few individuals fail to get out of such negative situations. The Qur'an has a

unique view of man, and his words contain guides that offer problem solving to all possible problems in life. Included in resilience is the ability of individuals who do not give up when facing pressures and problems [19]. This attitude is also present in digital activities during this pandemic where individuals must be able to manage their digital activities so that there are no problems caused by these activities. However, if this is unavoidable, then individuals must perform four elements of digital resilience. All four elements have been mentioned in the QS. Ar-Ra'd: 28, Al-Baqarah: 286, Al-Hadid: 22, and Al-Ankabut: 2–3 [20]. Based on these various problems, this research was conducted considering that the millennial generation needs to be equipped with a resilient attitude toward all digital activities.

2 Method

This research is a qualitative research with a case study approach. Data collection for case study research was carried out by direct interviews and observations to the research site. However, the collection of data in this qualitative study was supplemented by the dissemination of online questionnaires to supplement the interview data. This is due to pandemic conditions that limit the space for researchers to move. The focus of this research is students in Indonesia and Malaysia. The population of both countries consists of several universities. From Malaysia students come from Universiti Tun Hussein Onn Malaysia (UTHM) Johor Malaysia, Universiti Sains Malaysia (USM)-Pulau Pinang, Universiti Utara Malaysia (UUM)-Kedah-Malaysia, Universiti Malaya (UM)-Selangor, Malaysia, Universiti Malaysia Terengganu (UMT) Terengganu, Universiti Malaysia Kelantan (UMK)-Kelantan, while in Indonesia the students who will become informants are students from Muhammadiyah University Yogyakarta, Alma Ata University, Muhammadiyah University of Surakarta, Raden Mas Said State Islamic University. Analysis data was carried out starting by deductively making initial prepositions from existing conceptual data, then inductively researchers collected data, processed, and drew conclusions.

3 Result and Discussion

This research has been carried out in Indonesia and in Malaysia by means of in-depth interviews with teenagers who are doing online activities. Interview is focusing on finding four elements of digital resilience in the Islamic paradigm. Of the 27 students interviewed, it was found that digital activities have an impact on the learning process and the efforts made by Muslim students both in Indonesia and Malaysia are to get closer to their religion, but the methods taken are different so that the resilience of students in facing the influence of digital activities is closely related to their religious behavior. By worshiping and remembering God, they can withdraw from attachment and addiction to doing useless digital activities or negative digital activities.

Digital resilience is developed through four interconnected elements: understanding when it is at risk (Understand), knowing what to do to seek help (Know), learning from experience (Learn), and getting the right support to recover (Recover) [21]. Developing digital resilience is not a linear process, all elements are equally important and can be applied, at different levels and at any time. The data collected in this study relies on the definition and dimensions of digital resilience issued by the UK Council for Internet Safety (UKCIS) [22], so that from 27 informants from both countries, four important points of digital resilience were found, namely points about *Know*, *Understand*, *Learn*, and *Recover*. In the *Understand* dimension, there are four main questions, for the *Know* dimension there are three, the *Learn* five dimension, and in the *Recover* section, there are three. So, there are 15 points structured with the Islamic paradigm to interview, but nevertheless the question develops when in the proses interview.

3.1 Understanding Times of Risk

The first dimension is *Understand* where individuals who understand the positive role of the internet and are better able to navigate the online environment have better resilience. Therefore, supporting media literacy can have additional benefits in improving the ability to resist harm. Families have proven to be able to develop the resilience-based media literacy needed to reach individuals. Digital activities in addition to providing many benefits but not a few cause negative effects. As teenagers who are looking for many things, respondents also do not deny that they are also exposed to the negative effects of online activities [21]. However, because the respondents are already at the stage of late adolescent development, the task of development is to develop moral reasoning so that they are able to take a role in social life and adapt to applicable rules, customs, and habits so that they are not easily dragged down by the flow of immoral content (pornography) or trapped in false information (hoaxes) that lead to fraud [23, 24].

Respondents also realized that in addition to fake news and pornography, online games also included negative impacts in these online activities. Respondents argued that playing online games can create dependence, laziness (passive), obesity and can also have an attitude of not caring about what is happening around. Respondents when asked about what kind of online environment they think is dangerous, respondents mentioned that all online environments are dangerous because they often display indecent videos that contain psychopathic and violent elements, smell pornographic, contain links that lead to illegal transactions such as gambling and fraud. Applications that can also contain dangers include TikTok, MiChat, Instagram, WhatsApp, and others, although the application depends on its use. Respondents can also detect hazards through chat in cyberspace. If they are already involved in a chat with a stranger, they cover up their true identity and try to remain calm but continue to browse all information on social media about that person. The respondent applies to peruse the information about the person and is not easily provoked, and when danger

threatens, the respondent will immediately break the chat and block all social media on behalf of the stranger.

The results showed that respondents could control not falling into negative activities online by: limiting social media playtime, saving applications that support learning and communication only, avoiding applications that suggest content that contains negative effects, and filtering out what they want to see by filtering again what should be shared. Also divert the existing time by doing hobbies that lead to positive things and increasing activities in the real world by not being too curious about other people's lives. The diversion is by multiplying worship and doing housework. This is in accordance with the development of adolescence who already has an awareness of the values, views, and rules that apply in the surrounding environment [25]. Ulwan calls this phase a mumayiz phase where individuals can already distinguish between good and bad [26]. Also in him there is already an attitude of muraqabah [27].

3.2 Knowing What to Do to Seek Help

The second dimension is Know where the individual knows what to do to seek help from potentially harmful or inappropriate content that will damage the individual's psychology [28]. Know what to do to seek help from various approaches and sources [22]. Knowing resources on how to manage and follow up on behaviors and attitudes by using critical thinking is an important attribute for improving digital resilience in an educational context [29]. Building digital resilience is an effective way to ensure that teens are safer online and aware of the opportunities the internet has to offer. However, digital resilience is a complex approach that seeks to reflect the ways that individuals understand, recover, and learn from online risk, both individually and collectively [21]. Teens often look for simple solutions to complex problems, perhaps unsurprisingly that resilience-based responses have fallen into the shadow of initiatives that support simpler 'rules and tools' approaches to online safety. Knowing digital life and an understanding of online dangers have evolved and other approaches have not solved all the problems; this 'digital resilience' may be more widely used which equates to the idea of 'fortitude' and the ability to bounce back. Sometimes, this term is used as an excuse for poorly designed systems and to justify unjust power for which none of it has to do with digital resilience.

Knowing affected/accidentally entering the web that contains pornographic, violent, and criminal elements is something that cannot be prevented because sometimes respondents get carried away with emotions for a moment or sometimes accidentally enter the web because of the squash of links that bring to these sites. However, when the respondents experienced this, the respondent immediately cut off access to the site. The results showed that respondents would seek help in case of fraud or fraud in cyberspace. Most will tell the incident to a trustworthy/precise person such as a psychiatrist (if experiencing imprisonment) and parents. The purpose of the story is so that respondents get help, as an experience so that it is not experienced by

others and as a learning so that it does not repeat itself. Although some respondents choose to keep it to themselves, it can still be faced by themselves. Respondents also realized that they could not be separated from digital activities (using smartphones) because they were very accustomed to online activities. So, respondents feel very heavy if they are kept away from this digital activity. This dependence on gadgets cannot be blamed because respondents have been highly trained in daily use and are increasingly significantly used during the pandemic which relies on this online technology equipment as an online learning instrument [30].

3.3 Learning from Experience

The third dimension of digital resilience is learning knowledge and skills including learning how to recognize and manage risks and learning from difficult experiences gained from digital experiences [22]. Reynolds L. (2018) Digital activities carried out during the pandemic increased significantly compared to the years before the pandemic [29].

The results of this study show that teenagers use digital media to access YouTube for learning purposes through video tutorials containing learning information, tutorials on the use of applications needed during online learning, and up-to-date information systems that help to learn. Another thing that is learned from digital activities is to make it easier to communicate, find out the latest news, and also look for new things. Can also use electronic media well. Respondents at first had a bit difficulty adjusting to the online situation during the pandemic. However, over time the respondents even enjoyed interacting using online modes. Although sometimes this situation makes feelings uncomfortable and emotionally draining, all conversations and communication have to be done online. The pandemic situation also forces respondents to immediately become literate in information technology even though sometimes they are not very familiar with the applications used to interact. In the incomprehension of the respondents who are actually teenagers, they are able to immediately find out and learn quickly the application and how to access the information available online. This is not too surprising because the character of adolescents according to the stages and tasks of their development adolescence is a period of searching for identity by exploring its environment to satisfy high curiosity [24].

At the same time, adolescents must adapt to online learning situations (although it is difficult, they are accustomed to face-to-face communication and learning), access videos, and must use an asynchronous system, meaning that the responses obtained to problems in learning are not immediately responded to at the same time. However, after the pandemic lasted for almost three years, respondents were very used to even respondents who were already *mager* (lazy to move) because they were very comfortable with online learning and communication. The respondents were also forced to be literate in information and technology at the same time because they could not wait for a long time in learning one by one the learning applications used when learning online.

The results also showed that respondents during the pandemic used applications for learning such as Zoom, Google Meet, Microsoft teams, Bog Blue Butten, WAG, e-Learning, telegram, Google Classroom, and Edmodo. The respondents because of the compelling circumstances, the use of these applications was self-taught and less than optimal. However, over time because respondents want to learn, the application has become a necessity during online learning. Learning using information technology provides an experience of digital activities that can ultimately affect future elections, such as the ability to be entrepreneurial online [31].

3.4 Having the Right Support for Recovery

The fourth dimension of digital resilience is recovery which is a description of the adaptation process. By receiving the right level of support, people can bounce back when something goes wrong online. It is said that it is a trait that all human beings have by means of adaptation and evolution that arise naturally and instinctively. Digital resilience is defined as the process of recovering from a poor or adverse online experience to a level of functioning similar to that of the pre-trial by using the psychological ability to continue functioning while recovering from, adapting, and learning from disruptive events [32]. Al-Abdulghani argues that a person is cognitively well-positioned to embrace digital transformation and adopt new technologies.

The results of the study revealed that one of the problems arising from this online activity is the emergence of bullying, fraud, and so on. The respondents revealed that when this happened, the respondents sought out the truth of the information and sought to know directly from the source. However, what cannot be denied is bullying or bullying that occurs in line with online activities on various social media platforms. If the respondent experiences this, the respondent immediately seeks help and input from the event. One way to prevent this is to make arrangements on their cellphones and immediately block numbers that are suspected of being fraudsters or bullies or businessmen to sort and select information available on social media. If fraud or bullying cannot be overcome personally, the respondents who feel threatened immediately report the unpleasant act to the police.

The study also found how respondents coped with these unpleasant act with an approach of anticipating, limiting, and controlling themselves in online activities. If such activities are inevitable, respondents will use the power of netizens by virtualizing sellers and also their products and ultimately blocking social media and reporting to the authorities. The next anticipation is to keep sight, recite *ta'awuz* repeatedly as a way to seek calm, protection, and even forgiveness from Allah Almighty and chant dhikr to release all burdens. Respondents felt calm when doing worship such as prayers. During the worship, the respondents did not hold gadgets so that they became calmer and more peaceful. What worship respondents often do if they feel uneasy the effect of online activities is religious activities such as five-time prayers, reading the Qur'an, listening to recitations, reading the Qur'an, p.

uasa, multiplying do'a and istighfar are also active in mosques to pause the use of cellphones.

4 Conclusion

Based on the results obtained from the field, it can also be conveyed that digital resilience is developed through four interrelated elements: understanding when at risk, knowing what to do to seek help, learning from experience, and having the right support for recovery. In the part of knowing what to do, students are more able to control themselves because of religious factors so that they can avoid keeping themselves consistent in their main goal of looking for positive things on the internet, coupled with their understanding that the digital world is indeed full of many things so that it comes back to the culprit willing to choose which one and for their own good.

Developing digital resilience is not a linear process, and all elements are equally important and can be applied, at different levels, at any time. Related to resilience, 'learning how to recognize and manage risk, learning from difficult experiences, recovering and staying healthy, is an important part of individual and agency development'. Building digital resilience is an effective way to ensure that children are safer online and can take advantage of the opportunities the internet offers.

One of the factors in developing a resilient attitude is adaptability. This adaptability has been proven in the span of time during the pandemic. As a devout Muslim, what must be done is adaptability and not easily complaining about situations and conditions. In other words, a Muslim has been equipped to be tough, *adaptable*, and have high resilience in the face of all trials. This means that digital resilience in Muslim students can become Islamic resilience in the digital world or Islamic digital resilience where application and development can be carried out in subsequent research.

The results of the study became interesting when it was found that respondents were able to refrain from all the negative things that resulted from digital activities not only from their education and knowledge of the content of these digital activities but rather the ability to refrain based on a deeply religious understanding where most of the respondents were Muslim. They realize that the digital activities they do, even if no one is watching, they realize that the supervision of their god, Allah Azza wa Jalla, is more than the supervision of parents and the surrounding environment. It is because of this feeling of being watched that they are able to control themselves from apps that contain negative effects. Based on this experience, it can be concluded that the respondents have Islamic resilience. This is where digital activities based on religion are not just a checklist or a switch but that is where the value lies.

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The Role of E-Learning System Quality in Increasing E-Learning System Effectiveness

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Abstract In the era of the digital industry, all organizations adapt to advances in information technology. Likewise in the field of higher education. This study has two objectives: (1) to analyze the effect of e-learning system quality on e-learning system effectiveness in user perception and (2) to identify the problems encountered when using the Myklass e-learning system. The object of this research is an e-learning system called Myklass and uses a convenience sampling technique with a population of all users at a university in Yogyakarta, Indonesia. A quantitative approach with surveys and qualitative with interviews are applied in this research. This study used SEM AMOS and copied for data analysis. According to the findings, system quality and service quality both positively and significantly impacted user satisfaction and net benefit; however, information quality had no such substantial impact. These results showed that the student had not received satisfaction from and a net benefit from the information quality on the Myklass e-learning system. Based on the findings, the problem experienced by many students was that the Myklass system was down and in error. The solution given by the technical staff is to report the problem to the lecturer and it will be distributed to the technical staff.

Keywords E-learning · Information quality · System quality · Service quality · Net benefit · User satisfaction · Information system success model

1 Introduction

In today's digital era, information systems' development has increased as a result of advancements in Information Technology (IT) and its widespread application in numerous fields [1]. In the field of education, Information Technology is useful

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for managing to learn effectively. One of them is the development of an e-learning to support academic activities. According to Raspopovic (2008), e-learning system is instructional content or learning experiences delivered through electronic technology, placed between education and Information and Communication Technology (ICT) [2]. According to Market Research Future (MRFR), the growth rate of the global e-learning market per year over the period 2017–2022 is 13%. Referring to Globenewswire, e-learning market is expected to reach $457.8 Billion by 2026. This indicates that e-learning market is very promising.

Based on jawapos.com in 2017 Indonesia has an e-learning market of $12.2 Billion. Meanwhile, the Indonesian education system is ranked 54 out of 78 countries that are included in the world education ranking from the 2021 Word Population Review. Based on this data, it can be concluded that the education system in Indonesia is still low. This is based on several criteria, one of which is the lack of quality educational facilities such as e-learning. Thus, e-learning in Indonesia is required to develop better quality to increase effectiveness. E-learning effectiveness means that students can complete the online program they receive which represents the quality of an institution's educational system [3].

Information System Success Model of the DeLone & McLean (2003), information quality, system quality, and service quality are currently being given emphasis in e-learning and are highly valuable for assessing the success of various e-business, e-government, and e-banking [4]. Therefore, the author created a framework for the role of information quality, system quality, and service quality on user satisfaction and net benefits in e-learning Myklass.

2 Theoretical Framework

E-learning as a new paradigm in education is the use of information technology to spread knowledge and information in the fields of education and training. E-learning consists of using the web to access information regardless of space and time [5, 6]. In this research, e-learning systems are defined by the author as information systems. As a result, the success of the information system is equated with that of the e-learning system. The degree to which learning objectives are met might be considered learning effectiveness [7]. The concept of online learning today has influenced the patterns and behavior of students during the learning process, which can mainly be influenced by the effectiveness of online learning platforms.

2.1 User Satisfaction

User satisfaction has been underlined in numerous studies as a crucial factor in determining how successful an e-learning system is. A measure of how effectively an e-learning system meets users' needs and requirements is user satisfaction. This leads

to higher levels of satisfaction. User satisfaction is considered a user's responsiveness to the resulting skills. Satisfied users are those who find improvements in their work-related skills [8]. When a user is most satisfied, they are most likely to endorse using the information system. Thus, user satisfaction is a perceptual or subjective measure of IS effectiveness. Based on Raspopovic (2018), the user satisfaction model is measured by overall satisfaction, student experience, and recommendations on the ability [2].

2.2 Net Benefit

The net benefit is the perceived individual and organizational impact on tasks/performance and efficiency [9]. Chou and Liu (2005) describe net benefits as the extent to which the ultimate goal (desired information and abilities) can be achieved by the learner [10]. The individual impact and organizational impact dimensions are combined to create the net benefit variable. The individual impact is the achievement of the user after using or completing courses. This study focuses on individual impacts because this study assesses the net benefits of each individual. Based on Raspopovic (2018), the net benefit model is measured by increased learning, academic achievement, saving time, and gaining knowledge [2].

2.3 Information Quality

Information quality is referred to as content quality available in media or electronic products. According to Cidral (2018), information quality displays information that is by the accuracy, validity, and fairness of the system related to the contents of the system [9]. When someone feels that information system valuable, they are more inclined to use it. Information systems that provide high-quality content will increase users' intentions to engage in the services provided [11]. When the comparing pertinent studies, it was discovered that students relied more on course content than on the teacher's online presence. The model used in this research is to explain indicators of information quality in e-learning. In this study, researchers determine the quality of information broadly identified as various usability, understandable, interesting, and reliable.

2.4 System Quality

The e-learning portal system quality determines how easily students can access courses and other learning materials. The quality of a system, according to Raspopovic (2018), is measured in terms of user-friendly, reliability, flexibility,

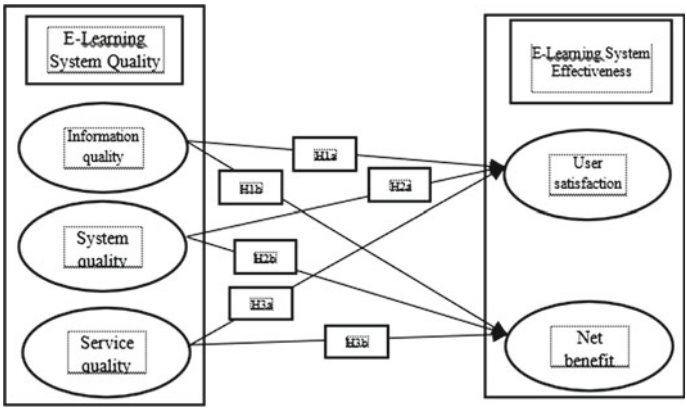

Fig. 1 Research model

stability, security, and response time. Zheng [12] said that the more user-friendly and structured the website, the better the quality of the e-learning system. The quality of information system is considered important in influencing user trust in a website. Studies show that system quality has a positive impact on usage and satisfaction [13] (Fig. 1).

2.5 Service Quality

By adding something special to already existing items that can increase user satisfaction, service quality plays a crucial part in bolstering competitive advantage. Wang [14] outlines numerous methods to evaluate the effectiveness of an effective service, such as an online learning platform that can enhance service delivery by offering relevant guidance and support through online media. The success dimension of service quality measures how well users are supported by the IS department and IT support staff [15]. Service quality in e-learning aims to measure the gap between student expectations and student experiences, such as perceived satisfaction, regarding the services provided, and relies on the important assumption that students can assess the service quality of an organization by comparing expectations and experiences.

2.6 Hypothesis

In this research, there are three independent variables and two dependent variables. Three independent variables describe the quality of the e-learning system, namely the information quality, system quality, and service quality. Two dependent variables

describe the effectiveness of the e-learning system, namely user satisfaction, and net benefits.

H1a: Information quality has a positive and significant effect on user satisfaction with the e-learning system.
H1b: Information quality has a positive and significant effect on the net benefits of the e-learning system.
H2a: System quality has a positive and significant effect on user satisfaction with the e-learning system.
H2b: System quality has a positive and significant effect on the net benefits of the e-learning system
H3a: Service quality has a positive and significant effect on user satisfaction with the e-learning system.
H3b: Service quality has a positive and significant effect on the net benefits of the e-learning system.

Additionally, this study will use a qualitative approach to address several issues. In this instance, it highlights the problems that users, specifically students and technical staff, experience as well as solutions to those problems. The qualitative results are meant to support the quantitative findings.

3 Research Methodology

This study's methodology, which combines quantitative and qualitative elements, makes use of primary data through surveys and interviews.

3.1 Respondent

A population is the entire set of subjects, activities, or objects that the researcher seeks to study [16]. The population in this study is a user of the Myklass e-learning system in higher education in Yogyakarta. The population in this study served as the basis for choosing the sample. The sample is all active users of the Myklass e-learning system, especially in the faculty of economics and business.

3.2 Sample Size

Ferdinand (2014) stipulates that the sample size is 6 scale multiple by the number of variable indicators to be analyzed. This study has 22 indicators, so the minimum number of samples taken requires several $22 \times 6 = 132$ respondents, and 156 respondents were willing to complete the questionnaire, according to the findings of the

questionnaire distribution. After closer examination, four respondents were found to not meet the required respondent requirements, leaving 152 respondents in the study who may continue to be examined.

3.3 Sampling Technique and Data Collection Procedures

The sampling technique for distributing the questionnaire used was a convenience sampling technique, meaning that members are easily approached to be part of the sample. Data collection techniques in this study were carried out using surveys and interviews. Questionnaires were delivered to respondents by sending a Google Form link via communication applications such as WhatsApp and Instagram and distributed offline by showing a scanned barcode. Two technical staffs were interviewed to answer the four last questions, namely the LSI (Information System Agency) and the admin from e-learning Myklass in faculty.

3.4 Measured Used

The items in this study are scored on a scale of one to six to avoid central tendency. The six scales are 1 (strongly disagree) to 6 (strongly agree). The operational definition of this research variable refers to indicators with a total of 23 questions, namely seven questions from the system quality dimension, four questions from the information quality dimension, five questions from the service quality dimension, three questions from the user satisfaction dimension and four questions from the net benefit dimension.

3.5 Data Analysis

There are both closed and open statements in this study, allowing for quantitative data analysis for closed statements and qualitative data analysis for open inquiries. The structural Equation Model (SEM) and the AMOS application are used for quantitative data analysis, while qualitative data analysis is being copied. The interview's most crucial phase is transcription. Aghion (2011) asserts that transcription is the conversion of a spoken system into written language. Coding is the next stage. Coding is the process of classifying respondents' responses to surveys and other material for analytical reasons. The questionnaire may be utilized following the selection because it is valid and reliable through validity and reliability testing.

4 Quantitative Result

4.1 Validity and Reliability Test

This study tested the validity and reliability tests with the output results of AMOS and Microsoft Excel. If the instruments have met the valid criteria, it means that the instrument can measure the concept. This study used Confirmatory Factors Analysis (CFA) with AMOS software. The data is said to be valid if the output value or loading factor is more than 0.5 (Ghozali 2017). In this study, the questionnaire is considered reliable if its Construct Reliability (CR) value is higher than 0.70. If the value of Construct Reliability is lower than 0.70, then the questionnaire is declared not reliable.

Table 1 shows that each statement item has a loading factor greater than 0.5. It can be said that each statement item is valid and suitable for use in subsequent testing. Results of the reliability test are displayed in Table 2. According to Table 2, each variable is considered reliable because it satisfies the criteria, specifically that the C.R. value surpasses 0.7.

4.2 Structural Equation Model (SEM) and Path Analysis

The initial data that was processed was 152. After analyzing the outlier data, eight data were deleted, so the remaining 144 data were re-analyzed. After analyzing 144 data, a goodness-of-fit test was performed. Initial testing presents the result of the model goodness of fit showing the value of Chi-Square = 508.056; Probability = 0.000; CMIN/DF = 2.299; GFI = 0.763; AGFI = 0.705. This model still shows no fit. Value of RMSEA = 0.095; TLI = 0.862; CFI = 0.879. This model also still shows marginal fit. It is necessary to modify the model by analyzing the results of Modification Indices (MIs) on the SEM output.

Data analysis used SEM AMOS with 23 indicators and 144 respondents after modification showed the value of Chi-Square = 410.427; Probability = 0.000; RMSEA = 0.080; CMIN/DF = 1.909; GFI = 0.807; AGFI = 0.752; TLI = 0.903; CFI = 0.918. All parameters are under the requirements so that generally it can be considered a good model although there are some still not fit and marginal fits such as Chi-Square, Probability, AGFI, and GFI. The Chi-Square value is 406.427, which must look at other indicators because the sample is large; generally, the Chi-Square value is ignored by the acceptance of the model (Bentler 1980). The probability value shows a smaller result of 0.05, which is 0.000. It is concluded that the probability value is not fit. The CMIN/DF value is 1.909 which indicates a fit model because it is below the cut-off value of 2.00. The RMSEA value is 0.080 which indicates that the suitability level of the RMSEA in this research model is fit (Fig. 2).

The GFI value is 0.807. The GFI value in this model is less than the recommended acceptance rate ≥ 0.90, so the GFI value in this model is a marginal fit. The AGFI

Table 1 Validity test

Variable	Indicators	Estimate	Cut-off value	Desc
Information quality	IQ1	0.654	≥0.5	Valid
	IQ2	0.606	≥0.5	
	IQ3	0.827	≥0.5	
	IQ3	0.774	≥0.5	
System quality	SYQ1	0.591	≥0.5	
	SYQ2	0.503	≥0.5	
	SYQ3	0.684	≥0.5	
	SYQ4	0.679	≥0.5	
	SYQ5	0.76	≥0.5	
	SYQ6	0.742	≥0.5	
	SYQ7	0.784	≥0.5	
Service quality	SQ1	0.821	≥0.5	
	SQ2	0.854	≥0.5	
	SQ3	0.706	≥0.5	
	SQ4	0.885	≥0.5	
	SQ5	0.791	≥0.5	
User satisfaction	US1	0.832	≥0.5	
	US2	0.887	≥0.5	
	US3	0.761	≥0.5	
Net benefit	NB1	0.861	≥0.5	
	NB2	0.839	≥0.5	
	NB3	0.601	≥0.5	
	NB4	0.802	≥0.5	

value is 0.752. The results of AGFI in this research model do not match the recommended acceptance value ≥ 0.90, and this shows that the level of suitability of AGFI in this research model is not fit.

The TLI value in this model is 0.903 with a recommended acceptance value of ≥ 0.90. This shows that the TLI value of this study has a level of fit. The CFI value in this model is 0.918 with a recommended acceptance value of ≥ 0.90. This shows that the CFI value of this study has a level of fit.

The findings of the hypothesis test show that while user satisfaction and net benefits are positively related to IQ, this link is not statistically significant. SYQ and SQ have a favorable and notable impact on US and NB. The following is a discussion of the results of the hypothesis.

Table 2 Reliability test

Variable	Symbol	Loading factor	Loading factor^2	Error	CR	Desc
Information quality	IQ1	0.654	0.427716	0.57228	0.809837	Reliable
	IQ2	0.606	0.367236	0.63276		
	IQ3	0.827	0.683929	0.31607		
	IQ3	0.774	0.599076	0.40092		
System quality	SYQ1	0.591	0.349281	0.65072	0.857906	Reliable
	SYQ2	0.503	0.253009	0.74699		
	SYQ3	0.684	0.467856	0.53214		
	SYQ4	0.679	0.461041	0.53896		
	SYQ5	0.76	0.5776	0.4224		
	SYQ6	0.742	0.550564	0.44944		
	SYQ7	0.784	0.614656	0.38534		
Service quality	SQ1	0.821	0.674041	0.32596	0.906918	Reliable
	SQ2	0.854	0.729316	0.27068		
	SQ3	0.706	0.498436	0.50156		
	SQ4	0.885	0.783225	0.21678		
	SQ5	0.791	0.625681	0.37432		
User satisfaction	US1	0.832	0.692224	0.30778	0.867196	Reliable
	US2	0.887	0.786769	0.21323		
	US3	0.761	0.579121	0.42088		
Net benefit	NB1	0.861	0.741321	0.25868	0.861315	Reliable
	NB2	0.839	0.703921	0.29608		
	NB3	0.601	0.361201	0.6388		
	NB4	0.802	0.643204	0.3568		

5 Discussion

Hypothesis 1a (H1a)

These findings indicate that the impact of information quality on user satisfaction is positive but not statistically significant (C.R. = 1.098 and $p = 0.272 > 0.05$). This means that the quality of the information provided by e-learning Myklass, whether or not it is good or not, will not have an impact on the creation of user satisfaction. It can be concluded that (H1a) is rejected because there is no significant effect between the two variables. This can happen because the information provided is difficult to understand and unattractive, so students do not feel satisfied. In addition, the information contained in the e-learning Myklass is usually not updated to the latest information, so its reliability is lacking.

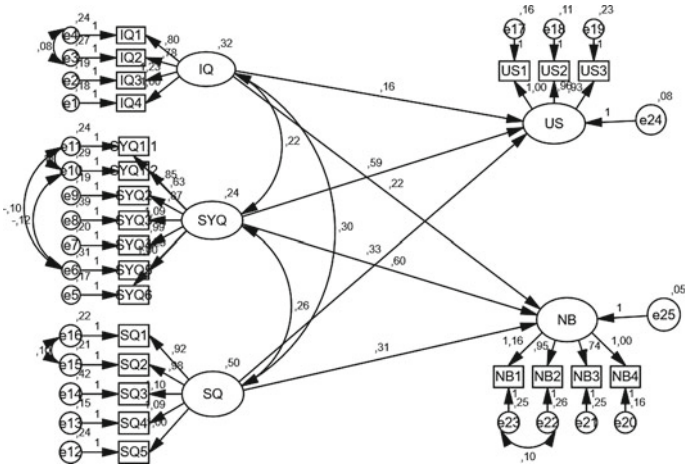

Fig. 2 Structural equation model

Hypothesis 1b (H1b)

These results indicate that there is a positive but not significant effect of information quality with net benefits (C.R. = 1.530 and $p = 0.126 > 0.05$). This means that the quality of the information provided by E-learning Myklass, whether or not it is good or not, will not have an impact on the benefits for users. Testing the (H1b) reads "the information quality has a positive and significant effect on net benefits", rejected because there is no significant effect between the two variables. This can happen because the information provided cannot increase student interest in learning and student academics, so students have not felt the benefits. Maybe students are more interested in finding information on the internet. In addition, the literacy rate of students is low, so a lot of the information contained in e-learning Myklass is ignored.

Hypothesis 2a (H2a)

These findings show that user satisfaction is positively and significantly impacted by the system quality (C.R. = 3.510 and $p = < 0.05$). That is, the better the quality of the system in e-learning Myklass will have an impact on increasing student satisfaction. Testing the (H2a) reads "system quality has a positive and significant effect on user satisfaction", accepted. This can happen because the Myklass e-learning system is considered flexible, user-friendly and provides a sense of security, stability, and reliability so that students believe using it which does not need much effort.

Hypothesis 2b (H2b)

These results indicate that the system quality has a positive and significant effect on net benefits (C.R. = 3.581 and $p < 0.05$). This means that the better the quality of the system in Myklass e-learning, the more students will feel the impact of good

benefits. Testing the (H2b) reads "system quality has a positive and significant effect on net benefits", accepted. This can happen because the Myklass e-learning system is easy to use, so students will feel the benefits of increasing learning power and increasing academic achievement.

Hypothesis 3a (H3a)

These findings suggest that user satisfaction is positively and significantly impacted by service quality (C.R. = 3.615 and $p < 0.05$). That is, the better the quality of service in e-learning Myklass, the higher the level of student satisfaction. Testing the (H3a) reads "service quality has a positive and significant effect on user satisfaction", which is accepted. This can happen because the services on Myklass e-learning are reliable and students feel cared for in service.

Hypothesis 3b (H3b)

These findings suggest that the impact of service quality on net benefits is both positive and significant (C.R. = 3.587 and $p < 0.05$). That is, the higher the level of service quality in E-learning Myklass, the better the benefits students will get. Testing the (H3b) reads "service quality has a positive and significant effect on net benefits", which is accepted. This can happen because the services of Myklass e-learning provide according to the needs of students so that students can improve their learning power.

6 Qualitative Result

In this section, the researcher obtained information with open questions attached to the questionnaire and conducted interviews with informants, namely technical staff from e-learning Myklass (Table 3).

System down and errors were the most often reported problems by students. These problems could be brought on by a technical staff who has not handled e-learning well, but they could also be brought on by users or students who have issues with poor internet connections or problems with the technology being utilized. In the student's opinion, the technical team at Myklass's response to issues in the down system is to

Table 3 Result from open question

No	Problems	Solutions suggested by technical staff
1	System downs and errors	Waiting for system improvement or students are expected to refresh the e-learning page
2	Unrecorded learning history and attendance	Contacting the lecturer and making new settings for attendance
3	Lack of file upload capacity size	Increase the size of the file capacity
4	No problems	No solution

ask students to wait while the system is fixed and students can refresh the Myklass page.

The learning history mentioned in this restriction refers to the desire of students to save their prior semester's content and assignments when changing semesters. Students who have attendance issues and who are not recorded believe that they have made attendance, but when checked again, they are not recorded and are regarded as absent. According to students, the technical staff's response to issues regarding the previous semester's courses and attendance that was not recorded was that students should report to the lecturer so that the lecturer could reorganize the attendance or students could provide proof of attendance that would later be presented by the lecturer.

When student-owned files are larger than the e-learning system can handle, there is a shortage of file upload capability in this limitation. According to students, the technical staff's recommendation for the issue of small file upload size is to improve the file size capacity. This is demonstrated by the fact that students can now upload Myklass files with a maximum file size of 10 megabytes as opposed to the initial maximum file size of 2 MB. Finally, the results of open questions stated that there were students who had no problems using Myklass. Therefore, no solution can be suggested.

Table 4 shows the results of interviews with technical staff regarding the problems experienced and the solutions used. According to LSI, issues with e-learning platforms are uncommon. Yet occasionally, a system will go down at the worst time, like right before bed. If it can still be fixed, it will be fixed straight away; otherwise, it will be fixed the following day. Additionally, LSI claimed that student behaviors, including gathering homework as deadlines drew near, contributed to the system's being down. The student problem according to LSI is system downs and errors, unrecorded attendance, enrollment problems, forgetting the password, and an exam that cannot open.

The system was down while the LSI was performing maintenance, which presented a challenge for the Myklass admin. If this occurs, the administrator claims that there is nothing else they can do but wait until the LSI has finished performing maintenance. Student problems according to the Admin of Myklass are forgot key-in or late key-in and decreased value caused by the presence not being recorded.

Based on the limitations previously mentioned, LSI asserted that the challenge in adopting the E-learning system was that it went down unexpectedly; the answer to this problem was to repair the system right away. The solution provided for users by LSI is problems with courses which can be reported to the lecturer, forgot password problems can press the "forgot password" button, and if the system is down due to student habits and the connection of respondents, students can set the time when collecting assignments.

Table 4 Result interview with technical staff

Item	Coding	Item	Coding
Results of interviews with LSI (Information System Agency)			
A problem faced by LSI	System down at an unexpected time	The solution used by LSI	Repair the system right away
Student problems in the opinion of the LSI	System downs and errors	Solution provided for users by LSI	Problems with courses can be reported to the lecturer
	Unrecorded attendance		Forgot password problems can press the "forgot password" button
	Enrollment problems		The system is down due to student habits and the connection of respondents, and students can set the time when collecting assignments
	Forgot the password		
	The exam cannot open		
Result interviews with Admin Myklass in Faculty			
A problem faced by the admin	Error during maintenance from the LSI center	The solution used by Admin	The admin will report or contact LSI because the admin is the same as a user who has more opportunities to edit
Student problems in the opinion of the admin E-learning Myklass FEB UMY	Forgot key-in or late key-in	Solution provided for the user by Admin	If a student forgets to key-in or is late, then the student reports to the study program so that it can be registered immediately
	Decreased grades caused by the presence not being recorded		For grades that go down, because attendance is not recorded, students can report to the lecturer

7 Conclusion

In the study of the role of e-learning system quality in increasing e-learning system effectiveness study on Myklass, conclusions based on quantitative approaches and conclusions based on qualitative approaches are presented, respectively. The result shows that system quality and service quality affect the effectiveness of the Myklass e-learning system, but information quality has little to no bearing. In other words, the Myklass e-learning system's information quality is insufficient to satisfy users and bring about positive effects for students. Problems encountered by students when using the Myklass e-learning system include system down or error; previous semester course data availability; unrecorded attendance; a limited amount of space for file uploads in e-learning; forgetting to key-in; forgetting passwords; and exams that cannot be opened. Problems faced by technical staff when implementing e-learning are infrequent system outages brought on by maintenance work and student behavior.

The solutions given by technical staff to address user problems are to wait for repairs, refresh the e-learning system, contacting lecturers and study programs connected to the subject, offering maximum file capacity uploads, providing a "forgot password" button, and enabling students to set the time. The best way to handle problems that happen during the implementation of the e-learning system is to fix the downed system as soon as possible, so solutions are utilized by technical staffs because it is unusual for a system to go down. It is advised that future researchers revisit the impact of the quality of the e-learning system on e-learning effectiveness and designate this a research gap.

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Intention Bank Customers' Use of İnternet-Based Banking Services

Arni Surwanti, Siti Nur Mubarokah, and Firman Pribadi

Abstract This study provides empirical evidence the determinant of using internet-based banking services. This research uses quantitative methods. This study used primary data with the sample of 100 customers who used internet-based banking services. The PLS is used for data analysis. The results of this study can aid decision-makers at the Indonesian bank in promoting the use of internet-based banking by emphasizing individualized and trusted services that are provided with a high level of security and privacy. The model's test findings imply that the choice to use of internet-based banking services is influenced by the tendency for technology acceptance, the importance of online personalization, customers' privacy concerns, E-trust, Technology leadership, and E-loyalty Practical. Implication of this research, the public bank should promote the adoption of internet-based banking services by emphasizing attention on personalization of services, privacy and trust.

Keywords Intention · Technology acceptance · Personalization · Privacy concerns · E-trust · Technology leadership · E-loyalty

1 Introduction

In Indonesia, one of the industries that has a significant impact on economic activity is the financial services sector. Technological advances in telecommunications and information technology continue to evolve including in the banking world and are increasingly competitive [1]. Along with the development of the times leading to the digitalization era, it has changed people's behavior patterns in using financial services, especially electronic banking services. Changes in people's behavior

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patterns have encouraged financial service providers to offer new innovations by providing *technology-based* services.

Electronic services or online banking services themselves have gained considerable attention in recent years. Given the internet's explosive growth and the industry's globalization, the majority of businesses are competing for bank clients in a fiercely competitive market [2]. A significant factor in the creation of more effective banking services is the use of established and mature information systems [3, 4].

Innovation in banking technology impacted in an increase in the use of electronic transactions. Transactions are currently shifting from cash to electronic transactions. It is crucial to understand what drives bank customers to use internet-based banking services. Initially, most bank customers could only do banking transactions at banks, or with Automated Teller Machines (ATMs) or telephones, however, many bank customers now have access to internet banking and online banking services. Internet-based banking services grew out of necessity to satisfy the needs of bank customers [5].

Banks are currently competing to create an online banking service where the service can provide conveniences to its users. Banks that want to compete in creating electronic banking services must understand the regulations made by Financial Services Authority Indonesia and the conditions that must be met to apply electronic banking services.

The Financial Services Authority defines electronic banking services as products that enable users to access information, communicate, and carry out financial transactions via electronic media. Banks provide electronic banking services, which can be used independently by customers while still taking security precautions, to better serve customers swiftly, easily, and in accordance with their needs.

Electronic banking services are described in Chapter I, Article 1 of Financial Services Authority Regulation Number 12 /Pojk.03/2018 relates to the provision of digital banking services by commercial banks as means of enabling bank clients to communicate, transact, and get information via electronic media. Customers can easily conduct banking activities, making payments, and other activities via the internet with the bank's website. E-banking is described by Pikkarainen et al. [6] as an online portal that gives bank users access to certain banking services, such as investing and bill paying. Delivering banking services to bank customers online is known as internet banking [7].

Mobile banking is a form of digital banking development that offers facilities from banks in this modern era. Mobile banking facilities include payments, transfers, history, and others.

Using internet banking, bank can make efficiency in operational cost because using less people and physical infrastructure. Internet banking provides a variety of electronic bank transactions without time or location constrained [8]. Using internet banking can decrease in the Bank's operational costs, such as handling fees, transaction fees, labor and administrative costs, which are the advantages that the bank may be able to obtain through the use of internet-based banking services [9].

Despite the many advantages and conveniences that internet-based banking services offer, many customers of banks continue to be hesitant to use them [10].

Concerns about using internet-based banking services by bank customers have led to views about how complex these services are; therefore, infrastructure and perception skills are also required (e.g., computers and the internet). Customers of banks are concerned about the lack of security and privacy when using banking internet-based services [11].

According to Salem et al. [12], bank customers' willingness to accept technology, the value that place on online personalization, their concern for privacy, their level of e-trust and leadership technology, as well as their level of e-loyalty give impact on how they use internet-based banking services. Banks can use internet-based services that will satisfy bank customers' expectations for making transactions at any time and from any location. AlKailani [8] discovered that perceptions of utility, risk, trust, and bank credibility all had an impact on Jordanians' willingness to utilize the internet banking. According to this study, trust and perceived risk are two important elements that affect how often people utilize internet banking [13].

The adoption of online banking services by bank clients is influenced by a variety of factors, according to prior studies. According to TAM theory, the acceptance of a technology requires an analysis of factors that affect acceptance that can come from users or the system itself. This research analyse the influence of the tendency for technology acceptance, the importance of online personalization, customers' privacy concerns, Technology leadership, E-trust, and E-loyalty on the use of internet-based banking services.

2 Literature Review

2.1 The Use of İnternet-Based Banking Services

The rapid development of the times has made the environment more competitive, resulting in reduced customer loyalty. Banking can offer online banking services as their competitive advantage to need to retain and acquire bank customers. Along with the development of information technology that leads to digital banking services, the bank is fully oriented to the needs of its customers by using digital technology through *devices* and applications (s*oftware*).

İnternet-Based banking services and electronic banking services in Indonesia known as E-banking. Internet-based banking services are a service offered by banks that allow customers to make financial transactions over a network of computers (investopedia.com-2020).

Internet-based financial services and electronic banking services are more commonly referred to as "e-banking" in Indonesia. The financial services' authority explains that digital banking services or online banking services are services that use electronic or digital means owned by banks or digital media that are carried out independently.

"Internet banking" is a service for carrying out financial transactions over an internet network, according to the Financial Services Authority. The process of using it is relatively very easy, simply by visiting the bank's website to make banking transactions (finansialku.com, 2019). According to the financial services authority, mobile banking is a service to conduct banking transactions via mobile phones, using applications on the handphone. A service provided by banks called mobile banking enables users to carry out a range of financial transactions utilizing the sharing features of cellphones. (cermati.com, 2015). According to Sathye (1999) in Mukherjee and Nath (2003) defines E-banking as banking activities that can be carried out by customers of the bank to access information such as balance checks, transfers, bill payments and others via internet networks.

2.2 The Concept of Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) is a model created to examine the elements that affect a technology's acceptance in an organization by Davis in 1989. The TAM model was actually adopted from the Theory of Reaction Action/TRA model introduced by Ajzen and Fishbein (1980) and proposed by Davis (1989), that is, an action theory that would determine a person's attitudes and behavior with a single well-founded premise regarding a person's reaction and perception of something. Users of information technology (IT) will influence attitudes and reactions in acceptance of technology.

2.3 Research Models

See Fig. 1.

3 Methodology

3.1 Data

The object of this study is a public go bank. The subject of this study is a customer of the public bank in Indonesia. The data source used in this study is primary data. This data collection is usually carried out by distributing *questionnaires* to the research subject. The questionnaires the researchers used were sourced from questionnaires that had been used previously by [12].

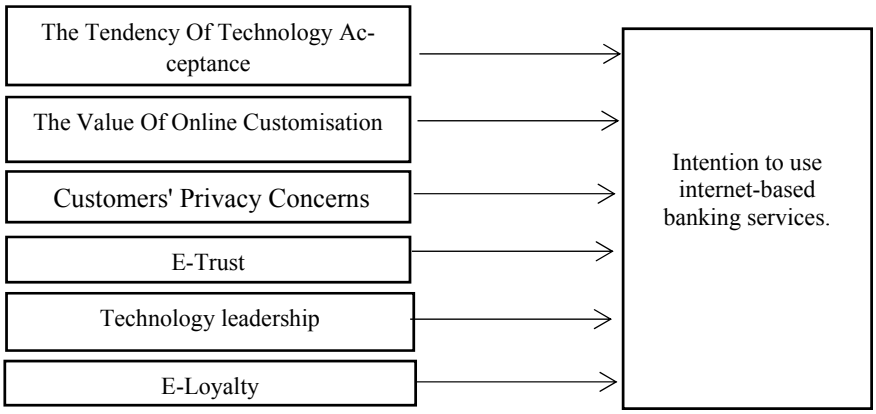

Fig. 1 Research framework

3.2 Sampling Techniques

All users of public banks who used online banking services made up the study's population. The sample represents a representation of the population's size [14]. The sampling method is non-probabilistic sampling especially the accidental method [14]. Measurement variable using the Likert scale. The five-point Likert scale is used to gauge how strongly a respondent agrees or disagrees with something.

3.3 Data Analysis Methods

After the necessary data has been collected, the next stage is to analyze the data with correlation regression analysis to determine the influence of independent variables to dependent variables. The Partial Least Square (PLS) analysis used in this study was carried out using the Smart PLS program version 3.0. Decision-making of the hypothesis can be carried out by event, i.e., on testing at a significance level of 0.05.

4 Analysis Results

In this study, *R-square* value testing was carried out which was used to explain to measure the degree of variation in changes in independent variables to dependent variables.

The higher the value of R^2, the better the model is at predicting the object of study. The structural model of this study can be seen in the following Fig. 2.

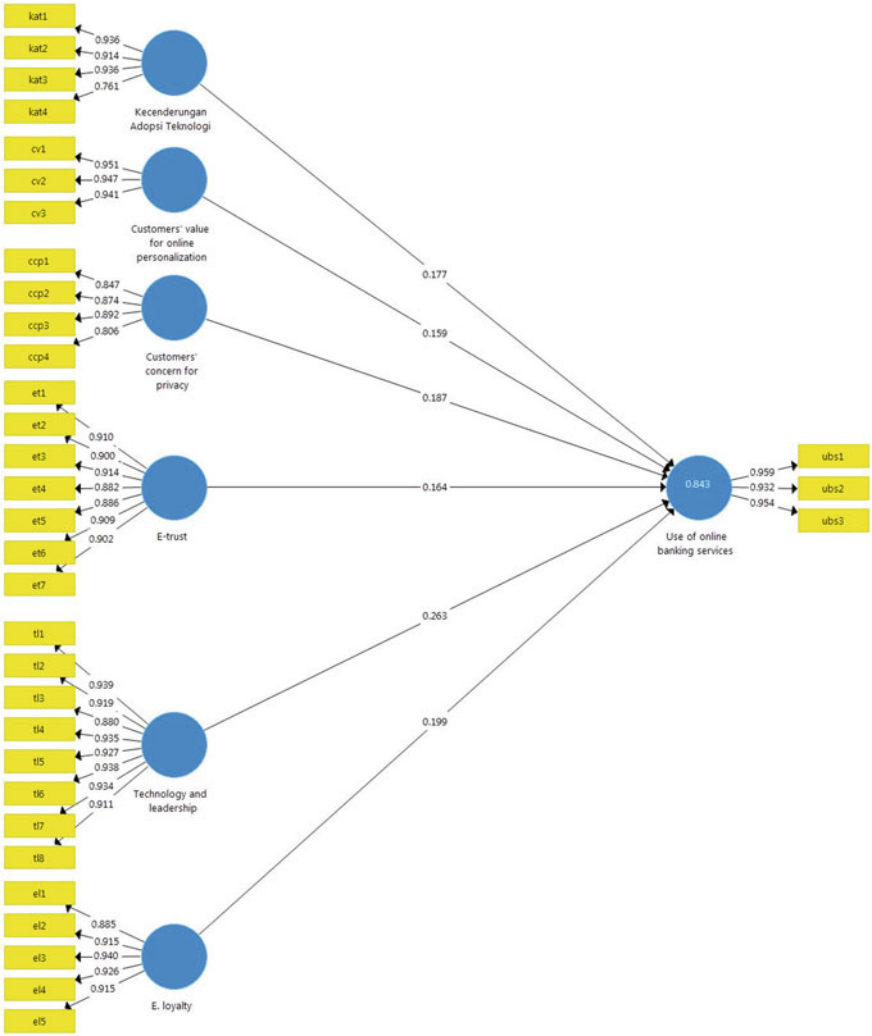

Fig. 2 Research structure model

Effect the tendency for technology acceptance, the importance of online personalization, customers' privacy concerns, Technology leadership, E-trust, and E-loyalty to the use of internet-based banking services has an R^2 or *R-Square* value 0.843 that give meaning as a good model (Ghozali, 2016).

Based on Table 1, it shows that the results of the R^2 explain that the percentage of the use of internet-based banking services was impacted by the tendency for technology acceptance, the importance of online personalization, customers' privacy concerns, e-trust, technology leadership, and e-loyalty of 84.3%, and 15.7% is influenced by other variables that were not studied in this study.

Table 1 *R*-square values

Variable	R^2
Intention to use internet-based banking services	0.843

Structure Model Test the Path Coefficient Model Hypothesis

The causality analysis used to determine the relationship between the variables is the hypothesis test. The influence that exists between exogenous and endogenous factors can be identified through causality analysis. If the p-value (probability) is less than 0.05, exogenous variables are said to have a significant impact on endogenous variables. Table 2 displays the findings of the hypothesis test.

Hypothesis testing is intended to test the influence of an independent variable on a dependent variable. In other words, want to test the significance impact of variable independent to dependent variable. In the results of this study table, the signification

Table 2 Hypothesis test results

Variables	Original sample	Standard deviation	*T* statistics	*P* values	Information
The tendency for technology acceptance → intention to use internet-based banking services	0.177	0.088	2.046	0.041	Accepted
The importance of online personalization → intention to use internet-based banking services	0.159	0.070	2.260	0.024	Accepted
Customers' privacy concerns → intention to use internet-based banking services	0.187	0.056	3.313	0.001	Accepted
E-trust → intention to use internet-based banking services	0.164	0.078	2.094	0.037	Accepted
Technology leadership → intention to use internet-based banking services	0.263	0.088	2.979	0.003	Accepted
E-loyalty → intention to use internet-based banking services	0.199	0.070	2.832	0.003	Accepted

level used is 5%. As shown in Table 2, the intention to use internet-based banking services is positively and significantly impacted by the tendency for technological adoption, the importance of online personalization, customers' privacy concerns, e-trust, technology leadership, and e-loyalty.

5 Discussion

5.1 The Impact of the Tendency for Technology Acceptance to Intention Bank Customers' Use Internet-Based Banking Services

The results show that the tendency of technology adoption has a positive and significant effect on the use of Internet-Based banking services by bank customers. The greater the tendency for technology acceptance, the greater Intention Bank Customers' Use Internet-Based Banking Services, due to technological advances have developed such as internet services, and other technologies.

This result is in line with TAM theory, where respondents have a tendency to use technology where technological advances have an effect so that respondents will have the tendency of technology acceptance. In addition, these results are in line with the research of Salem et al. [12] that the trend of technology adoption has a positive and significant effect on the use of internet-based banking services by bank customers. In this study, most respondents had a tendency to adopt technology toward the use of internet-Based Banking Services. This is because respondents believe in the technology used and the conditions or situations that support adopting the technology.

5.2 The Impact of the Importance of Online Personalization to Intention Bank Customers' Use Internet-Based Banking Services

The results show that the value of online personalization by bank customers has a positive and significant effect on the use of internet-based banking services by bank customers. The value of online personalization is more about a more personal relationship with its bank customers to meet the wishes of bank customers. The greater the importance of online personalization by bank customers, the greater the use of internet-based banking services by bank customers, because the internet-based services designed and offered by banks can influence bank customers in the use of internet-based banking services, as well as the ease of devices that can be accessed via computers, gadgets, mobile phones, etc., in using online services.

This is in line with TAM's theory that respondents believe that the value of online personalization will affect the internet-based services offered by the bank, so that bank customers can more easily use internet-based banking services. Additionally, these outcomes are consistent with the research of Salem et al. [12] that the value of personalization by bank customers has a positive and significant effect on the use of internet-based banking services by bank customers. The results of this study stated that some respondents stated an important factor in the value of online customization by bank customers. This is because each respondent has their own expectations regarding the value of online personalization.

5.3 The Impact of Customers' Privacy Concerns to Intention Bank Customers' Use Internet-Based Banking Services

The findings demonstrate that bank customers' privacy concerns have a positive and significant impact on the use internet-based by bank customers. The greater the concern of bank customers on privacy, the greater the use of internet-based banking services by bank customers because bank customers are very sensitive about the privacy information that will be used by the bank.

Bank customers' privacy concerns for affects respondents to the use of internet-based banking services by bank customers because the customers see the bank reputation. This is due to the importance of data regarding the privacy data obtained so that it affects the use of internet-based banking services by bank customers. These results are in line with the research of Salem et al. [12] that bank customers' concern for privacy has a positive and significant effect on the use of internet-based banking services by bank customers.

This research shows that some respondents think that privacy is very sensitive, so respondents are very careful in providing information to other parties. This is due to the concerns of bank customers regarding violations/losses that will be caused if providing privacy data.

5.4 The Impact of E-Trust to Intention Bank Customers' Use Internet-Based Banking Services

The results show that *E-Trust* has a positive and significant effect on the use of customers of banks using internet-based banking services. Bank consumers utilize internet-based financial services more frequently the larger the E-Trust, believing that these services are trustworthy, have competent technical staff, and deliver consistent information to demonstrate integrity and high ethical standards. The analysis findings concur with those of Salem et al. [12], who found that e-trust significantly and favorably affects how much bank clients use Internet-Based banking services.

5.5 The Impact of Propensity of Technology Leadership to Intention Bank Customers' Use Internet-Based Banking Services

The results show that *Technology and leadership* have a positive and significant effect on the use of internet-based banking services by bank customers. The greater the *Technology and leadership*, the greater the use of internet-based banking services by bank customers. This is because the technology shown by banks provides a competitive advantage compared to other competitors and provides the best service to satisfy the expectations of bank customers. This research is in line with TAM's theory that technology *and leadership* will influence the use of internet-based banking services by bank customers, and this is because respondents will use a technology if it provides benefits to respondents, where if it provides benefits. These findings are also consistent with the findings of Salem et al. [12] who found that leadership and technology had a favorable significant impact on how often bank clients use internet-based banking services.

5.6 The Impact of E-Loyalty to Intention Bank Customers' Use Internet-Based Banking Services

The findings demonstrate that e-loyalty influences bank customers' use of internet-based banking services in a favorable and significant way.

Because bank clients have faith in the services provided, they are loyal to the bank's services, and this loyalty is shown in the growing use of internet-based banking services by bank customers.

This research is in line with the research of Salem et al. [12] that *e-loyalty* has a positive and significant effect on the use of internet-based banking services by bank customers. This research shows that most respondents have e-loyalty to internet-based banking services due to factors that support bank customers to be loyal such as ease of use, customer trust, privacy policy, and so on.

6 Conclusion

Based on the description and analysis stated intention use of internet-based banking services is influenced by tendency for technology acceptance, the importance of online personalization, customers' privacy concerns, technology leadership, e-trust, and e-loyalty. The study's findings demonstrate that in order to deliver services to bank customers, banks must make significant investments in the newest communication and technological infrastructure.

7 Suggestion

Banks need to invest more in the latest information and communication technology infrastructure and provide necessary facilities for bank customers such as building customer service centers or designing advertisements so that consumers will tend to use internet-based banking and request additional online services. The existence of internet-based banking makes it easier for bank customers to use banking activities such as money transfers and making payments so that they can overcome problems related to location and time. Based on this research, providing banking advice is expected to design an easy and useful system in order to create a positive attitude for customers in connection with the adoption of internet-based banking services by bank customers. Enhancing the internet banking system's functionality would encourage bank clients to use it more frequently and will help them fulfill their desire to conduct transactions online at any time and from any location.

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Web Application to Improve the Competencies in the Area of Mathematics of 4th Grade

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Abstract The objective of this research was to determine how a Web Application influences the improvement of mathematics competencies of 4th-grade students of an educational institution. For this purpose, the ability of the students to solve problems with respect to the competencies in the area of mathematics was studied. In this type of applied research with a quasi-experimental design with a quantitative approach was used. For data collection, the survey technique was used with the questionnaire instrument, which was validated by expert judgment and analyzed by means of the Kr-20 reliability analysis, showing a favorable acceptance with a coefficient of 0.802. To measure the proposed indicators, a sample of 30 students was used, obtained from a population of a similar size. On the other hand, in the analysis of the data, use was made of the SPSS Statistics 28 statistical program, in which descriptive and inferential statistics were applied, as well as the Wilcoxon nonparametric hypothesis test. The results obtained showed that the use of the Web Application has a positive influence on the improvement of competencies in the area of mathematics, given that the significance obtained in its dimensions was less than 0.001, which is less than the theoretical significance $\alpha = 0.05$, thus rejecting the null hypothesis and accepting the alternative hypotheses proposed.

Keywords Web application · Competencies · Mathematics area

1 Introduction

Education over the years has been an important engine for the development of a country, considered as one of the most effective instruments for the consolidation of peace, poverty reduction, health improvement, achievement of gender equity, and

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stability. It is clear to say that education is a fundamental human right of all people that must be granted of the best quality for the improvement of students' lives and the eradication of illiteracy in the world [1].

According to Ref. [2], education has undergone significant changes in which technology has played an important role, since it has changed the ways of teaching and learning in educational institutions where classes were taught in a traditional way, but today they have given way to new methodologies that make use of Information and Communication Technologies, since they provide tools, resources, and programs to enrich students' learning. In addition, they are very useful for teachers' pedagogy, making it more didactic through visual, interactive, and novel aspects [3].

The use of ICTs in the world is no longer exclusive to developed countries, as they have gained importance in different countries, highlighting the possibilities offered by their tools to improve the quality of education [4]. This can be demonstrated by countries such as China, Singapore, Estonia, Canada, and Finland, which are the countries with the best education worldwide according to the reports obtained from the PISA 2018 tests because they stand out with good scores in the 3 areas evaluated, especially in mathematics, this is because they apply one of the best educational policies for the development of a country since they also bet very strongly on the advancement of technology [5]. On the other hand, in Peru, the results obtained in the PISA evaluation were not very gratifying. This problem is due to the fact that our country continues to occupy the last places, which shows that it is still far below several Latin American countries, which has alerted MINEDU to take decisions to improve the learning of schoolchildren [6]. Likewise, the latest national evaluations that were carried out and implemented by the Office for the Measurement of the Quality of Learning (UMC) of MINEDU show us that the results are not the expected and sufficient, since there is a percentage of students who still do not achieve the learning established and expected by the curriculum [7]. These problems show us that we must change the ways of teaching and learning in Peru, opting for new methodologies that benefit student learning using ICT, as they will allow us to eliminate traditional methodologies where students are memoristic and repetitive [8].

To solve this problem, it was proposed to design and implement a web application to help strengthen skills in the area of mathematics, providing through these games, readings and evaluations to strengthen the knowledge of students and then complement this process through the reports obtained that will be reviewed by teachers and will serve to determine which topics should be strengthened and thus improve the performance of their students.

This work is structured as follows: Sect. 2 contains the bibliographic study. Section 3 details the methodology implemented and its development. Section 4 presents the results and hypotheses of the indicators studied and their discussions derived from the analysis of the results. Finally, Sect. 5 presents the conclusions.

2 Bibliographic Study

Mathematics is a deductive science that focuses on the study of the properties and links existing in abstract elements such as numbers, geometric figures, icons, and among others [9]. Learning mathematics helps people to be able to search, organize, systematize, and analyze data to understand the world around them. This in order to develop themselves to be able to make decisions and solve problems in different situations in which they apply their knowledge and strategies acquired from this science. According to the National Curricular Design, the Mathematics Area is governed by a set of competencies that function as an ability to face different situations of reality in an effective way. The use of these competencies makes students remain in a constant learning process during their academic trajectory allowing them to demonstrate their mastery in the topics given in class [10].

In this process, mathematical knowledge is provided so that students are able to understand the topics covered in the area of mathematics such as units of measurement, understanding of natural numbers, statistical analysis, among others, in order for them to be able to be able to solve different problems using or applying this knowledge, not only in the academic field but also in everyday life [11].

According to the national curriculum proposal, the Mathematics Area is classified into 4 competencies, which define that mathematics has been developed as a means to describe, understand and interpret natural and social phenomena that have motivated the development of certain mathematical procedures and concepts specific to each situation [12]. The competencies in mathematics are shown in (Table 1).

Table 1 Competencies in the area of mathematics

Competencies	Approach
Solve quantity problems	Students should be able to solve problems or propose new ones that require building and understanding knowledge about number, number systems, their operations and properties [10]
Solve problems of regularity, equivalence and change	Students are able to characterize equivalences, generalize regularities and compare magnitudes, through general rules that allow them to find unknown values, solve restrictions and make predictions about the behavior of a phenomenon [10]
Solve problems of shape, motion and location	Students are guided and describe the position and movement of objects, as well as themselves in space, visualizing, interpreting, and relating the characteristics of objects with two-dimensional and three-dimensional geometric shapes [10]
Solve problems of data management and uncertainty	Students are able to analyze data on a specific topic (interest-study-random situations), allowing them to make decisions, reasonable predictions, and conclusions supported by the information produced [10]

3 Methodology

Agile methodology is considered the approach to decision making in projects, usually software projects, based on iterative and incremental development. It allows to manage projects in a flexible, autonomous and efficient way, reducing costs and increasing productivity. In addition, it is guided by the "Agile Manifesto" which is composed of 4 values and 12 principles that improve software development [13].

In this research we worked with SCRUM because of its flexibility and simplicity. This framework focuses on teamwork between client and supplier, where project members use a set of best practices and collaborative work to obtain the best result in product delivery. It is composed of Scrum Teams and their roles, events, artifacts, and rules that relate them, where all of them are essential for Scrum success [14]. The results of the "14th Annual State of Agile Report" have determined that this framework has been the most accepted and widespread globally, with 75% of respondents worldwide using it to address development problems [15].

3.1 Research Design and Type

According to its approach, this research is applied, since it is aimed at providing solutions to specific problems of society through the consolidation of knowledge for its application in different sectors, thus generating cultural and scientific development [16]. Likewise, the research presents a quasi-experimental experimental design because this type of design allows manipulating at least one independent variable in order to observe the effects on the dependent variables. This type of design differs from the "pure" ones, because the subjects are not randomly assigned, but the groups are already formed before the experiment and are called "intact groups". Similarly, in the quasi-experimental design, the "treatment" will be applied to the test group; on certain occasions a pretest will be applied, but a post-test will be applied [16].

3.2 Population and Sample

According to Ref. [17], a population is the set of all the measures of an investigated variable. For this research, the population will consist of 30 students in the 4th grade of primary school at I.E.P Alma Mater, in the district of Carabayllo. Lima-Peru 2021.

The sample is a representative subset of the population because it reflects the characteristics of the population. For this research, the calculation of the sample resulted in 30 students, of which 15 were classified in the Control Group and 15 in the Experimental Group.

3.3 Data Collection Instruments

The survey technique was used for this research, which is defined as an investigation conducted on a sample of specific individuals from a larger group [18].

The instrument used for the research is the questionnaire given that it is an instrument to be used through objective tests, this is defined as a "set of questions addressed to a representative sample or to the total set of the population under study with dichotomous scales", for the variable competencies in the area of Mathematics [19]. The SPSS software version 28 was used for the analysis.

3.4 Methodology Development

Sprint 1. According to the TaskBoard setup, the Sprint 1 user stories were classified as follows:

S01: The complete database was created with all the fields and parameters necessary for the operation of the web application activities (Fig. 1).

S02: The application login was developed which validates the data entered by the user, in case they are incorrect (shows error message) or correct (sends to the start interface).

S03: The user management interface has been developed with options for registration, modification, and deletion in the case of students and teachers.

S04: The exercise management interface was developed with options for registration, modification, and deletion. In the case of "Registration", an exercise is created with the type Assessment or Task, the corresponding unit, the type of competency of the exercise and the answers assigned through the combo box. And in the case of modification or deletion, the preloaded data are brought in from the search interface for the respective change or deletion.

Sprint 2. Following the TaskBoard, the user stories of Sprint 2 were classified as follows:

S05: The Unit Evaluation interface was developed, which is divided by competencies, each one with different themes corresponding to its unit. In this the student will have to review the topics covered in class complemented with didactic games and animations so that they can practice and understand each topic covered in class. Finally, they end with an evaluation to analyze how much the student understood (Fig. 2a).

S06–S07: The Student Search interface was developed, which contains the entire list of registered students. Also, for the teacher that contains all the list of registered teachers teaching Mathematics.

S08: The Administration Panel interface was developed with the results of the evaluations given by the students specifying the unit, their average and final score of each one of them. In addition, there is a button called "Detail" to be able to visualize

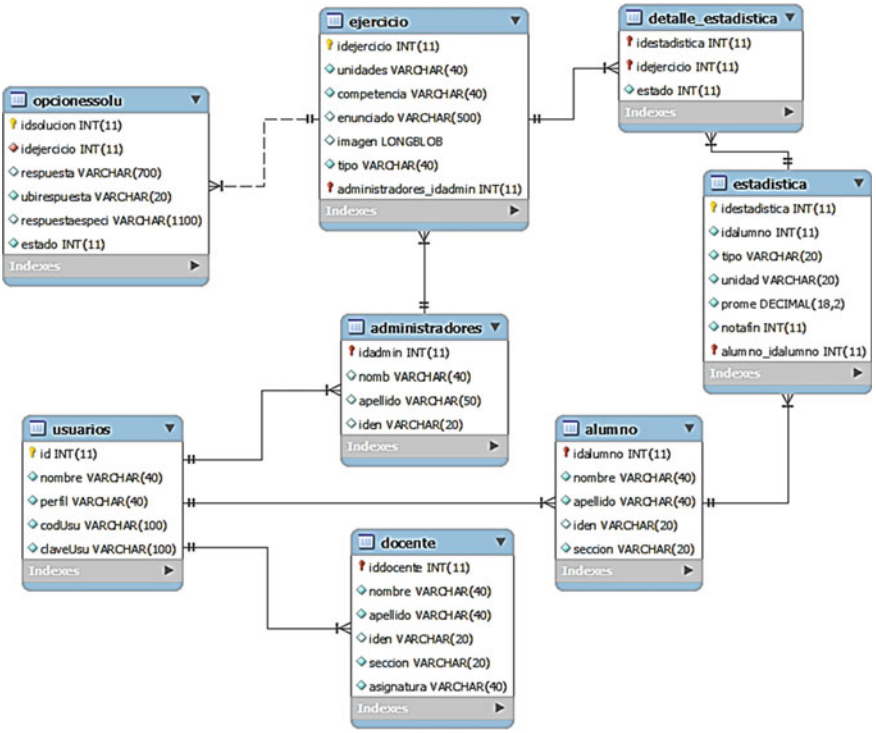

Fig. 1 Story developed in Sprint 1

in a more detailed way their evaluation showing the scores of each student with respect to the competencies evaluated in the unit (Fig. 2b).

S09: The Statistical interface was developed with the results of the evaluations given by the student specifying the unit, their average and final score.

Sprint 3. Finalizing the TaskBoard, the user stories of Sprint 3 were classified as follows:

S10: The Task interface was developed with some unit buttons, of which when one of them is selected, a list of previously registered exercises will be shown, which will be classified according to their corresponding competencies (Fig. 3).

S11–S12: The interface Queries was developed, where it shows the results of the evaluation and tasks, showing in both their averages and final grade. Likewise, the Reports interface was developed, where students and teachers are shown with all the information that was initially registered, and for the last report, the evaluations are shown with fields that describe the student's information and the results of the evaluations by unit.

S13: The administrator's menu page was developed where all the requirements are indexed in a visible and understandable way for the administrator's use.

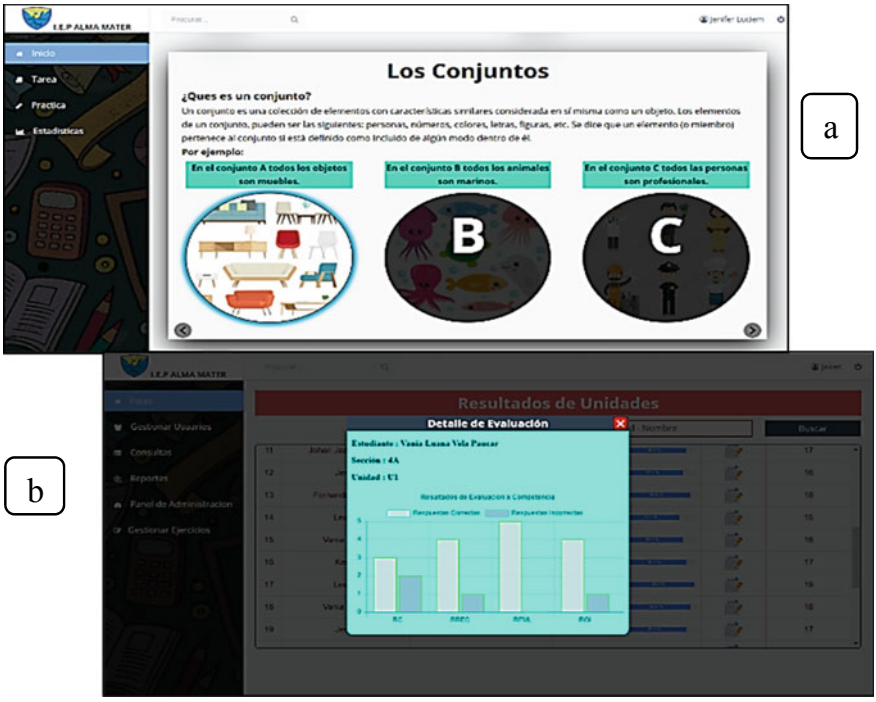

Fig. 2 Stories developed in Sprint 2

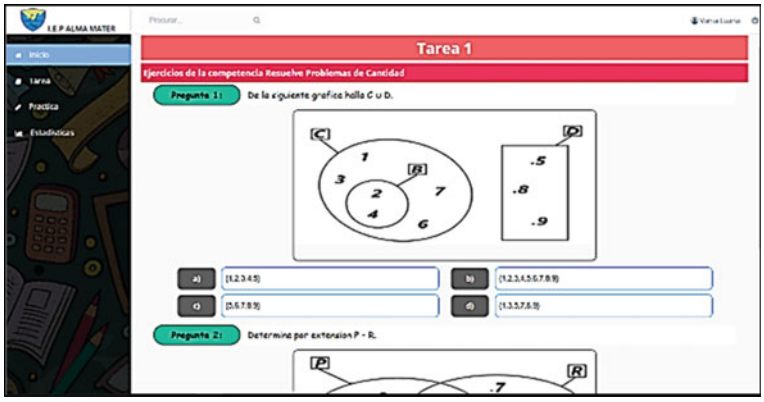

Fig. 3 Story developed in Sprint 3

S14: The main login page was developed, where the login access link, the support link, and the web application information are located.

4 Results and Discussion

4.1 Descriptive Analysis

Indicator 1–Number of quantity problems solved. According to the results observed in Table 2, the control group in the pre-test obtained a mean value of 2.07 and for the post-test a value of 2.60, which determines that there was no significant increase with respect to their learning, since it increased by 25.6%. However, in the case of the experimental group, the pre-test obtained a mean value of 2.13 and for the post-test a value of 4.13, which shows an increase of 93.90%.

Indicator 2—Number of solved regularity, equivalence and change problems. According to the results observed in Table 3, the control group in the pre-test obtained a value in the mean of 2.13 and for the post-test a value of 2.40 which determines that there was no significant increase with respect to their learning since it increased by 12.68%. However, in the case of the experimental group, the pre-test obtained a mean value of 2.13 and for the post-test a value of 4.27, which shows an increase of 100.47%.

Indicator 3—Number of solved problems of shape, motion and location. According to the results observed in Table 4, the control group in the pre-test obtained

Table 2 Pre and post results of the control and experimental groups on Indicator 1

Levels	Pre Test				Post test			
	Control		Experimental		Control		Experimental	
	fi	fi%	fi	fi%	fi	fi%	fi	fi%
Beginning	9	60.0	8	53.3	7	46.7	0	0.0
Process	4	26.7	7	46.7	3	20.0	3	20.0
Expected achievement	2	13.3	0	0.0	5	33.3	7	46.7
Exceptional achievement	0	0.0	0	0.0	0	0.0	5	33.3
Mean	2.07		2.13		2.60		4.13	
Median	2.00		2.00		3.00		4.00	
Mode	2		3		4		4	
Standard deviation	1.280		0.915		1.298		0.743	
Variance	1.638		0.838		1.686		0.552	

Table 3. Pre and post results of the control and experimental groups on Indicator 2.

Levels	Pre test				Post test			
	Control		Experimental		Control		Experimental	
	fi	fi%	fi	fi%	fi	fi%	fi	fi%
Beginning	10	66.7	11	73.3	10	66.7	0	0.0
Process	3	20.0	2	12.3	2	13.3	2	13.3
Expected achievement	2	13.3	2	13.3	3	20.0	7	46.7
Exceptional achievement	0	0.0	0	0.0	0	0.0	6	40.0
Mean	2.13		2.13		2.40		4.27	
Median	2.00		2.00		2.00		4.00	
Mode	2		2		2		4	
Standard deviation	1.125		0.990		0.986		0.704	
Variance	1.267		0.981		0.971		0.495	

a value in the mean of 2.13 and for the post-test a value of 2.60 which determines that there was not a significant increase with respect to their learning since it increased by 22.07%. However, in the case of the experimental group, the pre-test obtained a mean value of 2.33 and for the post-test a value of 4.13, which shows an increase of 77.25%.

Table 4 Pre and post results of the control and experimental groups on Indicator 3

Levels	Pre test				Post test			
	Control		Experimental		Control		Experimental	
	fi	fi%	fi	fi%	fi	fi%	fi	fi%
Beginning	9	60.0	9	60.0	7	46.7	2	13.3
Process	5	33.3	2	13.3	5	33.3	2	13.3
Expected achievement	0	0.0	3	20.0	2	13.3	3	20.0
Exceptional achievement	1	6.7	1	6.7	1	6.7	8	53.3
Mean	2.13		2.33		2.60		4.13	
Median	2.00		2.00		3.00		5.00	
Mode	3		1		2		5	
Standard deviation	1.246		1.447		1.242		1.125	
Variance	1.552		2.095		1.543		1.267	

Table 5 Pre and post results of the control and experimental groups on Indicator 4

Levels	Pre test				Post test			
	Control		Experimental		Control		Experimental	
	fi	fi%	fi	fi%	fi	fi%	fi	fi%
Beginning	9	60.0	9	60.0	4	26.7	1	6.7
Process	5	33.3	5	33.3	9	60.0	1	6.7
Expected achievement	1	6.7	1	6.7	2	13.3	8	53.3
Exceptional achievement	0	0.0	0	0.0	0	0.0	5	33.3
Mean	2.13		2.13		2.80		4.13	
Median	2.00		2.00		3.00		4.00	
Mode	2		1		3		4	
Standard deviation	1.060		1.060		0.775		0.834	
Variance	1.124		1.124		0.600		0.695	

Indicator 4—Number of solved problems on data management and uncertainty. According to the results observed in Table 5, the control group in the pre-test a value in the mean of 2.13 and for the post-test a value of 2.80 which determines that there was not a significant increase with respect to their learning since it increased by 31.46%. However, in the case of the experimental group, the pre-test obtained a mean value of 2.13 and for the post-test a value of 4.13, which shows an increase of 93.90%.

4.2 Contrastation of Hypotheses of the Indicators

According to the results observed in Tables 6 and 7 it is shown that the tables corresponding to the indicators present in the hypothesis test a significance level of less than 0.001, which is less than the theoretical significance $\alpha = 0.05$ thus determining, through statistics, that the use of the Web Application substantially improves the learning of competencies in the area of mathematics.

5 Conclusions

Currently most institutions continue to use very traditional methodologies in teaching and learning, without knowing the benefits and advantages of ICT, which is why the development of this project was proposed to demonstrate through the results obtained as it affects the implementation of a Web Application in the learning process in the

Table 6 Contrast of hypotheses indicators I1 y I2

Test statistics		
	I1 PostTest–I1 PreTest	I2 PostTest–I2 PreTest
Z	−4.080[b]	−3.769[b]
Sig. asin. (bilateral)	<0.001	<0.001
Exact significance (bilateral)	<0.001	<0.001
Exact significance (unilateral)	<0.001	<0.001
Probability at point	0.000	0.000

[a]Wilcoxon signed-rank test
[b]It is based on negative ranges

Table 7 Contrast of hypotheses indicators I3 y I4

Test statistics		
	I3 PostTest–I3 PreTest	I4 PostTest–I4 PreTest
Z	−3.804[b]	−4.018[b]
Sig. asin. (bilateral)	<0.001	<0.001
Exact significance (bilateral)	<0.001	<0.001
Exact significance (unilateral)	<0.001	<0.001
Probability at point	0.000	0.000

[a]Wilcoxon signed-rank test
[b]It is based on negative ranges

area of mathematics where it is observed through the results that provides students with great motivation and better academic performance. In addition to being a great support in teaching methodologies making them more dynamic and interactive.

From the results obtained, it was demonstrated that the use of the Web Application positively influences the improvement of competencies in the area of mathematics; given that the significances obtained in its dimensions were less than 0.001, which is less than the theoretical significance $\alpha = 0.05$, thus rejecting the null hypotheses and accepting the alternative hypotheses raised that focus on the improvement of learning for each of the competencies in the area of mathematics.

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Optimization of a Photovoltaic Station for Charging Electric Vehicles

Saul Beltozar Clemente, Winy Livet Herrera Escandon, Orlando Iparraguirre-Villanueva, Joselyn Zapata-Paulini, and Michael Cabanillas-Carbonell

Abstract The constant struggle to reduce greenhouse gas emissions caused by internal combustion vehicles makes electromobility a latent alternative solution. The main difficulty in its implementation is the scarce or non-existent presence of solar charging stations for electric vehicles in all regions. This paper illustrates the design optimization and simulation of an electric vehicle charging station that integrates solar energy. An optimal design of the charging station with MPPT, PID controllers, as well as current control strategies, is shown. The design took into account the dynamic needs such as the geographical area of maximum irradiance using PV GIS, an optimal system with PVsyst, the design, and simulation of the charging station showing the dynamic values of power versus time, as well as current versus time, validated by MATLAB/Simulink. After sizing it was obtained that the optimal charging station should have 3 photovoltaic systems of 19 modules distributed in 5 strings each, providing an average daily electrical power of 684 kWh.

Keywords Charging station · Photovoltaic · Solar energy · Electric vehicles

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1 Introduction

Climate change is a global emergency, this problem requires coordinated solutions at all levels in order to move toward a low-carbon economy, it was established in the Paris agreement, substantially reduce greenhouse gas emissions which would keep the increase in global warming levels below 2 °C by the end of the century [1]. Moreover, the transportation sector in Latin America and the Caribbean contributes approximately 34% of global greenhouse gas emissions, a situation that has unleashed serious public health problems in several cities in the region [2]. Air pollution associated with suspended particulates PM, O_3, NO_2, SO_2, CO, CO_2 is one of the greatest environmental threats to human health, producing millions of deaths every year, mainly affecting the most vulnerable and marginalized populations. This pollution is mainly caused by internal combustion vehicles [3]. In this context, electric vehicles become a sustainable development tool because their energy comes from significantly less polluting sources, which would allow better environmental, social and economic benefits [4].

Markets for electromobility are expanding rapidly, the sale of electric vehicles accounted for 9% of the global market in 2021 which makes 16.5 million vehicles, which represents 4 times the number of vehicles in 2019 [5]. The production of batteries for electric vehicles is also increasing very rapidly and it is estimated that production by 2030 will only cover 50% of the demand for that year [6]. It is important to use renewable resources to a greater extent in electric vehicle charging stations to reduce the reduction of pollutants in the air [7].

The road toward the mass use of electric vehicles in our country is still very early compared to European countries, but it is starting to take its first steps very quickly [8]. The sale of hybrid and electric cars during 2021 was 1455 units representing 251.7% compared to those sold in 2020 and in turn, 397.5% compared to the units sold in 2019, which shows similar behavior to the massification of electric vehicles worldwide [9]. The charging infrastructure for these vehicles is still quite insipient in our country, we can only identify 46 stations mostly distributed in the capital and major cities of the coast, which makes it difficult to increase confidence in the autonomy of these vehicles when making long journeys [10]. Due to this context, an efficient charging station based on renewable energy based on the internal photoelectric effect in monocrystalline photovoltaic cells has a huge potential to be developed and massified in the geographical areas with the highest irradiance [11].

Currently, the battery capacity of new electric vehicles varies between 38 and 77.4 kWh [12] with the exception of high-end vehicles such as the Tesla Model S, which has a capacity of 207 kWh [13]. The charging time of the battery of an electric vehicle depends on the power of its internal charger, most electric cars have an internal charger of 7.2 kW [14]. Therefore, the trend in the latest research is to increase the effectiveness of the use of electric batteries [15] and thus overcome the current range limitations of electric vehicles [16]. It is very important to change our energy sources to more environmentally friendly sources, and electromobility is a latent alternative and is expected to grow steadily in the coming years, also

its increased demand requires more charging stations with an optimal and efficient design, complying with policies regarding the use of electric vehicles [17].

2 Methodology

This section presents the phenomenological explanation of photovoltaic cells, the method, and the detailed application for the development of the project.

The photoelectric effect is a phenomenon that consists of the emission of electrons from a conductive surface by the incidence of high-frequency electromagnetic radiation, causing ionization of the excited atom where most of the energy of the incident photon is transformed into kinetic energy of the emitted electrons [18]. This incident energy comes basically from the sun, which is a medium-sized star with a radius of approximately 700 thousand kilometers, allowing it to continuously emit a power of 62,600 KW per square meter of its surface [19]. Solar radiation covers a large amount of the electromagnetic spectrum, the maximum solar radiation is centered in the visible spectrum band with a peak in its wavelength of 500 nm corresponding to the cyan-green color, also the photosynthetic radiation band in the visible spectrum ranges between 400 and 700 nm distributed: blue-violet (400–490 nm), green (490–560 nm), yellow (560–590 nm), red–orange (590–700 nm) [20].

For the development of the case we chose the V model methodology, which although it is a method used for software development, it is very applicable to the project we are carrying out since it establishes several phases, where integration tests are performed as the phases are completed, allowing to verify the progress of each of the complements helping to avoid errors [21].

Figure 1 shows the various ways in which an electric vehicle can be charged: slow (3–7 kW), semi-fast (11–22 kW), and fast (50–150 kWh).

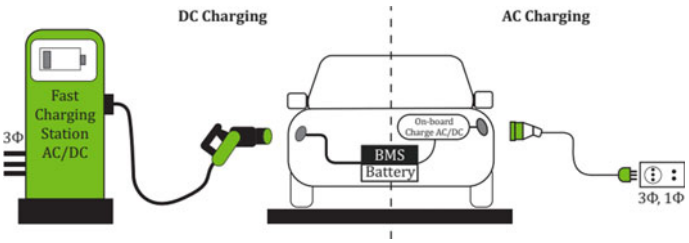


Fig. 1 Sistema de cargas de un vehículo eléctrico

2.1 2.1. Definition of Requirements

2.1.1 Photovoltaic Solar System

They consist of semiconductor plates of monocrystalline or polycrystalline silicon, and are responsible for transforming high-frequency electromagnetic radiation into electrical energy through the photoelectric effect.

To calculate the power in W_p generated by the photovoltaic system P_{SFV} we use the following equation:

$$P_{\text{SFV}} = \frac{L_{\text{md}}}{\text{HPS}_{\text{crit}} \times \text{PR} \times 1000} \tag{1}$$

where

L_{md} is the average daily energy consumption in kWh;
HPS_{crit} are the peak sunshine hours of the month;
PR is the overall performance factor.
The number of panels required is determined using the equation:

$$N_T = \frac{P_{\text{SFV}}}{P_{\text{MPP}}} \tag{2}$$

where

P_{MPP} is the power of the module in standard condition.

2.1.2 Selection of Grid Interconnection Inverters

The photovoltaic system shall be connected to a grid-tie inverter, considering that the nominal power of the inverter P_{inv}, should be between 80 and 90% of the power of the photovoltaic system.

$$P_{\text{inv}} = 0.8 \ldots 0.9 P_{\text{SFV}} \tag{3}$$

The voltage range of the MPP tracker of the inverter ($V_{\text{inv.min}} \ldots V_{\text{inv.máx}}$) must contain the maximum and minimum values that the photovoltaic system can supply at the maximum power point specified for a cell temperature of −10 °C and 70 °C, respectively, $\left(V_{\text{Gmpp(70 °C)}} y V_{\text{Gmpp(−10 °C)}}\right)$ in the 2 cases with an irradiance of 1000 W/m^2.

$$V_{\text{inv.min}} \leq V_{\text{Smpp(70 °C)}} \tag{4}$$

$$V_{\text{Smpp}} = N_s \times V_{\text{mpp(70 °C)}} \tag{5}$$

$$V_{\text{mpp}(70\,^\circ\text{C})} = V_{\text{mpp}} + \beta(T - 25) \tag{6}$$

$$V_{\text{inv.máx}} \geq V_{\text{Smpp}(-10\,^\circ\text{C})} \tag{7}$$

$$V_{\text{Smpp}(-10\,^\circ\text{C})} = N_s \times V_{\text{mpp}(-10\,^\circ\text{C})} \tag{8}$$

$$V_{\text{mpp}(-10\,^\circ\text{C})} = V_{\text{mpp}} + \beta(T - 25) \tag{9}$$

where

V_{Smpp} is the voltage of the photovoltaic system at its maximum power point at a given temperature;

V_{mpp} is the voltage of the photovoltaic module at its maximum power point at standard measurement conditions;

N_s is the number of panels in series;

β is the stress-temperature coefficient of the module;

T is the temperature.

The inverter must withstand the maximum voltage $\left(V_{\text{max.vació}}\right)$ that can be produced by the open-circuit PV system with a cell temperature of -10 °C and an irradiance of 1000 W/m^2.

$$V_{\text{max.vació}} \geq V_{\text{Soc}(-10\,^\circ\text{C})} \tag{10}$$

$$V_{\text{Soc}(-10\,^\circ\text{C})} = N_s \times V_{\text{oc}(-10\,^\circ\text{C})} \tag{11}$$

$$V_{\text{oc}(-10\,^\circ\text{C})} = V_{\text{oc}} + \beta(T - 25) \tag{12}$$

where

V_{Soc} is the no-load voltage of the PV system at a given temperature;

V_{oc} is the no-load voltage of the PV module at standard measurement conditions.

Maximum current ($I_{\text{inv.máx}}$) that the inverter must withstand when the PV system is short-circuited with a cell temperature of 70 °C and an irradiance of 1000 W/m^2.

$$I_{\text{max.vació}} \geq I_{\text{Ssc}(70\,^\circ\text{C})} \tag{13}$$

$$I_{\text{Ssc}(70\,^\circ\text{C})} = N_p \times I_{\text{sc}(70\,^\circ\text{C})} \tag{14}$$

$$I_{\text{Sc}(70\,^\circ\text{C})} = I_{\text{sc}} + \alpha(T - 25) \tag{15}$$

where

I_{Ssc} is the maximum short-circuit current of the PV generator at a given temperature;

I_{sc} is the short-circuit current of the PV module at standard measurement conditions;

N_p is the number of parallel panel strings;

α is the current–temperature coefficient of the module;

T is the temperature.

2.1.3 Selection of Protection Devices

PV generator protection. For each photovoltaic generator, a string box shall be installed to connect in parallel 5 strings with 19 photovoltaic modules connected in series. Each string box shall have at least 10 cylindrical fuse holders for 10 × 38 mm fuses, where the fuse size is determined by the following equation:

$$I_f = 1.5 \ldots 2I_{sc} \tag{16}$$

where

I_f is the current withstand strength of the fuse.

Likewise, the rated voltage (V_f) that supports the fuse is determined by the following equation:

$$V_f \geq 1.2V_{Soc} \tag{17}$$

Inverter protection. A thermomagnetic switch shall be placed at the output of each inverter having to comply with the output characteristics of the inverter:

Rated current: $I_n \geq 19.66A$.

Rated working voltage: $V_n = 380VAC$.

Protection of Wallbox chargers. A thermomagnetic switch will be placed in each circuit of each 11 kW Wallbox charger, having to comply with the charger's characteristics.

Rated current: $I_n \geq 48.26A$.

Rated working voltage: $V_n = 380VAC$.

2.1.4 Inverter with Charge Controller

Converts the low-voltage direct current coming from the solar panel into a conventional power outlet (alternating current). It efficiently manages the energy to the batteries protecting the system from overcharge and over discharge. To calculate the input current I_{ent} to the regulator is used:

$$I_{ent} = 1.25 \times I_{MODSC} \times N_p \tag{18}$$

where

I_{MODSC} is the unit current of the PV module under short-circuit conditions;
N_p is the number of parallel branches;
1.25 is the safety factor.

2.2 2.2. *Functional System Design*

Figure 2 shows the model of the electric vehicle charging station, which requires 3 solar photovoltaic systems, each consisting of 95 photovoltaic modules distributed in 5 strings of 19 polycrystalline photovoltaic modules each. For each string a string box is installed to monitor the current flow and detect any anomaly, a three-phase grid inverter is also connected to the system, a wattmeter to measure the power delivered, all connected to the general electrical panel in the same way as the electrical chargers, and a new primary network is also being considered.

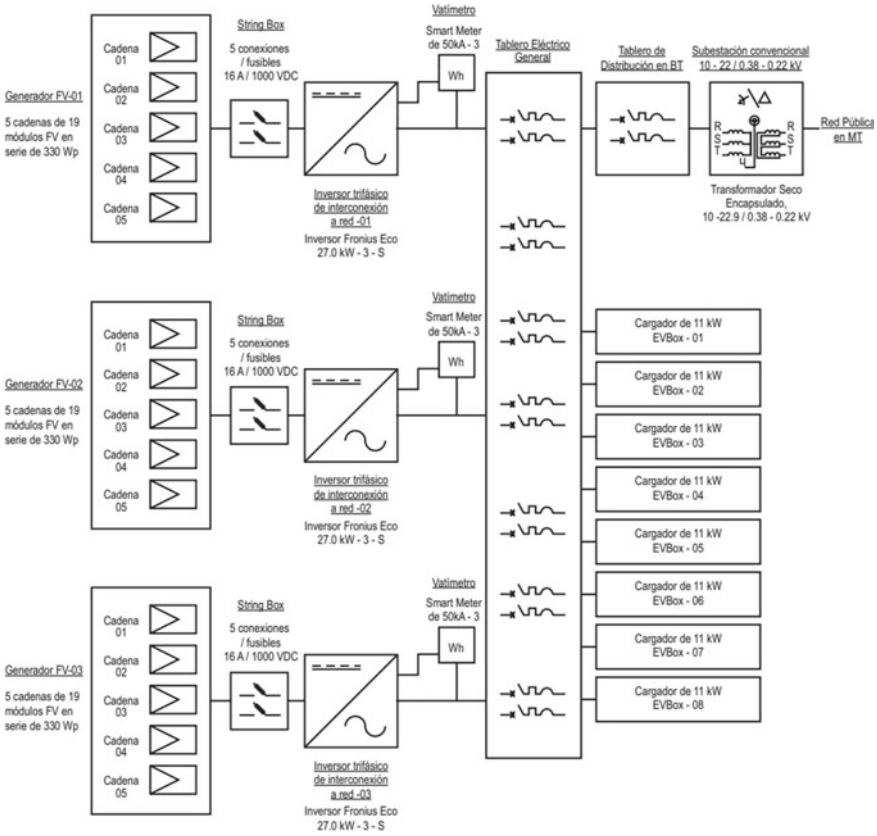


Fig. 2 Functional schematic diagram of the charging station

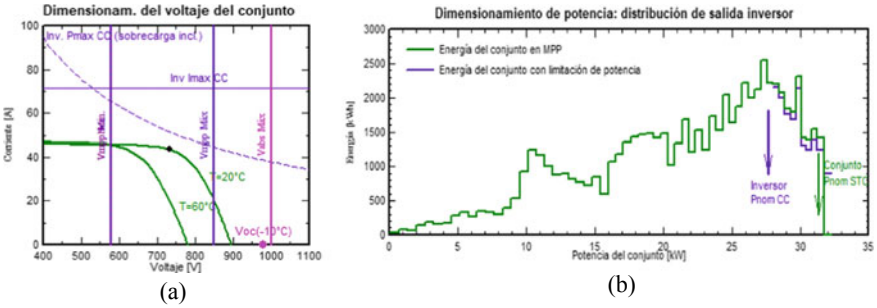
To perform the simulation in the PVsyst 7.2 software, we selected the typical meteorological year and based on the data from the PVGIS platform that works with the 2005–2015 database, provided by the national renewable energy laboratory. A geographic region was chosen where we can obtain a higher efficiency of our photovoltaic module, being selected the geographic coordinates latitude −12.0651 and longitude −75.2049 for the simulation process.

3 Results and Discussion

The results show that the following are needed 95 polycrystalline photovoltaic modules of 330 Wp from Amerisolar are required, distributed in 5 strings of 19 modules each, a three-phase grid-tie inverter of 27 kW–580/850 V of Fronius Eco brand, and a three-phase inverter of 27 kW–580/850 V of Fronius Eco brand. Each photovoltaic system generates 31.35 kWp of power in an area of 186 m^2 and the entire charging station generates 91.08 kWp of power in a total area of 568 m^2.

Figure 3 shows the sizing of the voltage, electrical power Fig. 3a shows the result of the variation of the current originated in the photovoltaic system which maintains a constant average value of 34 A for voltages lower than 600 V and an ambient temperature higher than 20 °C, Fig. 3b also shows the energy supplied by the MPP inverter reaches a maximum value of 2500 kWh and then decreases to its initial operating values.

Figure 4 shows the electrical energy injected by each photovoltaic system where the daily average is 228 kWh, making a total of 684 kWh daily of energy provided by the entire photovoltaic charging station, which is quite optimal for the execution of the project.



(a) (b)

Fig. 3 Voltage/power sizing

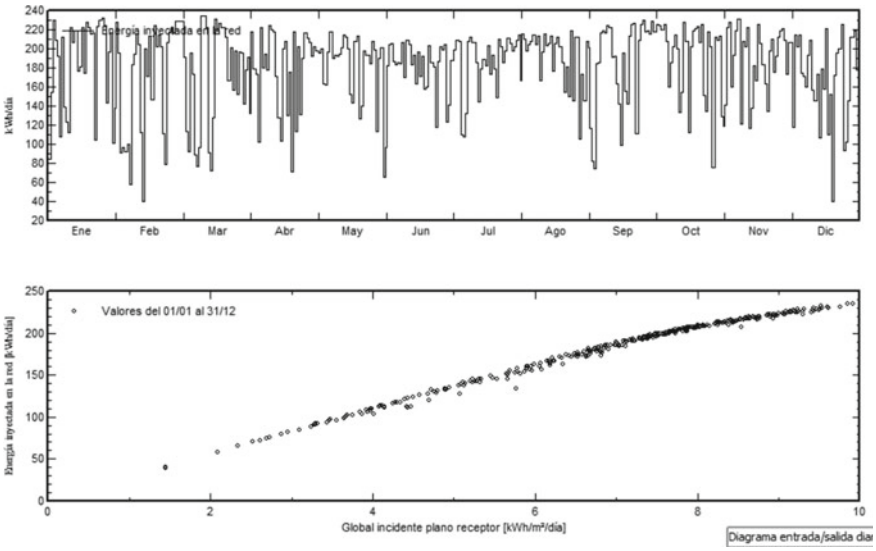


Fig. 4 Electrical output power

4 Conclusions

An electric vehicle charging station using photovoltaic cells is the most efficient way to counteract the effects caused by the gases emitted mainly by internal combustion vehicles.

In order to implement the charging station for electric vehicles, the following processes had to be followed (1) identification of vehicle battery characteristics in the charging process (2) search for the optimal zone with the best irradiance during most of the year (3) design the charging station according to the parameters established for each of its parts such as photovoltaic cells, inverters, and protection devices.

The optimal charging station requires 95 photovoltaic modules, distributed in 5 strings of 19 modules each, a three-phase inverter for interconnection to the grid of 27 kW–580/850 V. Each photovoltaic system generates 31.35 kWp of power over an area of 186 m^2 and the entire charging station generates 91.08 kWp of powerel on a total area of 568 m^2.

This study has both a theoretical and practical scope. As for the theoretical scope, it provides all the equations, formulas, and technical specifications that each of the devices to be used in the project must have. In practical terms, this study recommends to apply it in similar situations in those areas where the implementation of the charging station is required, even for other uses such as domestic or industrial. Finally, this project is not free of limitations, both in the theoretical and practical part, since similar studies have very different utility objectives to the one shown in the text, this allows future research work to better optimize the requirements.

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Predictive Model with Machine Learning for Academic Performance

Carlos Cecenardo-Galiano, Carolina Sumaran-Pedraza, Luz Obregon-Palomino, Orlando Iparraguirre-Villanueva, and Michael Cabanillas-Carbonell

Abstract Academic achievement (AP) in recent years has shown minimal progress with a difference of 0.05%, according to the report made by the Program for International Student Assessment (PISA). For this reason, the objective of this research is to build a predictive multiclass classification model for the AP of students in an elementary school. It was conducted with a dataset of 218 third-year high school students. The Cross Industry Standard Process for Data Mining (CRISP-DM) methodology was used to create the model, which consists of 6 phases and is effective in data mining (DM) projects. The random forest (RF) algorithm was also used. The results indicated that the RF model obtained the highest prediction rates compared to other studies, with an accuracy of 95% of the model, respectively. Finally, it is observed that the attributes that mostly influence prediction are the scores of Ability 02 end of I bimester, Positive Impression, Ability 01 end of I bimester, Ability 03 end of I bimester, and Adaptability. Thus, it is concluded that academic attributes are more relevant than psychological attributes in predicting RF.

Keywords Academic performance · Machine learning · Predictive modeling

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1 Introduction

The PA is very important in the educational system, so there are certain difficulties on the part of the student that impede their academic progress. Likewise, [1] mentions that the PA is the measurement of certain capacities acquired by the student through his or her formative process. For this reason, there are factors that influence learning such as socioeconomic factors [2], academic experiences [3], psychopathological aspects [4], and psychological factors [5], being this last factor where there are worrying levels of depression and low self-esteem, since it generates a negative impact on the student's PA, it is here where this factor will be taken into account as well as the academic factor in the development of this research. In addition, the Organization for Economic Co-operation and Development (OECD), conducted PISA, where the AP is compared to measure the level of competencies, knowledge, and skills of 15-year-old students every three years in 79 countries [6]. In such a way that Peru is one of the voluntary countries to perform these evaluations, where the results of the average measure for mathematics were 400 points, science with 404 points, and reading with 401 points, having in this last area as a result the level of performance in 54.4%, where it is observed that there was minimum academic progress from the years 2009 to 2018 with a difference of 0.05% [7]. Similarly, the Regional Comparative and Explanatory Study (ERCE) evaluates students' PA through the curricula applied in the 16 participating countries [8]. Peru is one of the countries that participated in this study, where reading, writing, mathematics, and science instruments were applied in the 3rd and 6th grades of primary school, to compare achievements and identify challenges, in which the analysis of the factors that influence learning was carried out. Therefore, it is observed that in the area of reading, the results were not optimal, since it remains at the level of achievement in progress, meaning that it is not possible to overcome this competitive level since there are difficulties in the academic process of the Peruvian student [9]. However, in the educational field, it took many years to apply artificial intelligence (AI) technology, especially in machine learning (ML) through predictive analysis performed by the algorithm for decision-making, in order to make new educational strategies and to be able to favor the student through the evaluation of activities or the management of student data, so as to provide educational quality in the process of knowledge and improve academic results [10]. In [11], he mentions that RF is one of the best models compared to other algorithms since it produces categorical maps based on decision trees to make predictions of success. For this reason, the algorithm to be applied in this research will be the RF. The main objective of the research is to develop a predictive model that predicts the AP of students in a public school in Peru, making use of the RF, because it is a very effective algorithm in the academic field and at the same time mentioned by other studies with similar topics.

2 Bibliographic Study

The PA is a very important issue in education as well as knowing the level or academic ability of the student and thus knowing what are the characteristics that could influence a student to have a low AP. In AP, it is necessary to know the level of knowledge of a student, because of this, they began to study the data that helped to find various factors that were related to learning, as well as to know the variables that were related to the AP thanks to the predictive model, by which they made the prediction and provided support to the teacher for the implementation of new strategies to help the educational quality [12]. In [13], a model was applied where the machine was given to make decisions based on student data, with previous data for the prediction of the students' average and making use of the RF algorithm, decision tree (DT), and linear regression (LR), where they identified that the algorithm with the highest accuracy was RF since it obtained a high average score based on its variables. In the same way, in [14] they used as data the evaluations of the practical work of the students within the version control system, to predict the academic level and evaluate them through the Model Evaluator (MoEv); at the same time, they also used the selection of characteristics in the input data, in order to obtain an accurate model and where it could be seen that the appropriate algorithms for the dataset were the RF that obtained 0.8% validation score, also the Naive Bayes (NB) with 0.8%, and the parametric method with 0.7%, being a precise validation score for the prediction of academic success. On the other hand, [15] mentions that making use of data from an online platform will be used to perform the empirical analysis in the verification of the reliability and feasibility of the algorithms that will perform the prediction of AP in online education, where they analyzed the DT and RF algorithms, obtaining the latter, as a result, a higher accuracy of 90%, which shows that the prediction helped both the teacher and the student to have significant improvements in learning and teaching. Likewise, in [16] they identified the characteristics that influence academic performance, where they were academic and socioeconomic characteristics, of which the proposed RF model obtained an accuracy of 0.833 and the F-measure with 0.831, while J48 obtained an accuracy of 0.794 and the F-measure 0.790. On the other hand, [17] used several resampling techniques, whose purpose was to handle the unbalanced data while performing the prediction with the two datasets, since for the verification of the problem method, they used the RF, K-nearest-neighbor (KNN), NN, XGBoost, SVM, DT, LR, and NB algorithms, achieving the best result using SVM-SMOTE as a resampling method with an accuracy of 78.44%.

3 Methodology

The methodology applied for this study is the CRISP-DM methodology, in order to perform the predictive model with machine learning for the PA of the basic-level public institution in Peru. According to [18], it mentions that the CRISP-DM

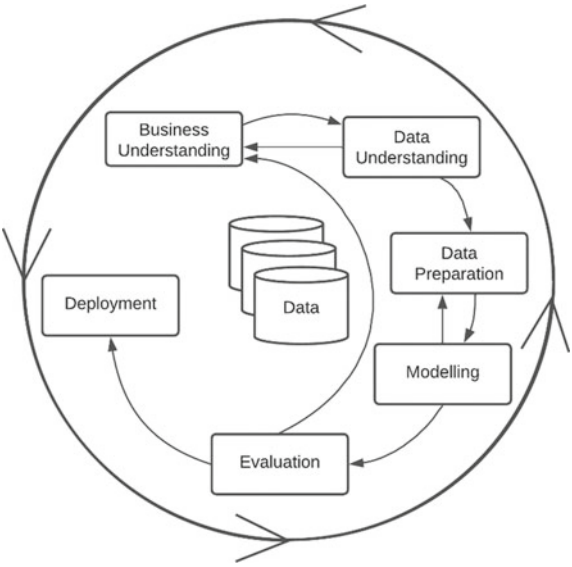


Fig. 1 Cycle of the CRISP–DM methodology

methodology is very efficient in data mining projects since this methodology is focused on performing the project tasks, to describe the development processes, which are composed of six phases: (1) business compression, (2) data compression, (3) data preparation, (4) modeling, (5) evaluation, and (6) implementation as shown in Fig. 1.

(A) **Understanding the business**

In this first phase of the CRISP-DM methodology, the understanding of the business is generated, which starts from the knowledge of the business objectives and at the same time of its needs, focusing on the determination of the objectives and requirements of the project, thus defining the main problem that can be solved by means of ML techniques, in which the problem of a public institution of basic level in Peru was analyzed, where it was verified that the students are presenting low levels in their PA; for this reason, the school will provide the information of the data of their students to identify and understand the requirements of the study, taking as a criterion of success the prognosis of the PA, to obtain high precision in the proposed model.

(B) **Understanding the data**

In this phase, business data are collected to analyze it, understand it, explore it, know its quality, find hidden data, etc. For the creation of the predictive model, the records of students who attended the 3rd year of high school were obtained, so that the final capacities of these same students in the 2nd year of high school as well as the capacities of the first bimester of 3rd year of high school and at the same time the psychological results of the evaluation of the Baron test, which

were carried out by the same students, where the information to be considered for the study would be reflected in the attributes of the database.

Table 1 shows the description of the data collected from the public elementary school, consisting of 21 attributes between psychological and academic data of 218 students, while the psychological attributes are numerical, and the academic attributes are mostly nominal. However, a certain amount of null data was identified because there were students in the 2nd year of high school who did not attend the 3rd year of high school, either by transferring schools or repeating the year, from which they will be eliminated later. In the same way, an imbalance was also identified in the weighted attribute through its results, since there were few students with a starting level and on the other hand more students with an expected level, thus clarifying that the public institutions of basic education in Peru consider as final grade or also called weighted, 4 levels of academic achievement.

On the other hand, Fig. 2 shows the final grades on the reading skills of the students of 3rd year of secondary school who were in 2nd year of secondary school in the same institution, showing that grades 1, 2, and 3 have "A" as the highest grade obtained by the students. In the same way, it is observed that the grades "AD" and "B" are almost similar in amounts obtained by the students, and the grade "C" is the lowest grade obtained by the students.

Table 1 Description of attributes

Description of attributes	
Name of attributes	ID, first name, last name, area name, grade, section, end capability 1 2nd, end capability 2 2nd, end capability 3 2nd, end capability 1 3rd, final capability 2 3rd, final capability 3 3rd, final weighted 3rd, intrapersonal, interpersonal, stress management, adaptability, and total emotional quotient
Type of results	In progress (B), expected (C), and outstanding (AD)

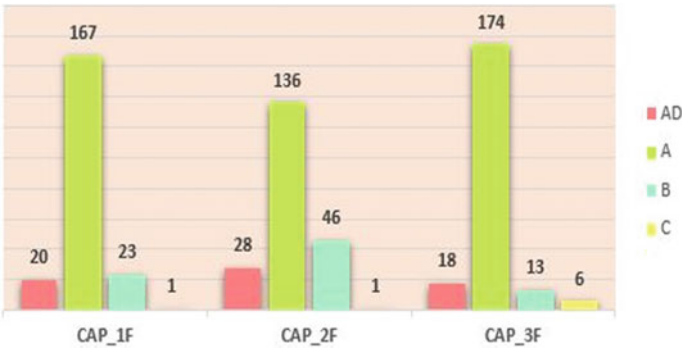


Fig. 2 Number of students obtained by grade in the 2nd year of secondary school final abilities

Likewise, Fig. 3 has a similar relationship with the previous figure, since the final capabilities of the first bimester of the students in the third year of secondary school, the grade "A" was the majority grade obtained. On the other hand, in the other grades, there was a small difference, since the grade "C" in capacities 1 and 2, there were no students who obtained that grade, and on the other hand, in capacity 3, the grade "AD" surpassed the grade "C" in the number of students obtained.

Finally, Fig. 4 shows the four levels of performance, which are the results of the weighted output attribute, where it can be seen that in 1 there are 8 students in the beginning stage of their PA, in 2 there are 36 students who are in the process of achieving a good PA, in 3 there are 141 students who are in the expected stage, which indicates that they are with a grade of "A", and finally in 4 there are 14 students who managed to establish themselves as outstanding with a satisfactory grade of "AD". At the same time, it is also possible to identify that the data provided by the educational institution are unbiased data.

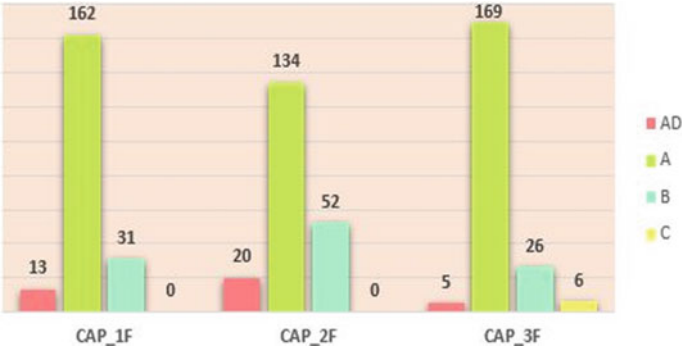


Fig. 3 Number of students obtained by grade in the final abilities of 3rd year of secondary school

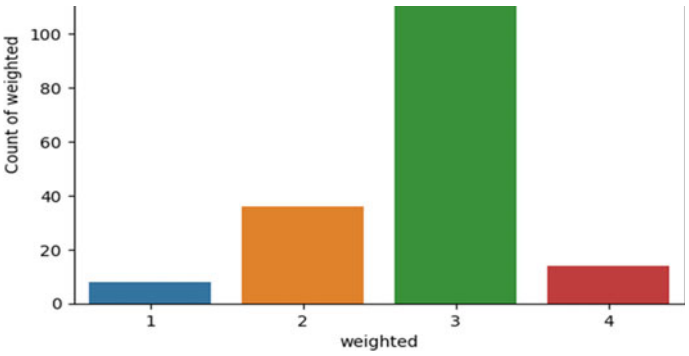


Fig. 4 Conteo de variables ponderado

(C) **Data preparation**

In this third phase, data processing activities will be carried out, where engineering techniques will be applied for the construction of the final database since it is necessary for the elaboration of the predictive model.

In this research, Excel techniques were applied, where the selection of relevant data, the cleaning of null and irrelevant data, the construction of new data, and finally the integration of the data were carried out. Thus, the arrangement of the data begins with the selection of the information, where there will be irrelevant data that will not contribute to the prediction, and then begins with the cleaning of the data identified as null and irrelevant, from which they were eliminated, leaving a record of 199 rows and 13 columns visualized in Table 2, and in the same way, the construction of new data will be carried out, where academic data were identified whose type is nominal and which will be replaced by numerical data, as well as psychological data whose type is an integer and which will have a limit of less than 140 and greater than 60, since the emotional quotient scores do not exceed those limits, thus ending with the data integration activity, where it will be integrated into the predictive model.

(D) **Modeling**

In this phase, the selection of the modeling technique is made, where the RF algorithm was selected and is an effective algorithm that creates models with higher accuracy in the results, because it is a classification algorithm with multiple DT and at the same time avoids the over-fits that DT has [19]. For this reason, the purpose of this study is to develop an ML model to predict the target

Table 2 Attributes with possible values

Attributes	Possible values
Total, emotional quotient	$140 > N > = 60$
Intrapersonal	$140 > N > = 60$
Interpersonal	$140 > N > = 60$
Adaptability	$140 > N > = 60$
Stress management	$140 > N > = 60$
Positive impression	$140 > N > = 60$
Ability 1 final	AD = 4, A = 3, B = 2, C = 1
Ability 2 final	AD = 4, A = 3, B = 2, C = 1
Ability 3 final	AD = 4, A = 3, B = 2, C = 1
Capacity 1 bimester	AD = 4, A = 3, B = 2, C = 1
Capacity 2 bimonth	AD = 4, A = 3, B = 2, C = 1
Capacity 3 bimonth	AD = 4, A = 3, B = 2, C = 1
Average	AD = 4, A = 3, B = 2, C = 1

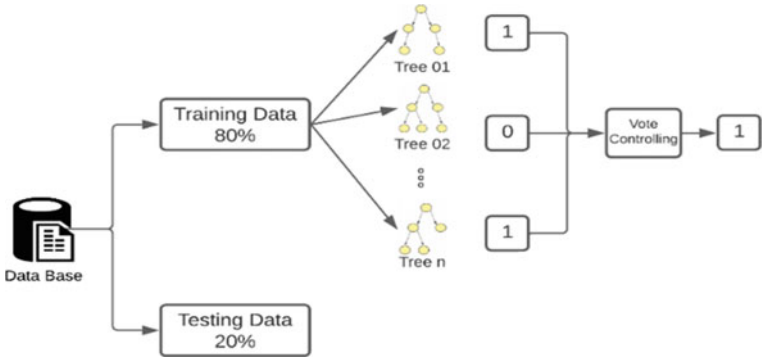


Fig. 5 Random forest prediction model

variable by means of rule-based learning, which is separated into two groups, the first being the training group, which will be made up of 80% of the records of the 3rd-year high school students with a total of 159 records, and the test group made up of 20% of the remaining records, with a total of 40 records. The output variable will be unknown, and at the same time, the algorithm will indicate whether the student is outstanding, expected, in process, or at the beginning, thus becoming a multiclass classification model. On the other hand, in the training stage, "n" DT will be constructed, and the majority voting method will be used to show more accurate forecasts, as shown in Fig. 5.

For the creation of the RF model, the commands will be carried out in the Jupyter Notebook console, where the dataset was divided into independent and dependent variables, whereby the dependent variable is the weighted students and the independent variables are the academic variables, as well as the psychological variables of the students. In the same way, the processed datasets will standardize the independent variables, using the StandardScaler method and will be divided into training data at 80% and test data at 20%. At the same time, it will have a random state of 2 rounds and an estimation of n trees, thus building the RF classifier, to train it on the training data and then make predictions on the test data.

(E) **Evaluation**

In this phase, the predictive model is evaluated to obtain a quality model, i.e., one that is reliable and accurate in predicting an outcome, while guaranteeing the objectives of the existing business problem. Thus, in this study the RF algorithm was used for the creation of the multiclass classification model, being programmed using Python Jupyter Notebook, where a variety of libraries were imported for its creation, in such a way that for the evaluation of the model the Scikit-Learn importing classification_report library was used, which serves to display the parameters already mentioned; in the same way, confusion_matrix was imported, and the matplotlib library, which is used to find the confusion

matrix and at the same time plot it, was imported from the same Scikit-Learn library to find the ROC curve and AUC, and the matplotlib library was imported to plot the performance curve.

(F) **Implementation**

In this last phase of Crisp DM, it will be analyzed whether the use of the information system will support the business need. After the evaluation of the predictive model, the implementation of the model will be carried out, where the monitoring and maintenance of the supervision of the data will be performed, since they will be continuously processed by the administrator and may be modified for some erroneous reason at the time of inserting the data since the implementation can be done through a web system or a mobile application that will have the connection with the server in the cloud. Finally, this phase is responsible for preparing a final report as well as fulfilling the objectives pursued in the development of the research through the model.

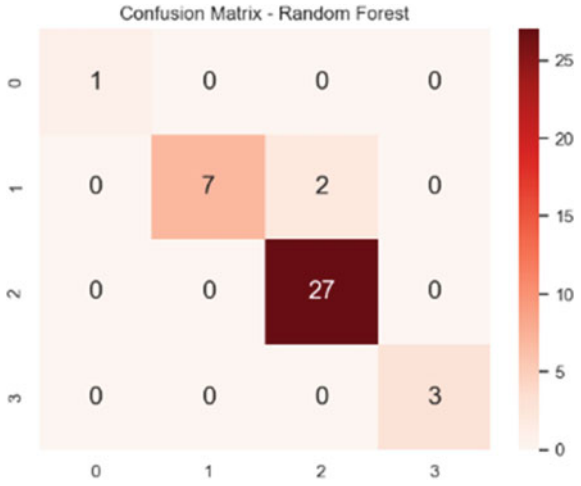
4 Results and Discussion

The main point of the research is to determine if the ML predictive model for the PA has a high predictive performance; for this reason, the correlations of the variables, performance parameters, the confusion matrix, and the ROC curve will be shown in graphs or tables, which will be shown as results as follows.

In Fig. 6, after running the classification model with the test dataset, we can evaluate its performance where the confusion matrix can be seen since it is responsible for identifying the incorrect and correct predictions of each of the weighted attributes, where the false positives and false negatives are the incorrect ones, while the true positives and true negatives will be correct. For this reason, it is identified that in class 0, which would be of the level in the beginning, it only has 1 correct prediction and 0 incorrect; in the same way in class 1 of level in the process, it has 7 correct predictions and 0 incorrect; on the other hand, in class 2 of level expected, it only has 27 correct predictions and 2 incorrect; and finally, in class 3 of level outstanding, it only has 3 correct predictions and 0 incorrect. Concluding that the model only had 2 false positives in class 2 of the expected level, where it is described that the model predicted 29 students with expected level, being that 2 students did not have that level.

After making the confusion matrix of the model, which is the basis for the following terms, the performance parameters are displayed, in which the accuracy parameter is the number of correct predictions, indicating that the model has 95% accuracy because there was a greater number of correct predictions, but it is also known that it is not a reliable parameter when having a model with unbalanced data [17], for that reason, in this study other parameters that are more reliable when it comes to seeing the performance of the predictive model of AP. Thus, in the accuracy parameter, where it is known that if the accuracy is 100%, this would indicate that all

Fig. 6 Confusion matrix



the predictions that the model made in that class are accurate and correct, but as we can see in the class of interest number 2, which is the expected level, it indicates that it has an accuracy of 93%, which would imply that all the predictions that the model had in that class were not accurate and correct; therefore, it did not have a maximum accuracy in its prediction, while the other classes do have a maximum accuracy of 100%. In the same way, the recall parameter or also called sensitivity mentions that it is the proportion of real true positives predicted by the model correctly, in which it can be observed that in class 1, the recall is at 70%, which would imply that not all students who really had a level in process were predicted by the model correctly, while in the other classes, they were predicted by the model since 100% was obtained.

Finally, the bracket shows the number of predictions for each class of the weighted attribute, being correct and incorrect, the most influential attributes in the prediction of the AP model, of which the attribute with the highest correlation is capability 2 of the first bimester of 3rd grade (CAP2BI), followed by the attribute positive impression (IMPRESPO), capability 1 of the first bimester of 3rd grade (CAP1BI), and capability 3 of the first bimester of 3rd grade (CAP3BI). From another point, it was also possible to identify the attributes with the lowest correlation, which were the interpersonal attribute (INTER) and capacity 2 of the second semester of the second year of the second bachelor's degree (CAP2F).

Finally, in Fig. 7 we have the ROC curve for the test data of the different results of the variable classes, where it is visualized that the result 0 and 3 would be of level in the beginning and outstanding, respectively, and have an area under the curve of 1.00; therefore, the performance of the model for the first result is good with respect to the TPR and FPR; on the other hand, we have the result 2 that would be of level expected, having the area under the curve of 0.92 almost approaching to 1. 92 almost approaching 1, interpreting that the model is also good for that result with respect to the TRP and FRP, and finally result in 1 indicates an area under the curve of 0.89, being a little farther from 1 but at the same time good in the

performance of the model with respect to the TPR and FPR, resulting in a good model for the prediction of each class of PA. This section compares the results with other studies that examined PA prediction, where it was possible to highlight that in Table 3, the accuracy result obtained by the model does not compare with other studies already mentioned, because it obtained a fairly high percentage. The article [20] had an accuracy of 91.19% using only academic and demographic data. Similarly, the article [21] proposed two models with the cross-validation method, which had different numbers of times and where they did not have a good result, with an accuracy of less than 65%. On the other hand, in Fig. 7, it was identified that the factors with the highest correlation for predicting PA were the academic factors, especially the final grades of the first bimester of reading skills, which in the article [20] had a similarity in the results, because for them the final grades of the first period and the second period were the most correlated with PA, leaving the other characteristics far behind. However, Fig. 7 also shows the ROC curve, one of the curves that provide confidence in the performance of the model, which is a multiclass model, and it was necessary to plot the ROC with different classes and thus obtain the AUC of each one. Thus, in the article [22], it is mentioned that they use the same number of classes as our proposed model and that its AUC is almost like ours [23, 24].

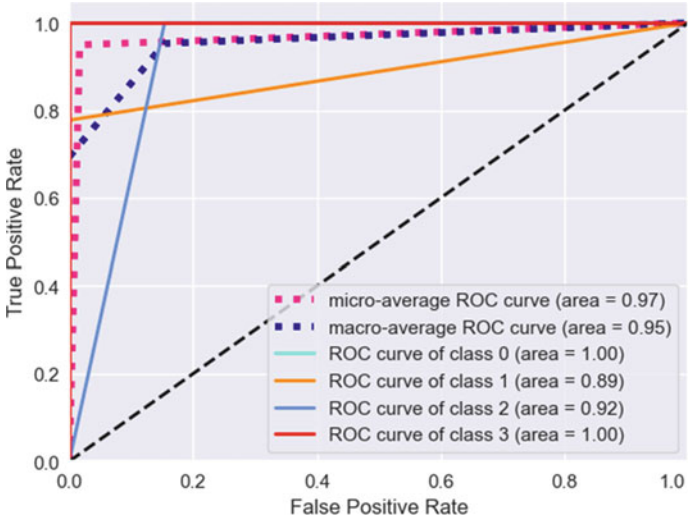


Fig. 7 Curve ROC a classes multiple

Table 3 Model performance parameters

Class	Precision	Recall	F1-Score	Support
0	1.00	1.00	1.00	1
1	1.00	0.70	0.88	9
2	0.93	1.00	0.96	27
3	1.00	1.00	1.00	3
Accuracy			0.95	40
Micro avg	0.95	0.95	0.95	40
Macro avg	0.98	0.94	0.96	40
Weighted avg	0.95	0.95	0.95	40
Simples avg	0.95	0.95	0.95	40

5 Conclusions

Every year, research is developed from different approaches on the PA of students, since it is a sensitive issue in the educational field that is rarely taken into account to understand why there are still students with different academic levels, whether high, medium, or low. It is difficult for institutions to process student data and correctly identify these factors to determine strategies to help improve AP levels. In this work, a multiclass ML predictive model for PA was developed, where the RF algorithm was used, since it is effective in the creation of models with greater accuracy in the results. Twelve psychological and academic attributes were used as input data and the weighted attribute as output data, resulting in 4 levels that categorize the AP (in progress, in the process, expected, and outstanding). The model achieved a rate of 93%, indicating that the prediction had high performance. Similarly, in the recall parameter, the in process level had a sensitivity of 70%. In the parameter F1-Score 88%, respectively, being these levels lower than the others, and finally, the accuracy is 95%. This means that the proposed predictive model demonstrates high performance in the prior prediction of the four PA levels, even though unbalanced data were used. Applying the RF model indicates that it is the most optimal with the best performance in predicting students' PA, which could serve as a great support for future research work in the educational field.

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Predicting Election Results with Machine Learning—A Review

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Abstract Election results are a topic that never stops being talked about and even more so that social platforms are the perfect medium where polarization to a political party is established. That is why many academics have seen the potential of this data source for the prediction of electoral elections. Therefore, it is necessary to review what kind of machine learning models perform better in predicting election results. Therefore, a literature review is carried out, following the guidelines of the PRISMA methodology, for which databases such as Scopus, IEEE-Xplore, Science Direct, Google Academic, Springer, Ebscohost, Iop, Wiley, and Sage were used. After the literature review analysis, a total of 1638 manuscripts related to the research topic were obtained, and the inclusion and exclusion criteria were applied. Thus, 69 manuscripts were systematized. The results showed that one of the models most used by the scientific community is sentiment analysis. It was also noted that the best performing model was random forest (RF), with an accuracy rate of 97%. In the second place, we have the recurrent neural networks (RNNs) model with an accuracy rate of 91.6%. However, unlike RF, RNN requires a high computational knowledge and effort. Finally, it is concluded that the RF model is the most suitable for the prediction of electoral results since it can perform better in this type of case.

Keywords Automatic learning · Elections · Electoral · Machine learning · Vote

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1 Introduction

The electoral election process is one of the most important processes in the development of each state, which is why the media become an indispensable tool for candidates. Currently, the means of co-communication with more concurrence and data traffic are digital platforms [1]. This medium is the one that means for many a means of free expression and easy access, where opinions are expressed on different topics, such as electoral elections, where they can comment on the candidates, either by their proposals or presentations in the media [2, 3].

The manipulation of social media for postulants is becoming more and more concurrent [4], since campaign strategies are more effective in this medium [5], so that the dispute for power is largely generated by this medium [6]. But not everything is negative, the posts and/or comments of users are one of the most valuable and easy-to-obtain contents [7], since they bring with them personal data and states in which the citizen is the perfect material to analyze [8]. However, analyzing this data can be confusing for traditional methods, as it brings with its user posts and bots [9]. Therefore, the aim of this paper is to review machine learning (ML) models for data processing, in relation to the prediction of election results [10, 11]. This discipline is divided into three categories: supervised learning, unsupervised learning, and reinforcement learning.

2 Bibliographic Study

Currently, not only political experts are called to express their opinions in digital media, but any user can spontaneously express their opinions on digital platforms, so much so that it ends up being a tool to measure the electoral preferences of a candidate.

The authors in [12] conducted a systematic literature review of 83 manuscripts to analyze and summarize how the prediction of electoral votes in social networks has evolved since its inception. To do so, they analyzed the quality and veracity of the manuscripts published within the electoral context. Finally, they concluded that the best results are developed with new concepts, such as regression methods trained with traditional surveys. Moreover, most of these methods do not exceed the limit of greater than 6% mean absolute error. In the same line, [13, 14] analyzed 25,000 tweets using deep learning to perform voter sentiment analysis. The result is that social platforms while providing large volumes of useful information to predict the electorate can also be used to manage electoral campaigns. It should also be noted that this model obtained an accuracy rate of 94.2% for the prediction of electoral results. Similarly, [15, 16] reviewed different numerical approaches to sentiment analysis techniques for predicting election results through social network data. They concluded that the Twitter social platform is promising for election outcome prediction. Moreover, in [17] they explain textual analysis that processes emotional states in

texts, which are classified into text-oriented monolingual, text-conversational, text-oriented cross-lingual, and emoji-oriented cross-lingual methods, all based on deep learning. On the other hand, 187 manuscripts were analyzed in [18], which aimed to determine whether social platforms are a complement to traditional surveys. It is concluded that social platforms do estimate traditional polls, specifically for the prediction of electoral results.

3 Methodology

To develop the systematic review, it is necessary to use a consistent methodology, which is why we will use the PRISMA methodology since this methodology provides us with a series of simple steps to document the related articles obtained in the systematic review process [19]. Likewise, the criteria it provides are indispensable to guarantee a correct review [20].

The following are the steps of the PRISMA method to be followed: identify relevant manuscripts; exclude duplicate manuscripts; eligibility analysis; and the comprehensive analysis of selected articles.

(A) **Research questions**

The questions determined in this research work are RQ1: Identify the most used machine learning models for predicting election results; RQ2: Identify the accuracy rate of the models used; and RQ3: Identify the mean absolute error (MAE) of the prediction models.

(B) **Search strategy**

To answer our questions, the following search string is determined, and this string contains certain terms that will help us to obtain the articles related to the topic of study. The following is the search string.

The search string, as shown in Fig. 1, was used in the following databases: Scopus, IEEE, Science Direct, Taylor & Francis, Google Academic, Springer, Ebscohost, IOP, Wiley, and Sage. Once this search has been performed, the resulting articles from each database are organized for further selection.

For the selection process, the recommendations of the PRISMA methodology are followed, which are the inclusion and exclusion criteria, so that only the most relevant articles for the research topic remain. The criteria determined for the following work are shown in Table 1, and the number of articles per database is shown in Fig. 2.

(Electoral AND vote OR elections AND vote OR election AND vote) AND (machine learning OR ML OR automatic learning)

Fig. 1 Search string

Table 1 Inclusion and exclusion criteria

Criteria		
Inclusion	I01	Studies related to electoral vote prediction
	I02	Studies related to machine learning
	I03	Include articles published in the range of years (2018–2022)
Exclusion	E01	Articles in Spanish
	E02	SLR articles
	E03	Books
	E04	Short papers

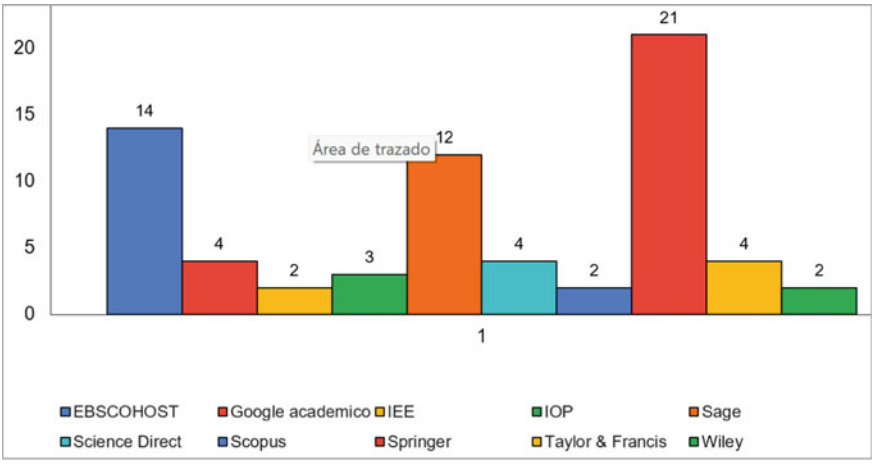

Fig. 2 Inclusion of elements table

Similarly, Fig. 3 shows the selection of relevant articles using the PRISMA methodology. For this purpose, 1638 articles from the main databases were analyzed with respect to the topic in question. After reviewing the articles, a total of 28 duplicates and 1475 excluded manuscripts that did not respond to the research questions were found. Finally, a total of 69 articles were obtained that responded to the research questions.

The 69 manuscripts are then organized into three categories, which are presented in the following tables: (1) manuscripts related to the most used machine learning models for the prediction of electoral results; (2) manuscripts related to the accuracy rate of the models used; and (3) manuscripts related to the average absolute error rate of the prediction models.

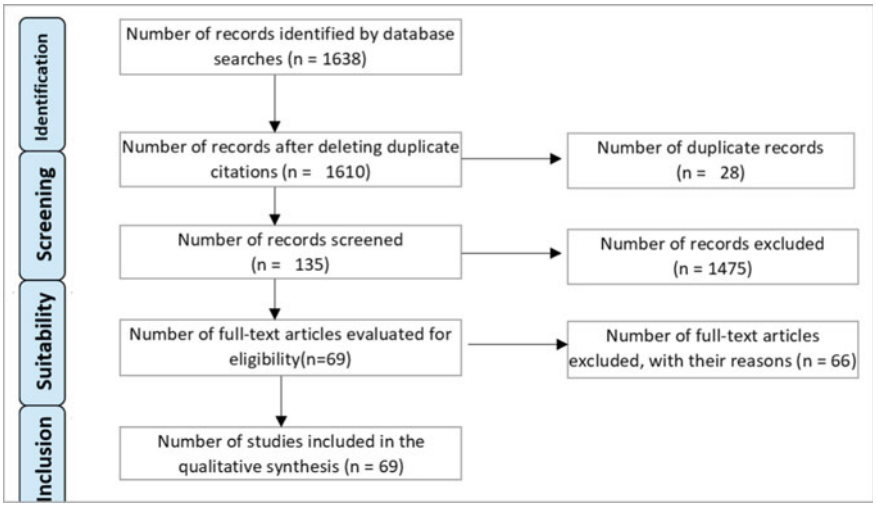

Fig. 3 PRISMA flowchart

4 Results and Discussion

As can be seen in Fig. 4, there is a greater production of articles in the USA, with about (22) publications. However, for the other countries, the magnitude of publications does not exceed (1–6) publications, which are: Brazil (1), Paraguay (1), Argentina (1), Mexico (1), Sweden (1), Romania (1), Turkey (1), France (1), Netherlands (1), Ireland (1), Finland (2), Italy (2), China (2), Pakistan (2), India (3), Indonesia (4), the UK (5), Germany (5), and Spain (6).

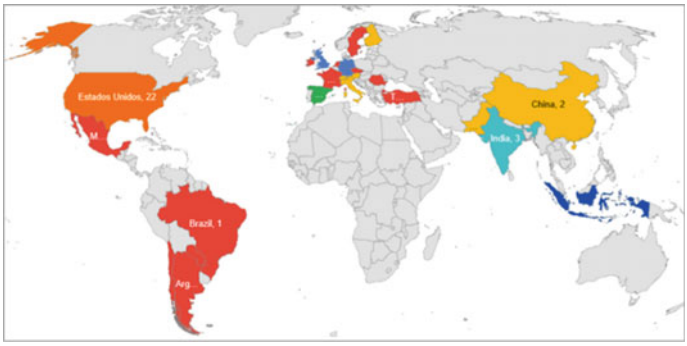

Fig. 4 Articles by country

RQ1: Identify the Most Commonly Used Machine Learning Models for Predicting Election Results

As shown in Table 2, the most widely used model in election predictions is sentiment analysis [16, 21–38], since this model emphasizes the abstraction of textual emotions using social networks. However, in [13, 14], it is contrasted that these data are not only useful for predicting election results but are also often used as a tool for improving election campaigns. Furthermore, in [15, 16], they differ on the different social platforms that are not suitable, stating that the Twitter platform is the safest platform for predicting election results. Secondly, we have text analysis [39–43] which has a similarity to sentiment analysis, and it mostly uses the same types of data.

RQ2: Identify the Accuracy Rate of Prediction Models

To answer RQ2, we performed an analysis of the accuracy rates found in Table 3, specifically in (20) manuscripts that answered this question. First, we have the random forest (RF) model [58] which has an accuracy rate of 97%; however, it differs from [13, 14], which have an accuracy rate of 94.2% for the sentiment analysis model, which means that, although sentiment analysis is more widely used, it is not more optimal than RF development. Moreover, this type of model does not require rigorous knowledge to achieve this level of accuracy. In [34], it ranks second, with a rate of 91.6% using the recurrent neural networks model; this model, unlike the RF model, requires a lot of knowledge and a high level of computation. Finally, in last place [51] with an accuracy index of 53%, we have the model sentiment analysis and K-nearest neighbor, which means that the union of these methods does not reach the maximum expected performance, explicitly for the prediction of electoral elections.

RQ3: Identify the Mean Absolute Error (MAE) of Prediction Models

From the analyzed papers (5), in Table 4, the mean absolute error (MAE) of the models was identified. First, we have [55] an error rate of 1.13% for the recurrent neural networks model, which gives us to understand that the model has an optimal performance with a low tendency to error. In the second place [37], with a mean absolute error of 3.50%, we have the sentiment analysis model, and this model was widely used by the scientific community; however, the performance is not the highest. Finally, we have [61], with a rate of 5% using the multilayer neural networks model, almost reaching the level of [12], in which they determine that regression methods have a rate no higher than 6%; this means that neural networks and a regression model are at the limit of not being considered optimal models. In addition, although this type of "multilayer neural networks" method is very little used, there is no doubt that the level of mastery of this model influences maximizing its high performance and low error rate [67].

Table 2 Manuscripts related to the most widely used automatic learning models for the prediction of electoral results

Ref	Quantity application		Most used ML models
[44]	1	Homegrown algorithm that uses certain aspects of machine learning to predict the UK and the US elections	Voting with stubborn nodes
[45]	1	Variant K-means algorithm for predicting the US political areas	Fuzzy C-means
[46]	1	Prediction algorithms for matching voters' positions with those of political parties	LMS and ML algorithm
[47]	1	Prediction algorithm for estimating US presidential election representation	Quantitative content analysis
[17]	1	Sentiment analysis model with certain deep learning criteria processing textual emotions for election prediction	Sentiment analysis and deep learning
[21, 38]	19	The use of social platforms as a data source for textual emotion analysis with machine learning criteria	Sentiment analysis
[48]	1	The use of sentiment analysis and classification using a social platform as a source for election prediction	Sentiment analysis and classification algorithm
[49]	1	Sentiment analysis for predicting Indian elections using Twitter data	Sentiment analysis and polarity
[50]	1	The use of sentiment analysis and NB to predict the Indonesian presidential election using social platforms as a data source	Sentiment analysis and NB
[51]	1	Sentiment analysis was used to find out the perception of Indonesian citizens on political issues	Sentiment analysis and KNN
[52, 53]	2	Twitter is used as a data source for the prediction of US presidential elections	CNN
[54]	1	Various models are tested to find out the best performance in electoral vote prediction using social platforms to feed the models	KNN, naïve Bayes, SVM, XGBoost, RF, LR
[55]	1	Two models are applied for Chilean election prediction using Twitter data to train the prediction models	Support SVM and NB

(continued)

Table 2 (continued)

Ref	Quantity application		Most used ML models
[56, 57]	2	Naive Bayes model is applied to predict voting intention and polarization in the US and German presidential elections	NB

Table 3 Manuscripts related to the accuracy rate of the models used

Ref	Model	The accuracy index (%)
[58]	RF	97.00
[59]	MLP	95.00
[60]		94.50
[61]		92.00
[62]		90.00
[54]	SVM	92.08
	Extreme gradient boosting	91.34
	LR	91.09
	RF	89.36
	NB	83.91
	KNN	71.29
[50]	Sentiment analysis and NB	90.00
[44]	Voting with stubborn nodes	90.00
[34]	Sentiment analysis	89.98
[22]		81.00
	MLP	73.84
[63]	Decision tree and C5.0 algorithm	84.27
[57]	NB	83
[64]	RF	77
	LSTM	76
[42]	Text analysis	74.00
[55]	Support vector machines	76.45
	NB	66.31
[65]	RF	63.9
	LR	63.4
[51]	Sentiment analysis and KNN	53.00

Table 4 Manuscripts with mean absolute error rate of prediction models

Ref	Model	The mean absolute error (MAE) of the predictive models (%)
[55]	Recurrent neural networks	1.13
[37]	Sentiment analysis	3.50
[66]	Temporal attenuation	3.04
[44]	Voting with stubborn nodes	4.74
[61]	Multilayer neural networks	5

5 Conclusion

After performing the systematic literature review, with 69 manuscripts related to the research topic, it is concluded that: one of the most widely used models by the academic community is the "sentiment analysis", and this model trends between the years 2018 and 2022 currently. The trend of this model is because its accuracy rate is around 81–90% performance for well-applied implementations. It should also be noted that poor implementation of this model can lead to a low level of accuracy, as some authors have previously stated. On the other hand, the trend of some models does not mean that it is a general rule to always use this model, to the point that the model with the best results was RF, with an accuracy rate of 97%. However, the RF model, unlike sentiment analysis, is more adaptable to different contexts. It may be an attractive alternative for data mining enthusiasts. In contrast to RF, we have in second place the RNN model with an accuracy rate of 91.6%; the difference of this model is that it requires deep knowledge, which may be a better alternative than sentiment analysis, but not better than RF. In addition, the mean absolute error rate should not be neglected, as it also determines whether the level of accuracy serves its purpose. In this case, the recurrent neural network model has a mean absolute error of 1.13%, making it one of the models with the lowest expected mean absolute error.

Finally, the knowledge acquired in this systematic review will help research enthusiasts to improve their knowledge base and motivate the use of new tools, with the purpose of improving the implemented models and methodologies. In addition, a model architecture for the prediction of electoral elections is proposed, based on RF.

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Machine Learning Models for Predicting Student Dropout—a Review

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Abstract Student dropout is a worldwide problem that affects an entire society; thus, being of great concern for academic institutions that seek to retain their students through different strategies, machine learning is the most used for the early detection of students at risk. For this reason, in the present work, an exhaustive systematic literature review study of manuscripts related to the prediction of student dropout was carried out. The articles were obtained from six databases, which were searched using the PRISMA methodology. A total of 88 manuscripts were selected from which 4 questions were posed. Finally, we obtained as an answer to the questions that the most used model is the random forest, with an accuracy of between 73 and 99% for predicting student dropout. For this, aspects such as academic, demographic, economic, and health aspects must be considered. Meanwhile, the technological tool for the models was the Python language according to this systematic review.

Keywords Model · Machine learning · Prediction · Student dropout · School dropout

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1 Introduction

Student dropout is a worldwide phenomenon that affects both students and those around them, including their immediate family members and consequently an entire society [1]. There are 235 million young people enrolled in universities worldwide, representing 40% of the world's enrolled students [2]. However, the governments of each country are not oblivious to this problem, because they are the great investments placed through a deficient educational system that does not contrast with the reality of a country [3], thus generating a great loss in its economy, being reflected in its population the results of such system, for a country that seeks to develop in a sustainable manner over time and a school population that in future should be part of the economy of a country [4]. On the other hand, higher education institutions have been implementing various strategies to mitigate or reduce this social scourge [5]. Thanks to the advances in technology that have allowed institutions to analyze the large volumes of data stored in their repositories, it has been possible to discover the factors that affect students who choose to withdraw, either temporarily or permanently [6]. Using the different techniques of machine learning (ML), it allows the identification of students who will enroll in the following periods and those who will graduate [7]. ML is a subset of artificial intelligence that makes use of data and an algorithm to simulate human learning [8]. They allow for finding patterns within the data [9]. The objective is to review the ML predictive models of neural networks for their models used by the authors, select the algorithm that best fits, and obtain a model that allows a better result in the prediction of those students who are at risk of dropping out. For this reason, it is important that educational institutions follow up with students [10].

2 Bibliographic Study

Thanks to ML, the exploration of the large volumes of data housed in the repositories of academic institutions has made it possible to find relevant patterns, thus supporting decision-making and formulating new strategic measures for the retention of students at risk of dropping out of their studies.

The authors in [4] conducted a systematic review by selecting 25 papers on the prediction of student dropout in MOOC online courses, in which ML is applied; concluding that the most used algorithm is logistic regression. The paper concludes by providing some solutions to combat this problem and recommendations for researchers. Similarly, in [6], they analyzed 67 papers related to the prediction of student dropout. The authors focused on the aspects most used to predict and mitigate this scourge and identified 14 ML techniques, being decision trees the most used by the different papers analyzed.

Also, [11] conducted a major literature review of educational data mining (EDM) for finding the students at risk to withdraw from their institutions from the periods

2009 to 2021; whose results indicate that various (ML) techniques were used to understand the reasons that cause student re-quitting and the use of two types of datasets, such as university repositories and institution's digital platforms. Whereas, [12] employed ML and deep ML techniques. They focused on identifying and categorizing the characteristics of online courses, strategies, and methodologies for obtaining patterns used for predicting the results. Also, in [13], the neural network is the most widely used in the study work, and the neural network (LSTM) achieves an accuracy of 87% for students' temporal performance data. Similarly, in [14], they conducted a systematic review, in which 190 works carried out between 2010 and 2018 were analyzed. Their objective was to direct the research for the following researchers who want to contribute to this field, to know the models, the learning sequence, and the optimization of the cost to functions. The study reveals that the challenges of training, hardware, theory, and quality prove to be a bane of EDM in relation to neural networks for undergraduate education. However, [15] analyzed the methodologies of 199 papers used to deal with student attrition in virtual learning environments. The study aimed to find solutions that apply (ML) strategies to counteract the high dropout rates.

3 Methodology

(A) **Research Question**

The present research work aims to reveal the contributions made by the different research works selected and analyzed. The study raises the following questions: RQ1: What learning models did you use to predict student dropout? RQ2: How accurate were the predictive models? RQ3: What factors or aspects did you consider predicting student dropout? RQ4: What tools did you use for the predictive model?

(B) **Search Strategy**

To answer the questions, a strategy was developed to search for manuscripts related to the prediction of school dropout. The string used to search for manuscripts related to the research topic was the following: (model AND machine learning AND prediction AND student dropout OR school dropout).

The string was entered in different repositories such as SCOPUS, SCIENCE DIRECT, EBSCO, GOOGLE ACADEMIC, IEEEXplore, and TAYLOR&FRANCIS, in order to find manuscripts related to student dropout prediction. First, manuscripts from the different databases, obtained by the search string, are identified to select the most relevant papers using the PRISMA methodology, filters are applied according to the aforementioned methodology, and the selected manuscripts are analyzed in detail to answer the previously planned questions (Table 1).

Table 1 Inclusion criteria and exclusion

Inclusion criteria	Exclusion criteria
Studies related to the prediction of student dropout	Revision work
Studies related to ML	Duplicate works
Open access papers	Books
Only works in the English language	Works in Spanish, Korean, and Portuguese
Papers published within the last 5 years	

We reviewed 1358 manuscripts. Those duplicate manuscripts unnecessary for our analysis were discarded. Articles unrelated to the topic were eliminated. 1189 were excluded after reviewing the manuscripts according to the criteria. Finally, 54 manuscripts were selected. Figure 1 shows the development of the PRISMA methodology.

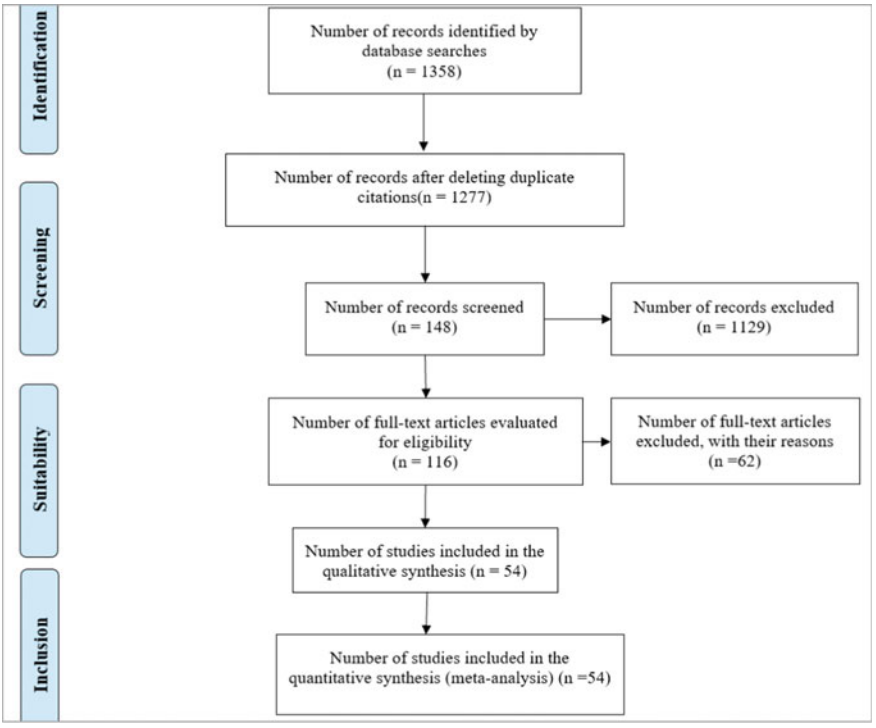

Fig. 1 Using the PRISMA methodology diagram

4 Results and Discussion

The manuscripts selected in this systematic review were the following: GOOGLE SCHOLAR (24), SCOPUS (18), EBSCO HOST (3), SCIENCE DIRECT (4), IEEE (4), TAYLOR&FRANCIS (1). Likewise, the People's Republic of China, the United States, and India contributed a total of 27 items among the three countries, being the highest, as can be seen in Fig. 2.

In the bibliometric analysis performed, the keyword "machine learning" predominates, which is shown in yellow with 25 occurrences; followed by "dropout prediction", in red. The bibliometric graph of the most relevant words was obtained with the VOSviewer software [16], as shown in the following Fig. 3.

Of the keywords found out of the 54 articles analyzed, "machine learning" is representing 14%, while "learning analytics" with 9% and "dropout prediction" with 7% are the most concurrent words.

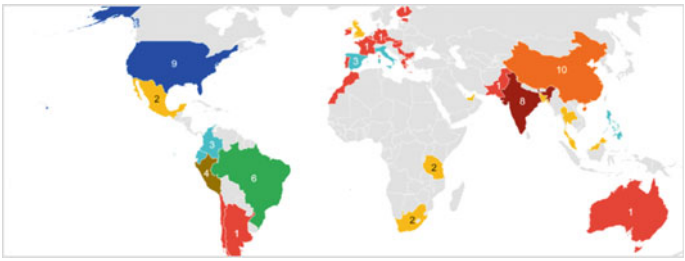

Fig. 2 Manuscripts by country

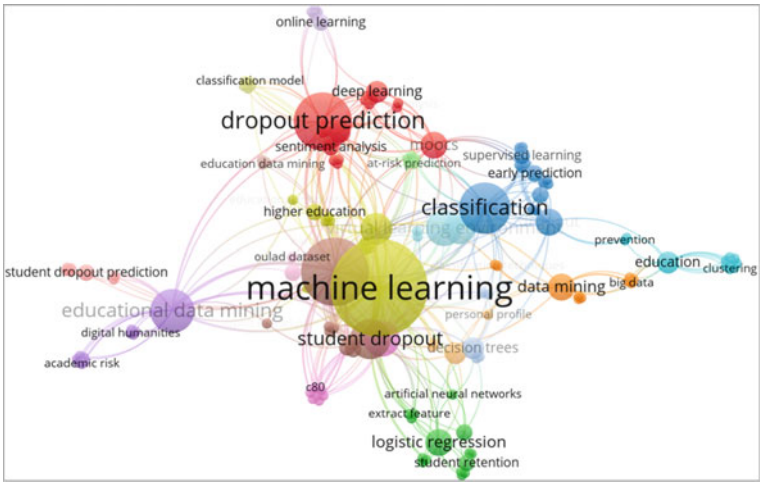

Fig. 3 Bibliometric map

Thirty-two (32) items were obtained, which are grouped into six (6) clusters. The clusters generated by the bibliometric analysis are presented below: Cluster 1: classification; Cluster 2: dropout prediction; Cluster 3: educational data mining; Cluster 4: logistic regression; Cluster 5: student dropout, and Cluster 6: machine learning.

RQ1. What Models Were Used to Predict Student Attrition?

In the different research studies, each author used the algorithm that he believed to be most convenient for predicting student dropout; likewise, [17] developed a predictive model with the random forest algorithm, which is the most used according to this systematic review. However, in [18], they considered the decision tree algorithm to be the most appropriate to respond to student dropout. Along the same lines, in [19, 20], logistic regression was the best for the identification of students at risk when compared with other algorithms. However, for [21], the support vector machine allowed early prediction of students during the first academic year. However, in [22], they considered the K-nearest neighbor algorithm to be suitable, highlighting that simpler classifier is better than other sophisticated models (Table 2).

RQ2. How Accurate Were the Proposed Models for Predicting Student Dropout?

The results regarding the level of accuracy obtained by the predictive models for student dropout. In [18, 20, 21, 23–25, 40] using the random forest algorithm, they recorded an accuracy between 73 and 99%. While, for the authors [17, 26, 27] using the decision tree algorithm, they obtained an accuracy between 69 and 99%, thus having one of the highest percentages, but also registering the lowest percentage. Similarly, in [22, 25–28, 38, 41, 42–47], they recorded between 78 and 97.8% accuracy with the logistic regression model, being very similar to the support vector

Table 2 Classification by learning models used

N°	Models	References
1	Gradient boosting machine	[23]
2	Random forest	[17, 24–28]
3	Decision tree	[18, 27]
4	Logistic regression	[19, 20, 29–31]
5	CHAID	[32]
6	COX	[33]
7	K-nearest neighbor	[34]
8	Feed forward	[35]
9	Support vector machine	[36]
10	LSTM	[37]
12	K means	[38]
13	Naive Bayes	[12]
14	FWTS-CNN	[39]

machine algorithm, which achieved an accuracy between 78 and 96.49% in the results of [16]. Similarly, in the manuscripts of [41, 47], the Naive Bayes recorded between 76 and 90.1% accuracy for the early prediction of student dropout. However, other studies to a lesser extent revealed that the gradient boosting machine recorded an accuracy between 73 and 93% in the studies conducted by [17] (Table 3).

RQ3. What Aspects or Factors Were Considered in Predicting Student Attrition?

Not all of them took into account the same factors for the early detection of student dropout. Along the same lines, for [10, 45], the factors considered were the demographic and academic data of the students, thus obtaining very considerable results for the prediction of student dropout. However, in [17, 18, 25], their predictive models analyzed purely academic characteristics, such as grades, weighted averages, and courses registered by the student, among others. However, in the studies of [17], the academic factor is used to predict student desertion, as well as the psychological factor, where feelings were subtracted from the notes taken by advisors to identify students at risk of dropping out. Similarly, in [11], they analyzed data on demographic and psychological aspects of students, with the type of student behavior being the variable that contributes most to the study. However, the authors [23, 28] selected demographic, academic, economic, and health aspects, the latter being one of the least analyzed aspects according to the authors, such as the student's disability variables (Table 4).

Table 3 Level of accuracy of the models

N°	Modelos	Precisión (%)	Referencias
1	GBM	73, 93, 78	[23]
2	Random forest	76.62, 88, 94.14, 96.77, 97.4, 80, 97.92, 95, 80.79, 87, 84.47, 93, 96, 91, 73, 86, 99	[17, 25, 27, 28, 48, 49]
4	Logistic regression	97.8, 95, 88.4, 78, 90, 84.8, 83.90, 84, 86.9	[19, 50, 51]
5	CHAID	97.95	[22]
6	COX	85.3	[15]
7	K-nearest neighbor	85	[40]
8	Feed forward	93.6, 88.81	[39]
9	Support vector machine	78, 88, 96.49, 85.3, 93.8, 90.42, 90.87	[21]
10	LSTM	85, 93	[37]
12	Naive Bayes	90.1, 89, 80, 76	[52]
13	FWTS-CNN	87.1	[25]
14	EDDA proposal	92	[22]

Table 4 Aspects or factors for predicting student dropouts

N	Factor	References
1	Academic	[17, 21, 26–28]
2	Academic, psychological	[53]
3	Academic, economic	[38]
6	Demographic, academic, economic	[24, 25]
7	Demographic, psychological	[54]
8	Demographic, economic	
9	Demographic, academic, economic, health	[19]

Table 5 Tools they used to predict student dropouts

Tools		
1	WEKA	RapidMiner
2	Jupyter	Language Python and library
3	SPSS	Language R

RQ4. What Technological Tools Did You Use to Build the Predictive Models?

In [55–57], the Python language was the most appropriate for the development of the algorithms, relying on the libraries that this language offers, such as sklearn for predictive analysis, NumPy for numerical data, among others. However, the studies in [26, 27] were performed with WEKA software, which offers a collection of ML algorithms. However, in [17, 21], the R language together with its caret library allowed performing the whole process, from the selection of variables, to model fitting, among other functions. While, in the results of [18, 25], the RapidMiner software was used for the data analysis, as well as for its simplicity of use (Table 5).

5 Conclusions

In the present systematic review article on the prediction of student dropout, 88 manuscripts were analyzed, and we can affirm that the most used models were the random forest in the studies of [18–21, 23–25, 40, 41, 54, 58, 59], and in [26–28, 37, 39, 47, 60, 61], the decision tree algorithm was used for the early detection of students at risk. However, from the manuscripts reviewed, it is revealed that the random forest somewhat-rhythm achieves between 76.62 and 99% accuracy, being very similar to the decision tree that obtains an accuracy between 96.88 and 99%. However, we must consider that the characteristics or attributes that best contribute are related to academic, demographic, economic, and social factors. However, to a lesser extent, some authors considered the health factor such as the student's disability. Finally,

for the development of the models, the Python language is undoubtedly the most widely used technological tool, because it works with a variety of libraries that make it possible for the codes to be simpler in the construction of the predictive models. For future work, it is recommended to consider other sources of renowned scientific databases, such as WEB OF SCIENCE, which is a platform that allows access to different databases and integration with other tools for the analysis of manuscripts.

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Brazilian Integrated Cross-platform Security Assessment Framework: Context of Cybersecurity Methodology

Ingrid Barbosa and Sérgio Ribeiro

Abstract Context is the circumstances set surrounding an event and encompasses all information about the analysis target, being a prerequisite for any assessment. The existing security assessment methodologies reinforce the importance of a context survey with quality. Its incorrect mapping can lead to false security feelings, and there is a lack of detailed methods for a proper context survey available in the market and the literature. In order to fill this gap, this paper presents the context of cybersecurity methodology (CoCs), which maps as much information as possible concerning the object under evaluation. This methodology will contribute to systems, products, services, processes, and organizations' cyber protection improvement, circumventing attempted attacks, and ensuring business continuity. The future work is CoCs validation in case studies and the addition of a computational tool to support the methodology application, facilitating the execution by the security specialist and reducing the chance of errors. This method is part of the integrated cross-platform security assessment framework (ICpSAF), within the scope of the Brazilian TecSEG project.

Keywords Cybersecurity context · Security assessment · Cyber risks

1 Introduction

Nowadays, worldwide cybercrime cost is estimated at US$ 255,000 per second. This scenario will be getting worse in the coming years. In 2025, they estimate that cybercrime protection will cost US$10.5 trillion for companies around the world [1]. It is not possible to act securely without knowing which risks to protect against. To this end, the security assessment process performs an investigation to reach an evidence-based judgment that allows for adequacy [2]. The process is complex, and the risk elements are dynamic and changing, with new vulnerabilities emerging all the time.

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In this way, the Brazilian government created the TecSEG project to study and develop methods and security components [3]. Thus, a framework is proposed to map new vulnerabilities, risks, maturity levels, and action plans [4]. Regardless of which process the managers choose to follow to implement the assessment, the first step is to know the cyberspace involved. A well-constructed context provides all the information needed in the subsequent assessment process.

Generally, the context survey is done empirically and intuitively. As a result, the assessment may be incomplete or even wrong, causing false feelings of security. Therefore, this work presents the construction of a context of cybersecurity methodology (CoCs) for telecommunications networks and services.

Section 2 presents the TecSEG Project. Section 3 presents the CoCs methodology, followed by Sect. 4, with the business focuses phase, Sect. 5 with the asset identification phase, Sect. 6 with the rules and obligations phase, and Sect. 7 with the risk appetite phase. Finally, Sect. 8 presents the conclusions. The paper is closed with acknowledgements and references.

2 TecSEG Project

The TecSEG Project (Tecnologias de SEGurança – Security Technologies) is a Brazilian government initiative which aims to develop secure components methodologies for security assessment and investigation linked to existing regulations and legislation. The main project objective is to increase cybersecurity in telecommunications networks and services [3].

The integrated cross-platform security assessment framework (ICpSAF) is part of the TecSEG Project and is an integrated framework that schematizes and makes the assessment process agile. A set of methodologies has been proposed in ICpSAF to cover and go beyond the expected results in the cybersecurity assessment process [4]. Figure 1 presents the model of the framework.

3 Context of Cybersecurity – CoCs

Context is a set of circumstances surrounding an event [5]. It is possible to map two types of context, the external context, with the environment that impacts the organization's goals; and internal context, which is internal processes adopted by the organization [6].

A security analysis needs both internal and external contexts. The lack of knowledge of the application context can cause a security analysis that will not cover or prioritize all risks since without the necessary knowledge it is not possible to map them, which can generate information that provides a false sense of security, or that does not direct security actions to the highest priority vulnerable point. Because

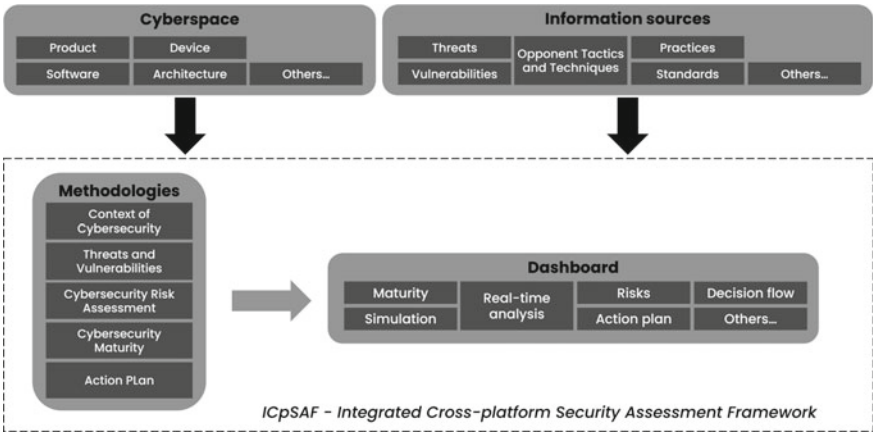

Fig. 1 Model for ICpSAF

the context encompasses all the information about the analysis target, it becomes a prerequisite for any evaluation.

The context is a fundamental part of the framework under development in TecSEG project, as it is the source of information for all other methodologies. Its incorrect mapping can lead to an incorrect application of the framework.

The context of cybersecurity methodology (CoCs) (Fig. 2) has the objective to map as much information as possible concerning the object under assessment, providing all the necessary knowledge to the security specialist, so that he can understand the scenario that will work and make a security assessment that represents the reality of the system. The methodology has 4 phases that will be described with the objectives, agents involved, inputs, procedures, and outputs.

4 Phase 1 – Business Focuses

The first step of this context survey methodology presents procedures to help the security professional to have an adequate understanding of business and systems. The security assessment has not only tactical and operational objectives but, above all, strategic ones [7]. In addition, a system loses its meaning if it does not have a business to support it and justify its existence and development [8]. In this way, all stages of an evaluation make the decisions based on the best strategy to ensure the business continuity behind the system [9].

This phase's objective is to understand the business focus so that it guides all assessment decision-making. For an adequate business focus definition, you must carry out seven steps. The security specialist should follow the sequential order proposed for a more logical understanding.

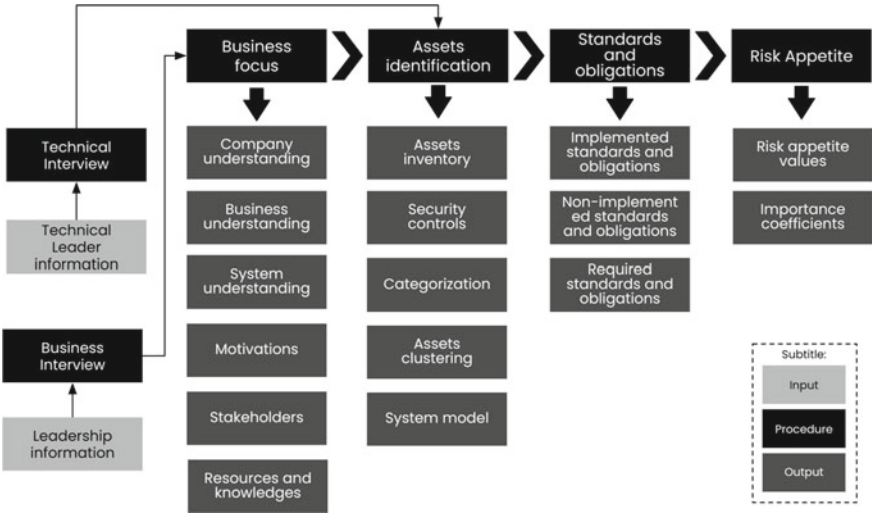

Fig. 2 Cybersecurity context methodology diagram

4.1 Step 1 – Interview

Input. Leadership information: This methodology assumes that the analysis performer security specialist does not yet know the under-evaluation system. Therefore, the information extraction from interested or responsible parties with multidisciplinary knowledge of the object under evaluation will contribute to the assessment as a role. The recommendation is that a senior management professional provide this information.
Procedure. Business interview: Each security professional may prefer to follow a particular process to extract the necessary information. We suggest a comprehensive questionnaire to map all the outputs of the following steps.
Output. Interview answers: Answers to a questionnaire with the responses completed during the interview (in full, without modification). The output generated in this step will be an internal input for the next steps.

4.2 Step 2 – Company Understanding

Input. Interview: From 4.1.
Procedure. Company analysis: This procedure consists of interview answers analysis and focuses on the company's understanding points.
Outputs. (i) Company definition: The company name, the company legal sphere, the number of employees, the age of the company, the company's mission, vision, and values. (ii) Governance: A summary of the company's governance process. (iii)

Organizational chart: The visual representation of the company structure. (iv) Roles and Responsibilities: List the function followed by the responsibility of the main stakeholders in this analysis. (v) Company Policies: The policies currently implemented in the company.

4.3 Step 3 – Business Understanding

Input. Interview: From 4.1.
Procedure. Business analysis: This procedure consists of interview answers analysis and focuses on the business understanding points.
Outputs. (i) Business definition: The business description, the business mission, vision, and values, the business value proposition, the delivery channels, the relationship process, the revenue sources, the key activities, the key resources, key partners, and the cost structure. (ii) Strategies: Future business goals and how they intend to achieve them. (iii) Current market: Current business customer segment. (iv) Future market: Customer segment that you want to reach shortly. (v) Confidentiality, integrity, and availability importance: Numbers from 0 to 10, 0 being none and 10 being very important.

4.4 Step 4 – System Understanding

Input. Interview: From 4.1.
Procedure. System analysis: This procedure consists of interview answers analysis and focuses on the system understanding points.
Outputs. (i) System definition: System explanation, user profile, number of system users, locations where the system operates/will operate (city, state, region, country), system purposes, number of people involved in the development by function (such as programmer, architect, tester, usability analyst, manager, or others). (ii) Incident History: The existence of incident history for this system with an optional paragraph describing the incident. Besides, the cybersecurity intelligence program exists with optional paragraphs with main agents and attacks on the sector. (iii) Life-cycle phase: Life-cycle phase of the under-evaluation system. It can be PoC, MVP, product, or others more specific. (iv) Activity area: Activity area, answered according to the current/future segment informed. (v) System policies: List of policies currently implemented in the system.

4.5 Step 5 – Motivations

Input. Interview: From 4.1.
Procedure. Motivation analysis: Interview answers analysis and focuses on the motivation understanding points to carry out this evaluation, such as whether there are standards that you would like to comply with, if there is a request for this assessment by a customer, partner, and/or stakeholder if there is a genuine concern with the security of the system, among others.
Output. Motivations list: List the motivations for carrying out this security assessment.

4.6 Step 6 – Interested Parties

Input. Interview: From 4.1.
Procedure. Interested analysis: This procedure consists of analyzing the answers obtained in the interview, focusing on the points that contribute to the understanding of who is interested in the results of this evaluation, to have an alignment of expectations between the parties.
Output. Stakeholder List: List of internal and external stakeholders. Stakeholders are customers, partners, or sponsors with direct influence on the business.

4.7 Step 7 – Resources and Knowledge

Input. Interview: From 4.1.
Procedure. Resources and knowledge analysis: This procedure consists of analyzing the answers obtained in the interview, focusing on the points that contribute to the understanding of the resources and knowledge available for this evaluation.
Outputs. (i) Resources list: Six lists with items of company resources that will be available for this assessment, namely: capital, time, people, processes, systems, and technologies. (ii) Knowledge list: A list of the knowledge that the company people who will act in support of this assessment have.

5 Phase 2 – Asset Identification

Failure to map an asset can create gaps where the company will not have a value vision. Consequently, it will have an exposed risk that will not be identified and may lead to an incident where the asset value will only be perceived when it is affected [10]. Avoiding the occurrence of an incorrect mapping is the objective of this phase of the context methodology, listing the sensitive assets, which can be any component of value to the company, whether tangible or intangible [11].

5.1 Step 1 – Interview

Input. Technical leader information: Using the information security specialist as the input source for this step assumes that no one is better at explaining a given process than the people who work on it. They are the process performers, the members of operational teams with deep knowledge about certain business functions or operations. The technical information is an external input, and there is no specific format as it corresponds to the respondent's knowledge and will provide when answering the interview questions.
Procedure. Technical interview: In this procedure, the interviewer needs to extract from the system expert the assets of the evaluation object and additional information related to them, i.e., owner, location, and security controls.
Output. Interview answers: Answers to a questionnaire with the responses completed during the interview (in full, without modification). The output generated in this step will be an internal input for the next steps.

5.2 Step 2 – Asset Inventory

Input. Interview answers: From 5.1.
Procedure. Asset inventory analysis: Analyzing the answers obtained in the interview, focusing on the points that contribute to the identification of the assets.
Outputs. (i) Assets inventory: Includes the list of all assets of the organization, the location of the asset in question, to explain whether it is in the organization's domain or outside this domain, and the owner of the asset since every asset considered relevant for the organization that has information or processing of important information, it must have an owner responsible for its classification and definition of access restrictions. (ii) Security controls (implemented): Refers to pre-existing security controls identification. Records must also be made in case of the non-existence of these controls.

5.3 Step 3 – Categorization

Input. Assets inventory: From 5.2.
Procedures. (i) Categories definition: The methodology applicator is responsible for defining how the assets will be categorized according to the organization's scope. These categories can be but are not limited to: communication, hardware, human, information, infrastructure, outsourced services, software, category "N". (ii) Categorization: Addition of a field called "category" to the asset inventory. Categorization makes it easier to analyze risks later.

Outputs. (i) Category list: A table with two columns with defined categories and their descriptions. (ii) Categorized assets: The assets inventory are updated with the "category" label and reordered according to the categories of assets.

5.4 Step 4 – System Model

Input. Categorized assets: From 5.3.
Procedures. (i) System assets inclusion: Include all system assets to be protected in the model and organize them in a hierarchical system control manner in vertical order so that it is possible to verify which entity has greater control. (ii) Operation flows inclusion: Include the flow of operations in the model so that it is possible to visualize the interactions that occur in the system between the assets. (iii) Interfaces inclusion: Include in the model all the assets' external interfaces to visualize the attack surface. This procedure can be carried out in parallel with the second procedure.
Output. System model: A diagram identifies system structure with all the elements related to cybersecurity, as well as understands its behavior.

6 Phase 3 – Legal Norms and Obligations

It is necessary to identify which standards and obligations you must follow for the compliant organization. In this way, it is important to verify which (i) internal policies, (ii) external policies, (iii) current laws, and (iv) specific regulations were collected in the previous phases. Senior management, data protection officer (DPO), legal, and information security responsible can participate in the verification of norms and obligations.

6.1 Step 1 – Implemented Standards and Obligations

Inputs. (i) Company Policies: From 4.2. (ii) System Policies: From 4.4.
Procedure. Existing rules and obligations identification: Create a group of all information regarding privacy and compliance currently complied with in the organization and the system.
Output. Existing Rules and Obligations: A list of all implemented rules, regulations, policies, obligations, and laws in the organization.

6.2 Step 2 – Standards and Obligations Not Implemented

Inputs. (i) Company definition: From 4.2. (ii) Business definition: From 4.3. (iii) System definition: From 4.4. (iv) Existing rules and obligations: From 6.1. (v) Motivations list: From 4.5.
Procedure. Non-implemented standards and obligations identification: Analysis of what are the motivations for carrying out this security assessment. Is there a desire to conform to determined rules, regulations, policies, obligations, and laws? In addition, based on the definition of the company, business and system identify whether there is a need to follow certain cybersecurity standards.
Output. Non-implemented standards and obligations list: A list of all rules, standards, regulations, policies, obligations, and laws are not currently implemented in the organization but must be followed to be compliant.

6.3 Step 3 – Concatenation

Inputs. (i) Existing rules and obligations: From 6.1. (ii) Non-implemented standards and obligations list: From 6.2.
Procedure. Necessary rules and obligations identification: Concatenate the rules, standards, regulations, policies, obligations, and laws already implemented with the ones that have not yet been implemented.
Output. Required standards and obligations list: A list of all necessary and mandatory standards and obligations for the organization considering the ones currently implemented and the ones that should be implemented in future.

7 Phase 4 – Risk Appetite

Risk appetite is the risk type and amount, at a broad level, that a company is willing to accept in its pursuit of value [12]. Appetites are unique to each company. They are based on strategies, and they influence company behavior, providing acceptable risk positions concerning the organization's objectives [13].

7.1 Step 1 – Understand Business Goals

Inputs. (i) Confidentiality importance: From 4.3. (ii) Integrity importance: From 4.3. (iii) Availability importance: From 4.3. (iv) Required standards and obligations list: From 6.3. (v) Rules and obligations requirements: External input. Information

provided for legislation requirements may modify the importance value of confidentiality, availability, and integrity.

Procedures. (i) Map and normalize provided levels: Transform the importance levels mapped into a percentage value of risk appetite. In the appetite case, it is inversely proportional, as the greater its importance, the lower the appetite for related risks. For each importance value, Eq. (1) will be used, which will result in individual appetite values, where A means confidentiality, integrity, or availability appetite, and I means confidentiality, integrity, or availability importance level. (ii) Validate the need to decrease appetite: Verify if the appetites mapped are consistent with the legal requirements, verifying when accepting the appetites mapped if any legal requirements are not met. (iii) Calculate appetite and importance coefficients: Individual risk appetite percentage values for confidentiality, availability, and integrity. When changing the appetite values, the importance levels are also changed, so it is necessary to recalculate the values to update them in the methodology. Equation (2) can be used to transform the appetite percentages into importance levels, where *I*new means the updated importance level and *A* means appetite.

$$A = \left(1 - \frac{I}{10}\right) \times 100 \tag{1}$$

$$I_{new} = \left(1 - \frac{A}{10}\right) \times 10 \tag{2}$$

Outputs. (i) Risk appetite values list: The final value of risk appetite for confidentiality, integrity, and availability. (ii) Importance updated values list: The final value of importance for confidentiality, integrity, and availability.

8 Conclusions

The incorrect context mapping can lead to a false sense of security. Because of this, the context of cybersecurity methodology (CoCs) was created, with the aim of mapping as much information as possible concerning the object under assessment. The model created has four phases that allow an understanding of the company, business, and system characteristics, an understanding of the motivations for carrying out the evaluation, the stakeholders and their expectations, and the resources and knowledge available. Besides that, the assets of the solution, the system components, and their existing controls. The rules and obligations that the object under evaluation must follow can be also identified, concluding with an alignment of risk appetite.

Because of the above, it is concluded that the CoCs methodology will allow an adequate understanding of the assessment scenario and can be used in vulnerability and threat identification, in risk assessment processes, in the creation of action plans, and even in cybersecurity maturity methods. This methodology will contribute to the

evolution of systems, products, services, processes, and organizations from a cybersecurity protection point of view, circumventing attempted attacks, and ensuring the continuity of the business.

In future work, this methodology will be validated in case of studies, in real environments. In addition, a computational tool will be developed to support the application of this methodology, facilitating the execution by the security specialist, and reducing the chance of errors. This methodology is in the patent application process at INPI (National Institute of Industrial Property – Brazil).

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Digital Twin for Predictive Monitoring of Crops: State of the Art

Tsega Y. Melesse, Francesco Colace, Simon Pierre Dembele, Angelo Lorusso, Domenico Santaniello, and Carmine Valentino

Abstract Recently, the use of digital twins in crop management has caught the attention of the agricultural sector. This technology is still in its early phases of deployment, and the state-of-the-art methodologies and adoption level of digital twins have not been thoroughly explored. To address this issue, this paper discusses the current trend of crop predictive monitoring using digital twin applications, focusing on the approaches used, adoption levels, and implementation challenges. Digital twins in crop management are still in the lab stage, and large-scale implementations in farming are not reported. Despite the benefits of increased crop productivity, the adoption of digital twins is hampered by challenges such as the complexity of modeling, poor high-speed Internet connectivity in rural areas, data security, significant investment costs, data accuracy, and a lack of knowledge about crop types and farming circumstances. Insights are provided to research academics, companies, and practitioners to help them understand the current state-of-the-art problems and future research prospects in the sector.

Keywords Digital twin · Precision farming · Smart agriculture · Predictive monitoring

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1 Introduction

Today, modern agriculture is under pressure from factors such as demographics, climate change, food waste, natural resource depletion, and health concerns [1]. The sector needs to be optimized to fulfill rising food demand driven by global population growth. One way to address this issue is to digitize agriculture by using IT resources to create digital twins. Digital twins are among the potential ICT-supported technologies for enhancing agricultural productivity and assisting precision farming operations. The agricultural sector is going through the so-called "fourth revolution" or "agricultural 4.0", which is being driven by the rapidly growing use of information and communication technology, which is essential for precision agriculture to exist [2]. The digital twin is considered one of the technologies having the potential to elevate the agriculture industry to new levels of sustainability and productivity.

A "digital twin" is a new idea that has come up with the development of cyber-physical systems in the industry. It combines sensors, computing power, communication tools, and executions into a single system to manage the whole life cycle of a product. The research trend in the use of the digital twin has recently gained traction, and the interest of researchers in areas such as manufacturing and services, oil and gas, transportation, food and beverage, agriculture, aerospace, construction, and the energy sector has risen significantly [3–6] In precision agriculture, the digital twin of a plant reflects its developmental stages in real-time and predicts its growth [7–10]. The digital twin of a crop is intended to achieve goals such as continuous monitoring and control of the plant development process, improved yield forecast accuracy, and timely formulation of suggestions on corrective measures. The constant tracking of crops through digital twins allows the timely identification of problems in the field and provides recommendations based on weather conditions or experts' advice. It is a crucial tool for maximizing productivity [8, 9] as well as providing agroecosystems with a new perspective for real-life [11].

Digital twins are a digital representation of an actual physical object that details and aggregates information about its construction, performance, efficiency, technical condition, failures and breakdowns, maintenance and repair history, and other relevant indications [12]. Digital twinning, unlike traditional simulation, enables the automated flow of data between a physical object and its digital counterpart, which is fully integrated into both directions. For full functionality, the digital twin must be enhanced with an architecture consisting of the physical asset (the target system to optimize), the digital twin (a virtual testing platform synchronized with the status of the physical object), and the intelligence layer that contains the rules and the knowledge to choose among the alternatives tested in the digital twin [13]. In the context of agricultural production, a visual interface on a smartphone, tablet, or computer would typically be used to connect with a digital twin. This would allow users to easily view information about the crop's status, history, and predicted future, like a forecast of crop growth. Purcell and Neubauer [9] outlined six theme areas for digital twin application in agriculture, including crops, product design farming, live-stock

farming, urban and controlled environments, supply and value chains, and environmental and infrastructure policies. To develop digital twins for smart agriculture, data can be collected from samples that are routinely taken for agrochemical soil studies, weather forecasts, notes obtained from agronomists in the fields, satellite and drone images of fields captured with hyper-spectral cameras, GPS tracking of machines and parameters of agricultural operations, etc. [14]. In this field, data-driven, physics-based (mathematical), and agent-based modeling approaches are commonly used. A plant's digital twin can be used for operational decisions in each field and for "what-if" scenario simulation, forecasting, and risk evaluation [14]. Combined techniques serve as the primary modeling approaches for digital twining [9]. Data-driven modeling uses machine learning and deep learning algorithms to model the state and behavior of physical entities, while physics-based models incorporate real-world phenomena into virtual representations to model behavioral characteristics mathematically.

Several research studies have been carried out on the potential use of digital twin technology in crop management [5, 11, 12, 14, 15]. However, the state of the art in the methodologies, adoption level, and current implementation is not fully studied. Thus, the goal of the systematic literature review (SLR) is to evaluate the level of methodology and adoption used to develop digital twins for crop monitoring, as well as the challenges associated with implementing this solution. Thus, the review is de-signed to answer the following research questions (RQs):

- RQ1: What approaches are used to create a digital twin capable of monitoring and predicting crop growth and development?
- RQ2: What is the extent to which digital twins are implemented in crop management and challenges?

The article is organized as follows: Sect. 2 highlights the research methodology, Sect. 3 discusses the research questions, and Sect. 4 provides the conclusion of the work.

2 Research Methodology

The systematic literature review was chosen for this study because of its capacity to eliminate bias while exploring and assessing relevant papers. The Scopus database has been used as a data source with the keywords "digital twin" and "crop". In the final screening, only papers related to digital twins in crop monitoring and prediction were considered. In the final analysis of the literature, 22 papers have been included.

After collecting the documents and removing duplicates, the following qualities were used to identify relevant documents:

- Papers are Journal articles, research articles, and conference papers.
- The articles are written in English.

- The primary focus of the article is on digital twin applications in crop monitoring and predictions.

According to Figs. 1 and 2, the selected papers were classified based on the publication year and document types. A significant increase in the publication rate can be seen for the years between 2019 and December 2022. In general, the research trend in the application of digital twins in the monitoring and prediction of crops has recently. Most of the selected publications come from conferences followed by Journal articles and review papers. Angin P. et al. 2020, Ahmed A. et al. 2019 and Jans-Singh M. 2020, Laryukhin V. et al. 2019, Chaux J.D. et al. 2021 are the three top authors contributing 71% of the total citations (Fig. 3).

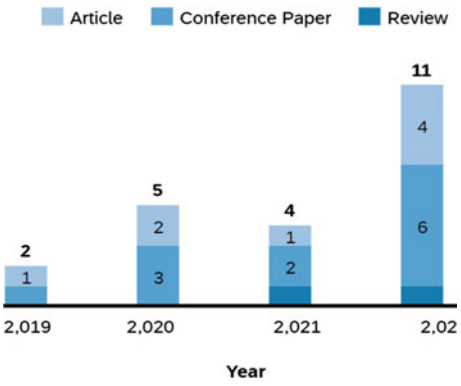

Fig. 1 Year of publication

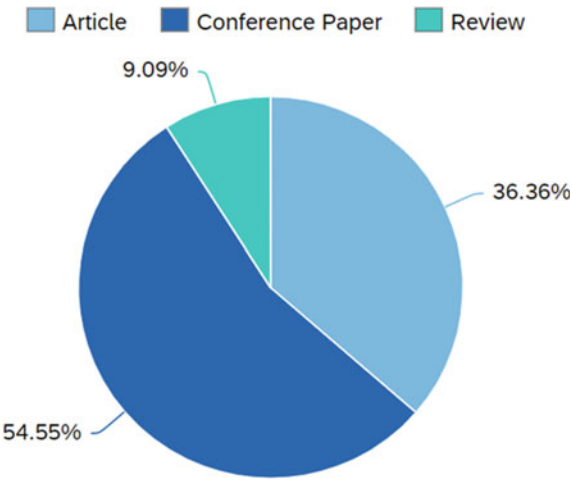

Fig. 2 Type of documents

Fig. 3 Top authors based on their citations

3 Discussion of Research Questions

3.1 Approaches Used in Digital Twin Development

In crop management, the digital twin has used several methods to gather and analyze plant status in real-time. Prediction of plant growth and development phases and yield forecasts are becoming more popular because they can adjust the timetable of individual plantings based on daily weather data or other factors [16]. This section describes crop monitoring and predicting approaches using digital twin technology.

Zake and Majore [17] suggested developing a smart agriculture digital twin using multi-perspective modeling. MultiDigiII methodology develops conceptual models at several abstraction levels to better depict complex systems. Complex systems require several modeling approaches, as one simple conceptual model cannot adequately capture their essence. This approach develops a digital twin that incorporates influencing objects and field objects like crops. Farmers and decision-makers can use real-time data and crop predictions to make climate-based decisions with the solution.

Laryukhin et al. [14] used ontology-driven knowledge bases, multi-agent technologies, and machine learning to create and maintain digital twins of plants that reflect their conditions and parameters for farm management during wheat production. In this case, software agents are used to mimicking real plants' growth and development. The agents are used for "what-if" scenarios to develop the best crop cultivation possibilities and learn from daily experience to support decision-making. By specifying domain ontologies and employing multi-agent collective decision-making, the proposed technique intends to assist farmers in making informed decisions. Similar schemes have been described by Skobelev et al. [18] utilizing ontological formalization of wheat development stages with descriptions of transition rules that take into consideration soil characteristics, weather conditions, etc. Digital twins

of plants reflecting crop development were developed using a multi-agent technology to improve yield estimates and agrotechnical planning.

The study by [18] presents a multi-agent strategy for developing plant digital twins that reflect plant growth phases and enable more accurate production forecasts and agrotechnical planning. It also suggests formalizing domain knowledge on new plant growth agrotechnology and automating precision farming decision-making.

Skobelev et al. [16] presented a digital tin of rice for growth prediction leveraging an ontology-driven multi-agent platform. Using expert guidelines from rice production and field data, the smart service predicts plant growth factors. The virtual model creates an agent with set requirements and specifications for each phase of rice growth and provides a multi-agent environment for the agents to interact.

Research by [19] employed remote sensing data, the Agricultural Production Systems Simulator (APSIM), crop modeling outputs, and machine learning to anticipate the complicated relationship between agri-environmental and crop rotation on wheat yield. Crop data can be used for yield prediction, geographic energy scenario analysis, and cross-domain flood risk analysis [20].

Pantano et al. [21] propose an image analysis pipeline to assign and identity markers to agricultural plants. The Rovitis robotic platform and crop ontology are used to test the algorithm's effectiveness. The result is found to be encouraging for robotic agriculture systems to address plants individually to optimize farming.

According to [14], a virtual system unit can predict the performance of the real system, allowing what-if analysis and optimization of the overall system, including plant development. Akroyd et al. [20] used digital photography to estimate plant development in various environmental situations. Recent studies have shown that digital twins can deliver autonomous services using intelligent data insights [22].

Table 1 categorizes digital twin methodologies in crop morning and forecasts based on the presented approaches by [18]. As a result, publications that focused on developing digital twin methodology in crop management were divided into three categories including mathematical (physics-based), data-driven, and ontological multi-agent models (Fig. 4). To describe the characteristics of crops and their growing environment, digital twins based on mathematical models use a collection of data such as dry weight, humidity, temperature, the composition of the soil, etc., although the validity of these models is currently being questioned [18]. The application of neural networks for crop yield prediction and monitoring is a promising method in digital twin development, but it has considerable limitations, including a long training process and the need for constant re-training in circumstances of uncertainty and dynamics. In a data-driven approach, deep learning models like convolutional neural networks and large data machine learning approaches can capture highly dynamic data but have low flexibility [9].

Ontological multi-agent digital twins could predict and monitor crops using "heterogeneous" data. A multi-perspective view is needed to build a digital twin that includes field objects and influencing objects [17]. Furthermore, [23] suggests using agent-based models and machine learning to create a digital twin of plants by extracting hidden patterns and dependencies from accumulating data to predict plant

Table 1 Summary of papers specifically focused on proposing digital twin methodologies

Purpose	Models used	References
Forecasting of harvest	Multi-agent	[18]
Resource management during wheat production	Multi-agent and ML	[23]
Obtain insights into the benefits of crop rotation	Data-driven	[19]
Forecast for the duration of plant growth and yield	Mathematical	[8, 24]
Crop yield prediction	Multi-agent	[17]
Develop a digital twin of plants	Multi-agent	[8]
Crop management	Data-driven	[22]
Supporting online forecasts on crop harvest	Data-driven	[25]

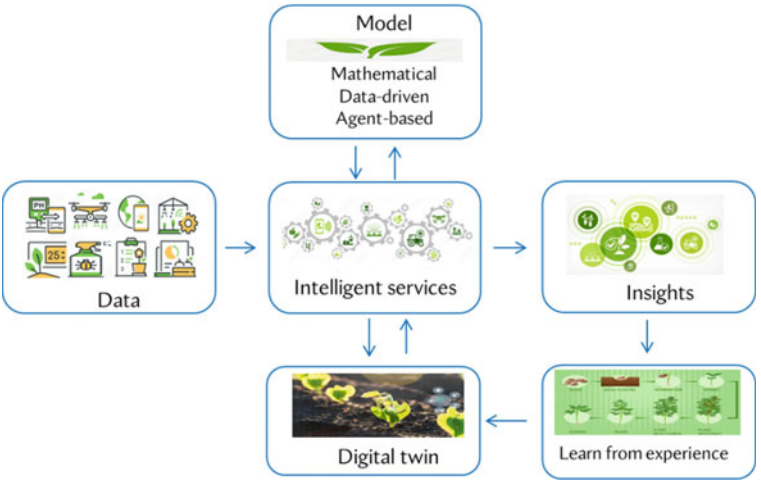

Fig. 4 General framework of the digital twin in crop monitoring

reactions to weather changes or farmers' actions including fertilizer intensification, etc.

3.2 Adoption Level and Challenges of Digital Twin Implementation

Most digital twins in crop management are experimental and only used in labs. The complexity of simulating living beings has contributed to this gap [9]. The crop management application of digital twins examined in this research is still in its early stages of development. Existing applications usually focus on basic monitoring

features or virtualize objects at a fine granularity. Lower granularity management is frequently extremely costly, and integrated software options are missing.

Due to insufficient high-speed Internet connectivity in rural areas, concerns about the physical security of digital twin equipment such as solar panels, communication towers, drones, and utility lines, and the difficulty of maintaining infrastructure due to their geographic isolation from each other and service centers, digital twin implementation faces challenges [12]. Another barrier to the adoption of digital twins in agriculture is the high cost of investment. In addition, the lack of knowledge regarding crop types and farming circumstances is another issue that demands field expertise. Because each crop, farm, and season are unique and require a specialized understanding of biological, chemical, and physical processes in plants and soils, it is essential to simulate optimal crops [23]. From a dynamic standpoint, agriculture is a difficult system to model [17]. For satellite-collected data, the accuracy of the remote information received is another obstacle, and weather-related issues impede the collection of satellite data.

4 Conclusions

The paper has focused on the state of the art in digital twin applications in the monitoring and prediction of crops. Several modeling approaches have been implemented in digital twin applications in the area, which include mathematical models, data-driven models, and ontology-based multi-agent models. Most papers follow a multi-agent approach to capture the interaction and influence of many agents in the field. So far, most of the digital twins' approaches are implemented at the laboratory level, and large-scale implementations are still in a limited phase due to the challenges, including insufficient Internet connectivity, concerns about security, the difficulty of maintaining, significant investment expenses, the lack of knowledge regarding crop types and farming circumstances, which demands field expertise, data accuracy, etc. From a dynamic standpoint, agriculture is a difficult system to model. In this paper, researchers, academics, companies, and practitioners are given insights to help them understand the current state of the art, adoption levels, and implementation challenges of the digital twin in crop management.

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IoT and Deep Learning for Smart Energy Management

Liliana Cecere, Francesco Colace, Angelo Lorusso, Francesco Marongiu, Michele Pellegrino, and Domenico Santaniello

Abstract The introduction of building information modeling (BIM) in the design and monitoring of public buildings has seen increasing use over time. Likewise, there has been a growing interest in the IoT paradigm within the construction industry. This study aims to integrate the two approaches to optimize the electricity consumption of a public building through the interpretation of data collected by dedicated sensors. The article proposes the study of a process applied to a real case study and discusses and comments on the preliminary results obtained. Finally, a meeting point is found between the IoT technology and the BIM methodology through the definition of digital twin (DT), understood as a digital copy of practical reality both in the design phase and in monitoring and forecasting. The type of data collected by IoT sensors commonly falls under the big data paradigm, which is generally not analyzable through traditional techniques. Therefore, in order to extract new knowledge from historical data, deep learning techniques have been used, which are able to analyze and identify relationships between data in an intuitive way that otherwise could not be detected.

Keywords IoT · BIM · Deep learning · Energy management · Digital twin

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1 Introduction

The use of building information modeling (BIM) methods has seen increasing interest and affirmation in the field of building design at different scales and functions. The most important advantages found by using an application totally based on the BIM paradigm are several: comprehensive maintenance plan, energy management, and thus energy and economic savings with an attached impact on environmental sustainability during the life of a structure. In this context, the way and amount of data collection encapsulates an important part of technological developments, and this innovation finds its fullest expression with the advent of the Internet of things and its autonomy in foraging data and information [1].

Indeed, the Internet of things underlies several innovative applications such as smart industries 4.0, smart cities, and smart buildings. The common ground between IoT technology and BIM methodology is precisely the concept of the digital twin understood as a digital copy of reality useful both in design and in monitoring and forecasting. So, in the following study, we focused especially on data management and visualization with the aim of being able to analyze the data for real-time monitoring and energy and economic efficiency. In addition, the study focuses on the graphical interface of the monitoring system to facilitate usability for interested users.

The data collection system makes use of wireless sensors and micro-electromechanical systems (MEMSs) connected to a microprocessor connected to a cloud system [2].

Once collected, these data must somehow be exploited to extract new knowledge useful, in this case, for better and more efficient management of energy consumption. Both in terms of size and speed of acquisition, it is unthinkable to analyze these data with traditional methods; but thanks to machine learning and artificial intelligence algorithms, it is possible to go about identifying patterns and relationships among the data in a completely automated way, going on to uncover relationships that are sometimes impossible to detect with normal statistical analysis techniques. This type of data is generally referred to as big data. They are typically datasets that are too large and complex for traditional data processing and management tools. The volume of data can vary greatly, but it is generally considered to be in the range of terabytes to petabytes. The variety of data types that fall under the umbrella of big data include text, images, videos, audio, and sensor data. The velocity of data refers to the speed at which data is generated and collected, which can be in real time or near real time. The veracity of data refers to the uncertainty and the quality of data, which can be incomplete, inconsistent, or biased.

Big data has many potential uses and benefits for organizations. For example, it can be used for customer insights, fraud detection, predictive maintenance, and real-time analytics. For example, a retail company can use big data to analyze customer purchase history and browsing behavior to personalize marketing campaigns and improve customer experience. Similarly, a healthcare organization can use big data

to improve patient outcomes by analyzing electronic health records and identifying patterns in patient data [3].

However, big data also poses several challenges. One of the main challenges is data management. Organizations need to have the necessary infrastructure and tools in place to store and process large volumes of data. Additionally, organizations must ensure that their data is accurate, complete, and consistent. This can be difficult when dealing with unstructured data, such as text and images, which may be difficult to interpret. Finally, there are privacy and security concerns associated with big data, as organizations must ensure that sensitive data is protected and used in compliance with regulations [4].

Overall, big data is a rapidly growing field that offers many potential benefits for organizations but also poses significant challenges. As the amount of data continues to grow, it is essential for organizations to develop strategies for managing, analyzing, and leveraging big data to improve their operations and drive growth.

This is where deep learning comes in as a method of extracting knowledge from historical data. The goal of this work is, in fact, to exploit a set of historical data from multiple sensors to go out and identify environmental situations that result in higher energy consumption, exploiting the ability of artificial neural networks to make predictions based on a predetermined history.

2 Related Works

BIM design is primarily based on the management of model information and contextually on the three-dimensional visualization of the artifact that allows easy visualization of the design idea, one of the limitations of software that handles this type of approach is the poor ability to autonomously record data from the design context on its own. Indeed, plug-ins based on visual programming are used to support design software that allow immediate interaction between the BIM environment and the sensor world, thus linking the virtual part with the real world through real-time data acquisition, this process turns out to be fundamental to be able to talk about digital twin [5–7]. This integrates seamlessly with new paradigms in computing such as the Internet of things, artificial intelligence, machine learning, and data analysis with spatial network graphs [8]. Thus, the prediction of future scenarios is possible through the use of machine learning and the application of artificial intelligence systems using data from sensors and produces new knowledge or predicts actionable scenarios by developing the collected data, with further development of the concept of the digital twin as a support for a predictive system. Indeed, a digital twin can be continuously updated in real time through a sensor network; the more sensors used, the higher the level of accuracy of the model under study, and consequently the better the prediction obtained through the collected data [9, 10]. There have been several approaches in the literature to integrating information from a sensor network with the BIM information model, integrating a visualization system, and the creation of automatically managed

actuators; some of these studies are limited only to optimizing energy consumption, while others are limited to managing the sensors remotely.

This study integrates IoT and BIM model technology, with data from sensors and modeling of future scenarios using deep learning techniques and then 3D visualization, where all sensors are visualized and placed within the BIM model [11]. The study echoes a case study previously carried out on a university classroom consisting of multiple sensors capable of producing data that feed a database addressed to the BIM model for the generation of a digital twin. The methodological proposal includes a study comparing different deep learning techniques to support a digital twin used for prediction tests of certain conditions recorded in the real environment under study.

3 Proposed Methodology

The study aims to evaluate the ability to visualize and manage a BIM model by autonomously and intelligently following a precise production scheme of the different phases of activities starting from the three-dimensional visual modeling of the case study object, to follow the placement of sensors and data collection. Precisely, data collection takes place on a cloud platform setup specifically for the management of an IoT environment, allowing for easy and intuitive visualization and management of information; next, an automated interface was developed that connects the sensor data in the cloud and the parametric design software and BIM modeling platform. Finally, the development of deep learning techniques refines a prediction of energy consumption and then activates energy consumption optimization functions through actuators [12]. The implementation of this workflow can be developed for both monitoring and prediction of existing buildings, but likewise utilized in more advanced stages of design to simulate different design solutions and then improve the same design. The designer then improves the characteristics by parameterizing the coefficients after determining the fundamental criteria and, therefore, the desired outcome. Several BIM programs have successfully used parametric design as a design change management engine; nonetheless, parametric systems have matured into useful design tools but are not yet regarded as comprehensive BIM design applications. Dynamo was used to link sensors to the BIM environment. Dynamo is an open-source, visual programming software that is straightforward to use even for those who are not proficient in computer programming and computer language. Visual programming is a kind of coding that, unlike text programming, does not need code compilation or knowledge of a text programming language; rather, it employs a visual interface in which the designer links nodes with established functionality. Collectively, these nodes constitute a wider functional network capable of fulfilling complicated objectives. This method is simpler to implement and explore than text-based programming. It enables architectural designers to do activities that were traditionally reserved for expert programmers.

Using the capabilities of the Revit API, designers may also leverage individual objects or object families to conduct parametric operations. Dynamo enables users to

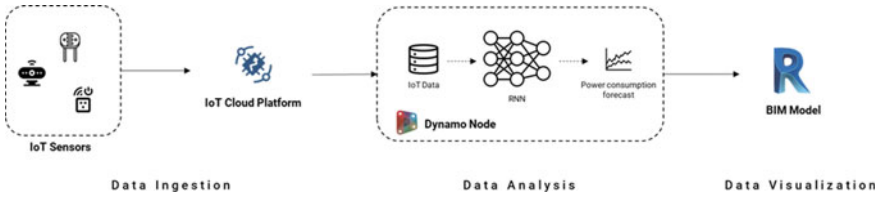

Fig. 1 Main system architecture

configure automation or computational platforms using a visual node-based compilation interface, enabling designers to undertake data processing and correlate structural and geometric parameter checks. The advanced architectural design is seen in Fig. 1.

4 Case of Study

The work is developed in two main phases, the first phase of construction of a complete digital twin and the second phase of construction of evaluation of deep learning techniques for energy consumption prediction. This study was carried out inside a public building, specifically, in a study room at the University of Salerno. The classroom under study was first monitored through light and lighting sensors, camera detection, and energy consumption.

The construction phase of the digital twin starts right from the construction of a basic architectural model that leverages visual programming and parametric design, especially visual programming allows the connection with the data collection platform, the set of values and the data visualization mode, and the automatic integration with the BIM working environment. In contrast, parametric design is leveraged for the visualization of the obtained data by scaling it in a 3D virtual space and positioning the sensors detected by an IoT-based platform. The data is then recorded on a cloud platform, ThingsBoard, which allows the data to be read and visualized immediately and easily, customizing the type of data according to the type of sensor selected or the design requirements. Using deep learning techniques, all the data were then analyzed to build a neural network model capable of predicting energy consumption from the sensor data. In particular, the literature shows how recurrent neural networks are effective in going to solve those problems related to regression [13].

4.1 Neural Network Implementation

The innovative idea of the work was to build a customized Dynamo node capable of making predictions about the energy consumption of the monitored environment to be fed directly into the BIM model so as to study its impacts in future [14].

The neural network model was implemented using the TensorFlow software library using Python as the programming language. TensorFlow is a library developed by Google and is one of the most widely used tools in machine and deep learning [15]. One of the main advantages of this library is that it can abstract the general neural network model from the actual implementation making it easy and intuitive to first design and then train any type of neural network.

To achieve this result, a dataset was first constructed in which all the data on an environment and consumption made over a 12-month period were collected by taking 3 measurements per day for a total of about 1000 measurements for each sensor type. Having the need to have a numerical value related to a numerical regression on time series, a recurrent neural network (RNN) was chosen to be trained, but based on radial basis function (RBF) layers with the purpose of obtaining a predictive model capable of inferring energy consumption from a set of input parameters [16].

The neural network was designed using 4 sequential recurrent layers using the following scheme:

- The first level is characterized by the input of type (6, 3), where 6 represents the number of measurements to be included in a single time window, and 4 represents the number of sensors plus the timestamp. This level has 12 output neurons of type dense. A time window of 6 measurements was chosen because 48 h of environment activity is covered.
- The second hidden layer, on the other hand, consists of 6 RBF-type neurons.
- The third level still consists of 8 RBF-type neurons.
- The fourth, and final output level, is formed by a single output neuron of type dense. Since we have the need to obtain a single numeric value as output.

All neurons use SoftPlus as their activation function. The neural network was trained using Adam as the optimization algorithm [https://doi.org/10.1109/IWQoS.2018.8624183], while the initially, collected dataset was partitioned using 90 percent of the data for training while 10 percent as test verification. All data, after being partitioned into time windows, were randomly shuffled before being given as input to training (Fig. 2).

Having thus obtained the trained model, a custom node was then implemented in the Python language for the Dynamo software, which is able to process the data from the BIM model and then go on to make the energy consumption forecast.

The node was also implemented using the same TensorFLow library used for model generation (Fig. 3).

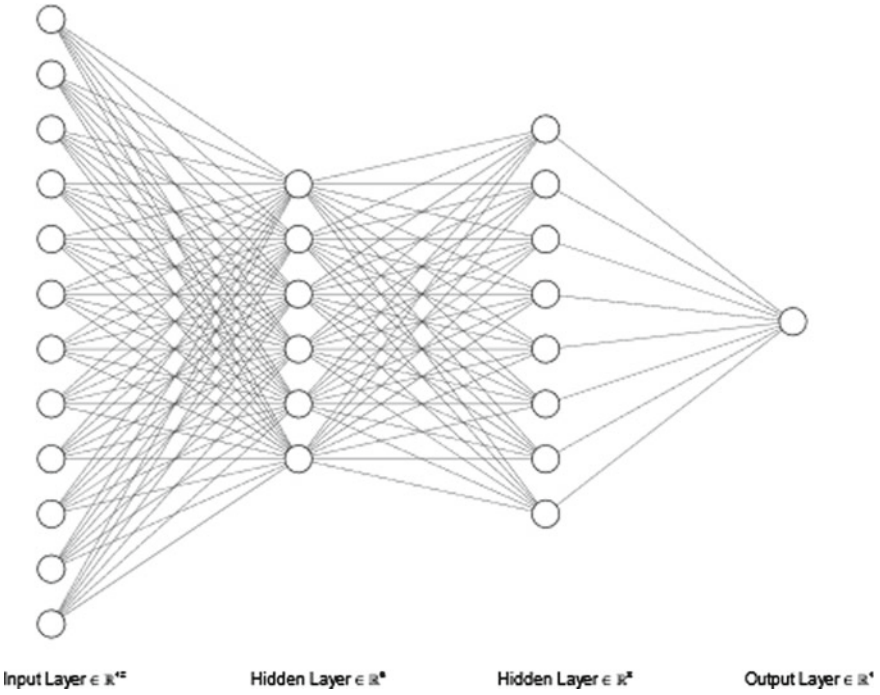

Fig. 2 Neural network architecture

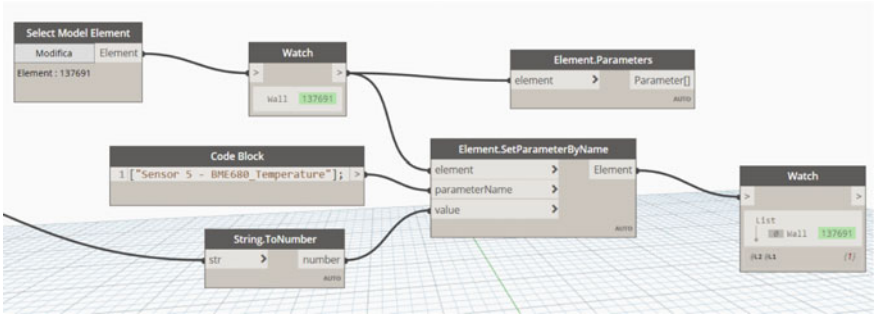

Fig. 3 DynamoBIM custom node

5 Results

During the training phase, the mean square error was used to evaluate the performance of the network. Specifically, it was obtained that on the realized dataset, the network was shown to have an accuracy ci about 93.2% compared with the test data.

The loss function of the network is

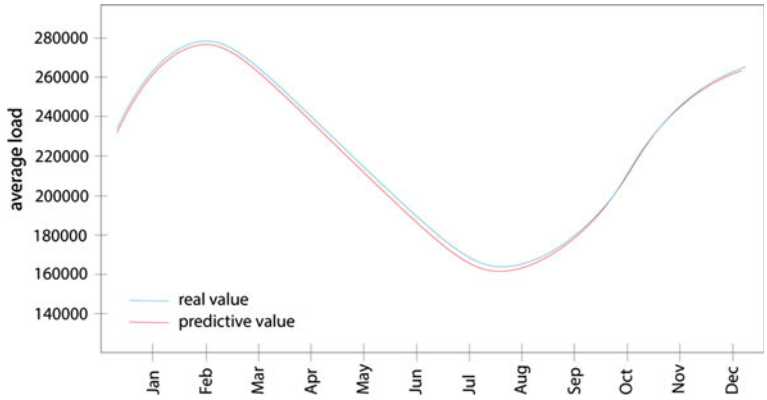

Fig. 4 RNN training results

$$\mathcal{L}(p) = \frac{1}{n}\sum_{i=1}^{n}(y_i - N(x_i, p))^2$$

where p is the vector of parameters related to the recurrent neural network and $N(x_i, p)$ represents the output of the network (Fig. 4).

From the point of view of BIM modelling, as seen above, thanks to the use of the dedicated Dynamo tool, it is possible to visualize the consumption conditions of a given space in real time and obviously aggregate the data for more general control and monitoring [17]. This type of setup allowed two different advantages. The first advantage is to monitor consumption and create management rules in order to limit energy consumption, the second is to monitor the correct functioning of the system and its efficiency, in order to prevent breakdowns and service interruptions. Thus, within the BIM environment, it is possible to visualize the data history in order to improve the management of the public asset. The use of the data not only feeds an informative database, but at the same time, it is possible to graphically visualize the real conditions of the environment being monitored, thus creating a digital twin that can be inspected and modified according to needs and possible future changes, so that not only numerical forecasts but also the design of the spaces can be made.

6 Conclusions

This work aims to exploit the potential of BIM coming from architectural design with IoT and deep learning coming from computer science, and this interdisciplinary approach was exploited to make predictions regarding the energy consumption of a real environment. In fact, the case study was monitoring and controlling lighting in a public environment such as a university lecture hall and how user behavior affects energy consumption. This data enabled the training of a predictive model based on

deep learning techniques, specifically recurrent neural networks, to produce projections of likely future scenarios that might develop. The creation of the digital twin made it possible to visually translate what was being produced within the DL. Indeed, it is possible to simulate either by using a specific parameter such as, for example, daylight intensity and then see how the actuators adjust to the different location or conversely set certain consumption parameters and visualize the resulting conditions. The experimental results, although preliminary, have shown promising results. They have shown that the system can learn and handle some actions autonomously. Future developments include expanding the database with other useful sensors to refine the data, introducing contextual parameters that could improve the system's reliability performance, and developing an application that could help users manage the building.

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IoT Approach for Development and Optimization of a System for Dry Peeling of Tomatoes

Angelo Lorusso, Francesco Marongiu, Tsega Y. Melesse, Antonio Metallo, Rosalba Mosca, and Domenico Santaniello

Abstract In recent years, tomato peeling has been done using steam and lye. Both methods are more expensive, less environmentally friendly, and highly polluting. Thus, a search for sustainable alternatives is needed. Among these is radiative heating. Heat is used to soften the skin of tomatoes and then peel them off, making this method simple, cost-effective, and easy to apply. However, there are some obvious limitations. Radiant heating peeling systems are sized based on the set-up and the average tomato diameter. Since tomatoes come in different diameters, the emissivity value and, consequently, the thermal power transferred by the lamp to the tomato will also differ. As a result, the process takes place at temperatures other than those optimal for the setup, so the product may not have the desired quality. The goal of this research is to suggest an improved dry peeling process that can standardize the process in terms of quality. A control system built on the Internet of things paradigm was investigated in order to provide a monitoring system to support an approximation of a solution. So, a process was created that takes the particular situation into account and implements the IoT principles.

Keywords Dry peeling system · Process control · IoT · Sensors · Industry 4.0

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1 Introduction

Sustainability is a major concern for the tomato processing industry [1–3]. With the development of infrared dry-peeling technology, hot lye can be replaced. The IR dry-peeling process relies on infrared heating panels to quickly heat up tomatoes, resulting in a thinner thickness of peeled-off skin and slightly firmer texture of peeled tomato. Food processors adopt this method due to its advantages of high efficiency, negligible water use, and sustainability [4, 5]. By irradiating the tomato surface with infrared radiation and selecting a suitable value of power density, temperature, and time, it is possible to increase the Young's modulus of the peels. As a result, the adhesiveness of the peel is reduced. These findings demonstrated the effectiveness of the novel IR dry-peeling process for tomatoes [6]. Peeling tomatoes is a challenging task, especially when different types of tomatoes must be peeled. However, some critical aspects of peeling tomatoes using infrared radiation heating were outlined by [7]. To peel tomatoes successfully with infrared radiation, one must realize both rapid and uniform heating on the tomato surface. An infrared heating system was designed to be installed in a food processing facility. This research is intended to improve the heating uniformity of tomatoes transported along by a conveyor belt, in order to obtain an optimal design of infrared heating systems. In order to obtain an optimal design of infrared heating systems, the irregular shape of tomatoes and their different exposures to the heating source when transported along by the conveyor belt need to be considered. In this context, a typical configuration for industrial peeling is realized by means of a plane matrix of infrared emitters [8, 9]. Firstly, to retrieve tomato thermal response to infrared heating, a numerical approach is necessary due to the complexity of the geometry. Previously, the authors attempted to descry the process using an analytical model: An infinite body subjected to a suitable source of pulsating heat was considered because the proper time scale was small [10, 11]. For peeling purpose, it proved useful to assume that the heating process would end a specified temperature was reached [4, 8, 12]. Achieving the best heating uniformity also means considering rotation speed and relative position to the source. After designing the system, determining the optimal parameters, and obtaining a temperature profile that guarantees the right heating uniformity and high-quality product, a controller was designed that would allow us to obtain a peeling process with similar temperature profiles to the reference one. De facto the presence of processing residue on the surface of the lamp, etc., affect emissivity values [9, 13] and therefore heat exchange. In order to regulate the intensity of the thermal flow, the rotation speed was adjusted since it is natural that the quality of the product decreases as we move away from ideal conditions. As a result, we can provide optimum thermal power to achieve peeling under the established condition. A standardized process in terms of temperature and therefore of quality is thus obtained using an IoT system [14].

2 Mathematical Formulation

2.1 Analytic Solution

For compare the final results, the analytical model used in [10, 11] fort start the study. Usually, a good peeling process calls for a very brief heating time of no longer than 60 s, attaining a surface temperature of around 100°C, which enables the peel to separate [4, 8, 12]. The semi-infinite medium in our study has combined boundary conditions of the second and third kinds, which represent convective heat exchange and periodic heating, respectively. Consideration is given to one-dimensional heat conduction and constant thermal characteristics. The heating intensity is considered to change sinusoidally with time while the source is on, i.e., in the first half of the period (Fig. 1), while it is zero in the second half. As a result, periodic nonhomogeneous boundary conditions that highlight the semi-amplitudes and characteristic angular speeds Ω of tomato rotation are required. When constant properties are considered and heat is transferred using internal conduction, instead of evaporation, dimensionless energy balance equations and associated boundary conditions have nonhomogeneous linear properties:

$$\partial^2\theta \big/ \partial\xi^2 = 2\partial\theta \big/ \partial\tau \tag{1}$$

$$\partial\theta \big/ \partial\xi\big|_{(0,\,\tau)} = \hat{\hat{q}}(\tau) - \mathrm{Bi}\big(\theta - \theta_f\big) \tag{2}$$

$$\theta(\xi \to 0,\ \tau) = 0 \tag{3}$$

$$\theta(\xi,\ 0 = \tau) = 0 \tag{4}$$

where the following dimensionless parameters have been introduced $\theta = (T - T_i)\big/(\Delta T_{\mathrm{ref}})$ is the temperature; the group $\Delta T_{\mathrm{ref}} = \frac{\dot{q}_0 x_{\mathrm{ref}}}{k}$ is a reference temperature difference related to the maximum wall heat flux, $\dot{q}_0$, and to a reference length $x_{\mathrm{ref}} = (2\alpha \cdot t_{\mathrm{ref}})^{1/2}$, k and α being the tomato thermal conductivity and diffusivity; the reference time, $t_{\mathrm{ref}} = \Omega^{-1}$, was chosen such as the dimensionless time resulted $\tau = \Omega \cdot \tau$, Ω being the angular velocity of the source; the dimensionless space variable was defined such as $\xi = x\big/x_{\mathrm{ref}}$, and finally, $B_i = (h \cdot x_{\mathrm{ref}})\big/k$ is the Biot number, $\hat{\hat{q}}(\tau) = \frac{\sin(\tau)\left[1 + \mathrm{sign}(\sin(\tau))\right]}{2}$ is the normalized wall heat flux. The analytical solution was obtained and validated in the previous works [11, 15]. As expected, the solution, as in Fig. 1, depends not only on the values at time τ, but it also depends on the heating previously experienced at each revolution, i.e., at each $\tilde{\tau} = i\pi$. The analytical solution was used to validate the approximate solution.

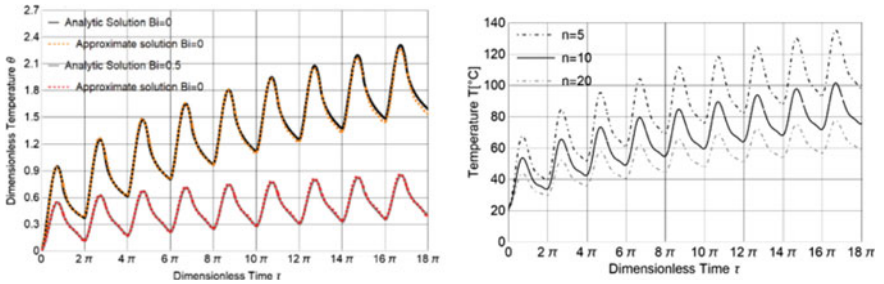


Fig. 1 Dimensionless surface temperature @$\xi = 0$ analytic versus approximate solution, surface temperature at different rpm values

2.2 *Approximate Solution*

The solution reached in the preceding paragraph looks to be fairly intricate, and thus, an approximation approach to the same problem is used to produce a simpler solution. The problem was solved by applying the integral method. It was possible to obtain the solution of problem (1–4) by choosing an approximate solution that makes explicit the dependence of the spatial variable:

$$\begin{aligned}\theta^*(\xi,\ \tau) &= a(\xi)\mathrm{erfi}\left(\tau^{1.5}\right) + (0.443 + 0.240\ \mathrm{Bi})\sin(0.5\tau)^2 \\ &+ (0.230 - 0.352\ \mathrm{Bi})\sqrt{\tau} \\ &+ (0.1860 \cdot 168\ \mathrm{Bi})\sin(2.112 - \tau)^3 \\ &- (0.235 - 0.249\ \mathrm{Bi})\sin(-\tau)^3 \\ &+ (0.158 - 0.165\ \mathrm{Bi})\sin(-1.587 - \tau) \\ &+ (0.207 - 0.144\ \mathrm{Bi})\sin(0.418 - \tau)^2 \\ &+ (0.177 - 0.297\ \mathrm{Bi})\mathrm{erf}(-\tau)\end{aligned} \tag{5}$$

Equation (1) has been integrated into the time coordinate and τ :

$$\int_{\tau=0}^{\tau=20\pi} \left(\frac{\partial^2\theta}{\partial\xi^2} - 2\frac{\partial\theta}{\partial\tau}\right) \cdot d\tau = 0 \tag{6}$$

By imposing that the approximate analytic equation satisfies the integral and applying a boundary conditions, we obtain:

$$\begin{aligned}\left(6.601 \times 10^{107719} + 0.318\,i\right)a''(\xi) - \left(1.563 \times 10^{107724} - 2\,i\right)a(\xi) \\ + 4.993\ \mathrm{Bi} - 3.302 = 0\end{aligned} \tag{7}$$

$$
\begin{aligned}
b.c.\ 1) \ - \ & \left.\frac{\partial \theta^{*}(\xi,\ \tau)}{\partial \xi}\right|_{0,\ \tau} \ = \ \hat{\dot{q}}(\tau) \ - \ \mathrm{Bi}\left(\theta \ - \ \theta_f\right) \\
& \Rightarrow \ a(0)\left(-\ \mathrm{erfi}\left(\tau^{1.5}\right)\right) \\
& = \ \frac{1}{2}\sin(\tau)(\mathrm{sgn}(\sin(\tau)) \ + \ 1) \\
& - 0.5[-(0.177 \ - \ 0.297\ \mathrm{Bi})\mathrm{erf}(\tau) \\
& + \sqrt{\tau}(0.230 \ - \ 0.352\ \mathrm{Bi}) \\
& + (0.186 \ - \ 0.168\ \mathrm{Bi})\sin^3(2.112 \ - \ \tau) \\
& + (0.235 \ - \ 0.249\ \mathrm{Bi})\sin^3(\tau) \\
& + (0.207 \ - \ 0.14\ \mathrm{Bi})\sin^2(0.417 \ - \ \tau) \\
& + (0.443 \ - \ 0.240\ \mathrm{Bi})\sin^2(0.5\tau) \\
& - (0.158 \ - \ 0.165\ \mathrm{Bi})\sin(\tau \ + \ 1.587) \ + \ a(0)\mathrm{erfi}\left(\tau^{1.5}\right)]
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
b.c.\ 2) & \theta^{*}(\xi \ \rightarrow \ 0,\ \tau) \ = \ 0 \\
& = \ (0.177 \ - \ 0.297\ \mathrm{Bi})\mathrm{erf}(\tau) \\
& + \sqrt{\tau}\,(0.230 \ - \ 0.352\ \mathrm{Bi}) \\
& + (0.186 \ - \ 0.168\ \mathrm{Bi})\sin^3(2.112 \ - \ \tau) \\
& + (0.235 \ - \ 0.249\ \mathrm{Bi})\sin^3(\tau) \\
& + (0.207 \ - \ 0.144\ \mathrm{Bi})\sin^2(0.417 \ - \ \tau) \\
& + (0.443 \ - \ 0.240\ \mathrm{Bi})\sin^2(0.5\tau) \\
& - (0.158 \ - \ 0.165\ \mathrm{Bi})\sin(\tau \ + \ 1.587) \\
& + a(3)\mathrm{erfi}\left(\tau^{1.5}\right) \ = \ 0
\end{aligned} \tag{9}
$$

The solution $a(\xi)$ was obtained:

$$
\begin{aligned}
a(\xi) \ = \ & \frac{1}{\mathrm{erfi}\left(\tau^{3/2}\right)}\mathrm{e}^{-\ 153.90\ \xi} \\
& \left[-\ 6.94 \ \times \ 10^{-\ 202}\mathrm{e}^{307.81\ \xi}\sqrt{\tau}\right. \\
& + 1.06 \ \times \ 10^{-\ 201}\mathrm{Bi}\ \mathrm{e}^{307.81\ \xi}\sqrt{\tau} \\
& + 5.34 \ \times \ 10^{-\ 202}\mathrm{e}^{307.81\ \xi}\mathrm{erf}(\tau) \\
& \left. - 8.95 \ \times \ 10^{-\ 202}\mathrm{Bi}\ \mathrm{e}^{307.81\ \xi}\mathrm{erf}(\tau)\right.
\end{aligned} \tag{10}
$$

$$
\begin{aligned}
&+ 3.19 \times 10^{-107}\mathrm{Bi}\, e^{153.90\,\xi}\mathrm{erfi}\left(\tau^{3/2}\right)\\
&- 9.62 \times 10^{-107925}\mathrm{Bi}\, e^{307.81\,\xi}\mathrm{erfi}\left(\tau^{3/2}\right)\\
&- 6.25 \times 10^{-202} e^{307.81\,\xi}\sin(0.417 - \tau)^2\\
&+ 4.33 \times 10^{-202}\mathrm{Bi}\, e^{307.81\,\xi}\sin(0.417 - \tau)^2\\
&- 5.62 \times 10^{-202} e^{307.81\,\xi}\sin(2.112 - \tau)^2\\
&+ 5.06 \times 10^{-202}\mathrm{Bi}\, e^{307.81\,\xi}\sin(2.112 - \tau)^3\\
&- 1.33 \times 10^{-201} e^{307.81\,\xi}\sin(0.5\tau)^2\\
&+ 7.24 \times 10^{-202}\mathrm{Bi}\, e^{307.81\,\xi}\sin(0.5\tau)^2\\
&+ 0.003\sin(\tau)\\
&- 2.93 \times 10^{-404} e^{307.81\,\xi}\sin(\tau)\\
&+ 0.003\ \mathrm{sign}[\sin(\tau)]\sin(\tau)\\
&- 2.93 \times 10^{-404} e^{307.81\,\xi}\mathrm{sign}[\sin(\tau)]\sin(\tau)\\
&- 7.07 \times 10^{-202} e^{307.81\,\xi}\sin(\tau)^3\\
&+ 7.50 \times 10^{-202}\mathrm{Bi}\, e^{307.81\,\xi}\sin(\tau)^3\\
&+ 4.78 \times 10^{-202} e^{307.81\,\xi}\sin(1.587 + \tau)\\
&- 4.98 \times 10^{-202}\mathrm{Bi}\, e^{307.81\,\xi}\sin(1.587 + \tau)\Big]
\end{aligned}
\qquad \text{(10 (continued))}
$$

and therefore the complete solution. It can be shown that the magnitude of the temperature fluctuations resulting from the Eq. (8) differs from that resulting from the corresponding exact Eq. (5) by no more than 1.5% for Bi = 0.5 and 1.2% for Bi = 0 (Fig. 1).

A dimensional formulation was used to calculate the temperature profiles as a function of the rotation speed Fig. 1. The dimensional temperature profile was evaluated assuming $T_i = 20°\mathrm{C}$, $\dot{q} = 40,000\ \mathrm{W}/\mathrm{m}^2$. The value of the heat flux was estimated by assimilating the emitter and the two-body tomato characterized by $\varepsilon = 1$ and uniform temperatures equal to 650 and 60°C, respectively [5, 9, 13]. How do you expect the increase of Ω determines a reduction of temperature profile, with decreasing sensitivity as Ω increases (Fig. 1). The amplitude of temperature fluctuations (ΔT) for each lap was also evaluated for different number of revolution Fig. 2, Table 1.

$$\Delta T_n(\tau) = a \cdot \tau^b + c \cdot \tau \tag{11}$$

As the number of revolutions decreases, the temperature difference increases. For regulation purposes, so, it is useful to evaluate, for each revolution, the ΔT as a function of n (Fig. 2). The data was fitted using an exponential function of the type:

$$\Delta T_\tau(n) = A \cdot n^B + C \cdot n \tag{12}$$

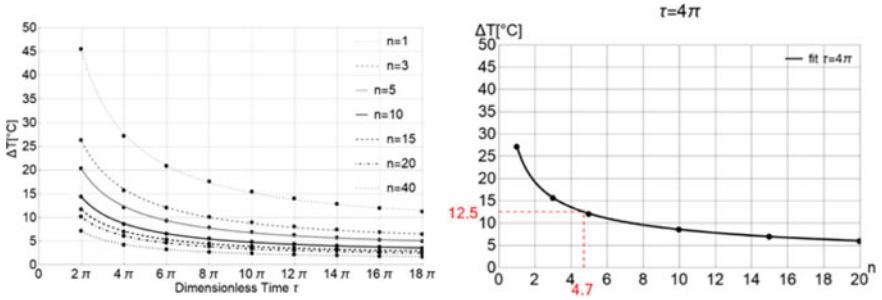


Fig. 2 Amplitude of temperature fluctuations, and function of n at $\tau = 4\pi$

Table 1 Amplitude of temperature

Function of τ				Function of n			
τ	a	b	c	n	A	B	C
2π	45.494	− 0.5	$4.651 \cdot 10^{-17}$	1	174.156	− 0.735	0.0459
4π	27.206	− 0.5	$3.334 \cdot 10^{-17}$	3	100.549	− 0.735	0.0265
6π	20.876	− 0.5	$4.450 \cdot 10^{-17}$	5	77.885	− 0.735	0.0205
8π	17.599	− 0.5	$2.031 \cdot 10^{-17}$	10	55.073	− 0.735	0.0145
10π	15.505	− 0.5	$5.520 \cdot 10^{-17}$	15	44.967	− 0.735	0.0118
12π	14.017	− 0.5	$5.007 \cdot 10^{-17}$	20	38.942	− 0.735	0.0102
14π	12.890	− 0.5	$9.302 \cdot 10^{-17}$	40	27.536	− 0.735	0.0072
16π	11.998	− 0.5	$4.924 \cdot 10^{-17}$				
18π	11.269	− 0.5	$1.054 \cdot 10^{-17}$				

In this way, an estimate of ΔT for each period as the number of revolutions varies is obtained.

3 Materials and Method

The experimental setup of Fig. 3, relating to the peeling of tomatoes with radiation, belongs at the first step of Pan's activity, Li et al. [8] and Pan et al. [4]. The study is divided into two parts: logic control and IoT system.

3.1 Logic Control

To realize successful peeling, surface temperatures are to be raised to values as high as 100°C in a very short warming up period, typically no more than 60 s. [4, 8, 12]. By setting the rotation speed value to 10 rpm and the thermal flow value to 40,000 W/m^2, the peeling process is completed in 51 s.

$$t_{\text{end}} = \tau_{\text{end}} \cdot t_{\text{ref}} = 17\pi 3 \big/ \pi = 51 \text{ s} \tag{13}$$

Therefore, after obtaining the rotation speed value which allows to obtain the optimal peeling quality, the dimensional temperature profile relative to the value $n = 10$ and $\text{Bi} = 0$ was taken as a reference for the regulation system. Indeed, in the case of natural convection the value of Bi is very small, therefore for simplicity of calculation it was chosen equal to 0 [10, 11]. For regulation purposes, the error is evaluated at each rotation as follows:

$$\text{err}_i = T_{\text{sensor},\, i} - T_{\text{targ},\, i} = T_{\text{sensor},\, i} - (\theta * (0,\ i)\Delta T_{\text{ref}} + T_0) \tag{14}$$

for $i = 2\pi : 2\pi : \tau_{\text{end}}$, where $T_{(\text{targ},\, i)}$ represents the temperature at the end of the period corresponding to the reference temperature profile. Thus, the ΔT_{targ} value necessary to reach the target temperature in the next rotation is evaluated:

$$\Delta T_{\text{targ},\, i + 2\pi} = T_{\text{targ},\, i + 2\pi} - T_{\text{sensor},\, i} \tag{15}$$

By particularizing Eq. (15) at time $i + 2\pi$, the value of n to be used for regulation is obtained:

$$\Delta T_{\text{targ},\, i + 2\pi} + \text{err}_i \big/ 2 = A_{(i + 2\pi)} n^{B(i + 2\pi)} + C_{(i + 2\pi)} n \tag{16}$$

The method's efficacy may be examined using a straightforward example. The geometric irregularity of the tomatoes and/or the presence of processing residues on the lamp's surface affect the value of, which results in a reduction in the thermal power transferred [11, 15, 16]. The radiative heat flux value is supposed to drop to the value of $\dot{q}^* = 33,000 \text{ W} \big/ \text{m}^2$ under the same operating conditions. The decrease in the heat flow leads to the decrease in the ΔT_{ref}, and consequently, the temperature profile is lower $\left(\Delta T^*_{\text{ref}} < \Delta T_{\text{ref},\, n = 10}\right)$. Heat flux reduces, and hence, the rate of temperature rises decreases. Thus, by not actuating the regulation, the temperature profile shown in the Fig. 3 is obtained.

As shown, we move away from the predetermined optimal conditions. Ad-hoc regulation is implemented to keep the temperature profile similar to the reference one even if work conditions change. Consequently, when the temperature drops below the reference temperature, the rotation speed is reduced, and vice versa. First of all, at the end of the first rotation, the surface temperature of the tomato is measured with a pyrometer. The thermal response is simulated in the presence of a thermal power

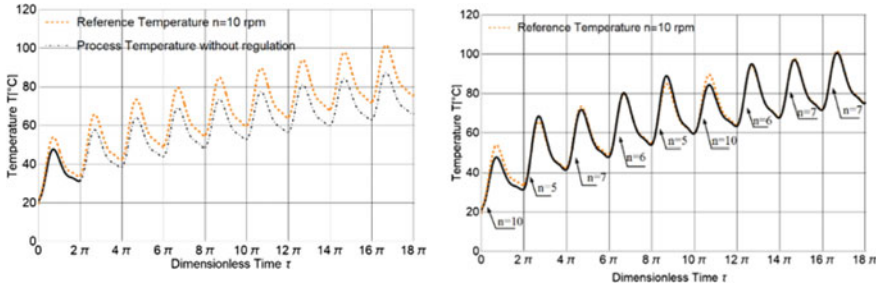


Fig. 3 Temperature profile without regulation, temperature profile with regulation

transferred by the lamps equal to $\dot{q}^*$..

$$T_{\text{sensor},\,2\pi} \;=\; T_{1^\circ}(0,\;2\pi) \;=\; T_0 \;+\; \Delta T^*_{\text{ref}}\theta^*(0,\;2\pi) \tag{17}$$

with $T_{1^\circ}(0,\;\pi)$ representing the temperature read by the pyrometer in the first period. After the calculation of the target temperature at the end of the first rotation Eq. (8), the error is evaluated Eq. (17).

$$\text{err}_{2\pi} \;=\; T_{\text{targ},\,2\pi} \;-\; T_{\text{sensor},\,2\pi} \;=\; 34.1 \;-\; 31.5 \;=\; 2.6\,^\circ\text{C} \tag{18}$$

The $T_{\text{targ},\,i\,+\,2\pi}$ is then calculated Eq. (18):

$$\Delta T_{\text{targ},\,4\pi} \;=\; T_{\text{targ}}4\pi \;-\; T_{\text{sensor},\,2\pi} \;=\; 11.2\,^\circ\text{C} \tag{19}$$

and finally, by means of Eq. (15), particularized at time $\tau \;=\; i \;+\; 2\pi$, the correct value of n is obtained:

$$\begin{aligned} \Delta T_{\text{targ},\,4\pi} \;+\; \text{err}_{2\pi}/2 \;&= 27.206n^{-\,0.5} \;+\; 4.651 \;\cdot\; 10^{-\,17}n \\ \Rightarrow n \;&=\; 4.7 \;\sim\; 5 \end{aligned} \tag{20}$$

A number of revolutions is chosen which, in the period between 2π and 4π, achieves a ΔT necessary to reach the target temperature at 4π, entered to consider the fact that the starting temperature is lower than in the ideal case $(+\,\text{err}/2).(+\,\text{err}/2)$.

The temperature profile in Fig. 3 is built by following the same steps for each period.

Even when the working environment is not ideal, the control system can adjust the heating intensity and rotation speed to achieve the correct temperature. It has been demonstrated that even when the operating circumstances diverge from the ones that were predetermined, the regulating system is still able to adjust by changing the rotation speed, the heating intensity, and subsequently the temperature profile. In this way we have an effective method which allows us to have a standardized peeling process regardless of different working conditions. It can also be noted that the

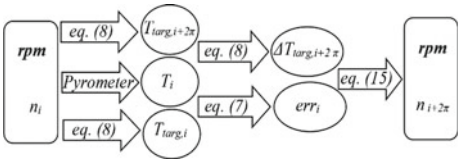


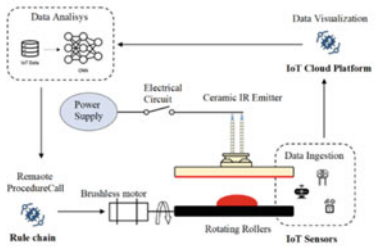
Fig. 4 Regulation procedure

average temperature obtained from the regulated temperature profile 66.3°C and that relating to the reference 67°C are generally the same, with only a very small error. Thus, even though the set-up conditions are different, a peeling process has been got that is entirely similar to the individual thought-out optimum, both in thermal conditions and in terms of quality. We can recap it as follows (Fig. 4).

Known the optimal value of n, the peeling process starts. At the end of the i period, through Eq. (8), we extract the T_{targ}, at period i and at period $i + 2\pi$, and through the pyrometer the temperature of tomato. Equation (17) allows us to calculate the temperature jump required to reach the target temperature at the next period, while Eq. (18) the error. Using Eq. (15), the number of revolutions for the following period is obtained. This results in a standardized peeling process in terms of process time, temperature, and quality.

3.2 IoT Architecture

The mathematical models that explain the best tomato peeling control procedure have been empirically examined in the preceding chapters. It is clear that the fundamental analytical answer ends up being a computationally costly procedure. As a result, a system of approximative solutions that is much simpler to calculate has been established on the basis of the examined elements. The tomato's surface temperature, size, and degree of ripeness are important information for regulatory purposes. It was chosen to study a control system based on the Internet of things paradigm in order to create a monitoring system to support an approximate solution. For this reason, a system of sensors was developed to continuously and in real-time monitor the values that feed the control system, which is based on an approximation of the solution. As a result, a set of rules was developed to control the actuators, in this case the tomato transport and rotation system. This data is collected using specialized sensors as well as IR and video cameras. The temperature and humidity sensor monitor the general environment in which the process takes place, in order to ensure that the surrounding conditions are similar throughout the process. The tomato's level of ripeness and the degree of "red" are controlled by the RGB color sensor in accordance with the measured temperature. The lamp's intensity level and, consequently, its heating effectiveness are monitored by the light sensor. Additionally, an IR camera is used to measure the tomato's surface temperature, and a camera and the proper image processing software are used to measure the tomato's size. The



	Sensors	Parameters
Temperature	DHT22 (Adafruit Industries New York, NY, USA)	General system temperature
Humidity	DHT22 (Adafruit Industries New York, NY, USA)	General system humidity
Thermal Camera	MLX90640 24x32 IR Thermal Camera Breakout - 110 Degree FoV (Adafruit Industries, New York, NY, USA)	Tomato surface temperature
Light RGB	TCS34725 (Adafruit Industries, New York, NY, USA)	Tomato ripening and colour
Light Intensity	BH1715 (NCD I2C, Vista, USA)	Lamp light intensity
Camera	Raspberry Pi High Quality HQ Camera - 12MP (Adafruit Industries, New York, NY, USA)	Number and size of tomatoes

Fig. 5 IoT architecture

information gathered by the sensors is then gathered and viewed on a specific platform called Thingsboard, which enables data management through dashboards for each sensor [17, 18]. The data is then examined using machine learning techniques as a node, feeding a set of rules that are based on the study's formula for approximate solutions. In fact, as can be seen from the diagrams previously described, the rotation time affects the surface temperature of the tomato and, consequently, the success of the final peeling. The values obtained feed an actuation system that acts on the motors that manage the tomato's rotation. Therefore, the objective is to ensure that there is a standardization of the proposed system in order to satisfy the criterion described concerning the optimization of times and rotations of tomatoes. Additionally, by using an IoT approach, the system can continuously monitor the mechanical components that are in use, like motors and lamps, in order to create a predictive maintenance system for the entire plant [19, 20]. This will ensure that the system is always operational and will prevent unforeseen interruptions of the mechanism (Fig. 5).

4 Conclusion

After having carried out a preliminary study and having obtained the value of the rotation speed and therefore of the temperature profile, which makes it possible to obtain a peeling of excellent quality, at the chosen set-up (distance and power of the IR lamp, average diameter of the tomatoes, etc.), it is important to put in a logic of control which allows us to obtain a conforming to that sought when the set-up conditions vary. Any cause that takes us away from pre-established conditions, for example, a diameter of the tomato lower than that tested in the preliminary study, can be assimilated to a variation in thermal power exchanged between the lamp IR and tomato. In particular, the surface temperature of the tomato has a lower profile than the reference one if the thermal power is lower, vice versa in the opposite case. Therefore, to obtain the same temperature profile for the peeling process, a control logic has been put in place which allows the thermal power between the IR lamp and the tomato to be varied by adjusting the number of revolutions. Through the study

of the analytical model and the approximate solution, an estimate of the amplitude of temperature fluctuations $\Delta T(n)$ for each period as the number of revolutions varies was obtained. Consequently, the Eq. (15) is used to determine the value of the number of revolutions for the following period after evaluating the temperature error between the sensor temperature and the target temperature (obtained from the approximated solution) at each period and the temperature jump required to reach the target temperature at the next period.

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Modeling and Simulation of Conveyor Belt Speed Using LabVIEW Software

Honorato Ccalli Pacco and Noe Benjamin Pampa Quispe

Abstract In industrial and agro-industrial companies, it is necessary to use conveyor belts for the transfer of bulk or packaged products from one environment to another, either for processing or for storage, which has a significant cost in the processes in said industries. For this reason, studies are needed to find the operating efficiency of the transport system. This research work was carried out in the computer laboratories of the Professional School of Agroindustrial Engineering of the National University of Moquegua. The National Instrument Laboratory Virtual Instrument Engineering Workbench (LabVIEW) software is used for the modeling and simulation of the speed of the conveyor belt, and it is a visual programming language, which allows graphic programming more easily than other types of linear programming. As a result of the modeling and simulation research work using graphical visual programming, a fast speed, an average speed and a slow speed were recorded on the conveyor belt under study with an expected response.

Keywords Simulation · Conveyor belt · Speed · LabVIEW

1 Introduction

Energy consumption can be reduced from 50 to 100%, when a program model is used to optimize the operation of a conveyor belt according to the authors, [1] when they carried out the research work on "optimal and energy efficient operation of conveyor belt systems with downhill conveyors". The LabVIEW software was used by, [2] where it was able to record temperature and humidity data when designing and developing the forced-air system in the egg incubator mounted on a conveyor belt

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that adapts to different types of conditions of eggs for their incubation for a certain time, which shows the importance of the conveyor belt in the industry and its study of operating efficiencies is necessary, and the importance of the LabVIEW software used in the control of industrial processes. In results obtained in work carried out by the authors, [3] in "Drying of olive (Olea europaea L.) leaves on a conveyor belt for supercritical extraction of bioactive compounds" show that there is a very interesting alternative to dehydrate olive leaves using a conveyor belt that allowed evaluating the effects of temperature on dehydration, which will be used to extract bioactive compounds using the supercritical extraction method, and where they could mathematically model the operations of dehydration, extraction, and analysis of the extracts. In the installation of a conveyor belt for the purpose of visual control of a product that slides on said belt, allowed the authors, [4] when they carried out the investigation of "High Speed Vision Based Automatic Inspection and Path Planning for Processing Conveyed Objects". To conclude that the studies allow to reduce operating costs and improve the productivity of the process, for this, methodologies that allow the control of movement in the moving conveyor belt with products to be inspected must be used. In work done by [5], aiming at the speed regulation problems of the constant torque load such as adjustable speed asynchronous magnetic coupling (ASAMC) matching belt conveyors, the variation of the acceleration under the matching condition of the air gap at the start of the belt conveyor is quantified. On this basis, a soft start control strategy for the matching of ASAMC and the belt conveyor is established. Fuzzy control was used to control and stabilize a generalized model of a mineral conveyor belt, where the authors [6] proposed quality control to solve stability problems in the system. In "Procedures of Detecting Damage to a Conveyor Belt with Use of an Inspection Legged Robot for Deep Mine Infrastructure" in work carried out by the authors, [7] demonstrate the importance of conveyor belts in different industries, since they are responsible for the horizontal or vertical transport of thousands of tons of mineral material in mines, covering large distances that can be traveled from 0.5 to 2 km from the depths of the same, that is why they use an inspection robot to detect any failure when they are operating at one hundred percent, they consider that it is the main and critical component of the system. In addition, these belts are the most expensive, and their damage would cause undesirable stoppages in mine operations. Automatic bottle filling using programmable logic controller (PLC) constitutes a user-specified volume selection, in which the user can input the desired amount of liquid or water to be inserted in the bottles. It is generally used where many bottles of the same volume are to be filled by passing bottles over the conveyor belt, [8]. The authors [9] carried out a simulation study of a double conveyor belt to verify the active speed control that they had proposed, and in this, they obtained as a result that an average of 16.21% would be the energy saving in eight hours of operation compared to other constant speed operation. The following authors, [10] in a work carried out in "Healthy speed control of belt conveyors on conveying bulk materials", have demonstrated the important role that conveyor belts have in industries to transport bulk materials for which they carry out the study on the speed control with the intention of reducing energy consumption in their operations,

and for this they apply an estimation–calculation–optimization method, which determines the minimum speed adjustment time, thus guaranteeing transitory operations. Regarding transient operations and according to experimental results obtained, the method used was successful since it determines the minimum speed adjustment time, guaranteeing the temporary acceleration and deceleration operations. The running duty of a conveyor belt may be modified by modifying the duty-cycle value of the PWM signals that controls the transistors of the H-bridge that supplies the DC motor, [11]. Using a conveyor belt, the authors [12], in a work carried out in "Conveyor-belt drying of Eugenia uniflora L. leaves: Influence of drying conditions on the yield, composition, antioxidant activity and total phenolic content of supercritical CO_2 extracts" obtained leaves of Eugenia Uniflora L dehydrated at different temperatures in forced air drying and at different exposure times on the dryer conveyor belt, demonstrating the important application of conveyor belts for research experiments for different areas of science, likewise they conclude that the conveyor belt is an alternative to dehydrate leaves for extraction or preservation research.

In the research work "High Speed Vision Based Automatic Inspection and Path Planning for Processing Conveyed Objects" carried out by the authors, [4] they have concluded that they can achieve savings in agricultural production, using a conveyor belt system, which transports the agricultural product for inspection and to remove defective products or due to lack of quality, and therefore, an efficiency in the transport of product to be inspected and the efficiency of operation of the conveyor belt would have greater productivity in the company.

In the analysis carried out by the authors [13], about the LabVIEW software, from National Instrument, they demonstrate its importance as a graphical virtual programming language that is very easy to use and that can replace a large amount of complex and expensive hardware, using for acquisition data, instrument control, and industrial automation, such as in the simulation and speed control of a moving system through virtual instrumentation.

In conclusions obtained by the authors [14], in the research work using the LabVIEW software in the modeling and simulation of a photovoltaic system that was connected to the network, they propose the modeling of the identified photovoltaic module to obtain main parameters and successfully validated the designed and developed experiment. With the use of the National Instrument LabVIEW software, which is the graphic programming language and which greatly facilitates virtual programming, the authors [15], in their research work, were able to use it for automated measurements of Eddy currents.

The research presents the modeling and simulation mechanisms proposed by several authors; then the implementation of the process of modeling and simulation of the speed of a conveyor belt is presented; the simulation results observed in the speed of the conveyor belt are also presented. The following sections present the conclusion, future work to be done, and the corresponding references.

2 Materials and Methods

2.1 Materials

To carry out this research work, it was necessary to have the following materials and accessories, a Dell brand laptop with 5G Ram memory, with a 500 GB hard drive. A software of the National Instrument the LabVIEW that allows us to use as a graphic programming language whose main scope of application of this software is in the measurement, control and automation of industrial and agro-industrial processes. Programming is done using two windows called a front programming panel where it contains the interface, and the window called block diagram panel is where monitoring and data management are programmed and where the graphics code is included; it is necessary to have a conveyor belt instrumented with basic sensors or instruments that allow modeling and simulating the control of the system, as suggested by authors, [16]. **Sample Heading (Third Level).** Only two levels of headings should be numbered. Lower level headings remain unnumbered; they are formatted as run-in headings.

Sample He

2.2 Methodology

To carry out the research on "Visualization of virtual environment through LabVIEW platform", the authors [13] use a tool for modeling, simulation, and control, the National Instrument LabVIEW software, and graphical programming to simulate and control the speed of a belt conveyor for the virtual visualization of the process. Using a computer allows us to simulate an instrument or device for what is called a virtual instrument, the National Instrument presents a software called LabVIEW, which means laboratory virtual instrument engineering workbench, this is a graphic programming language, and when it is used in a personal computer, it is easier for us to model, simulate, and control a system operation using different control accessories, cables, functions, sensors, transducers, meters of different magnitudes, etc. With the National Instrument LabVIEW software, we can very easily build graphical representations of lines of operations that we call virtual instrumentation as we can see in Fig. 1, a window that shows block diagrams of different operations programmed with icons, circuit of cables, and others in a window called block diagram panel. In another window of the LabVIEW device known as the front panel where drivers and indicators can be or are installed as shown in Fig. 2. All this according to how the authors present, [13].

The LabVIEW software has been chosen for the modeling and simulation of the speed of the conveyor belt, knowing that its graphic programming is very easy and a

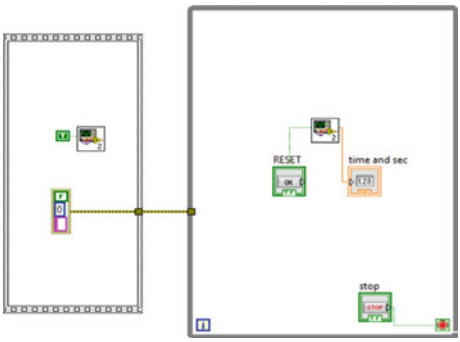

Fig.1 Block diagram of simple timer circuit. *Source* [13]

Fig. 2 Front panel of simple timer circuit. *Source* [13]

programming expert is not needed, compared to others who have linear programming and special programming knowledge is required, and many authors recommend.

By suggestions of different authors, the development of the modeling and simulation of the speed control of a conveyor belt was carried out, showing complete programming diagrams on the block panel and the different components of the system on the front panel of LabVIEW.

With the use of the LabVIEW software, it was possible to incorporate a simple timer for counting the time in milliseconds or another unit that is necessary. We use the indicated simple timer to show the count of time in the unit of seconds.

In the displacement of the system, the information of the performed action is given. In a functional global variable using the while cycle that allows adding data until the virtual instrument remains in memory. The LabVIEW software uses date and time data to then convert the time to seconds. When T is selected in the while system, which is a true response, it is there that the system starts operating; then if F is selected, it is a negative or false response, and in this case, the system does not start operating.

The subtraction numeric symbols are used to subtract the current time and the past time in system operation. Addition numeric symbols are used to add subsequent times and show the times elapsed in system operation. The block diagram panel structure consists of one or more subdiagrams or frames, which will be executed

sequentially. It is the window to reset the timer, group of errors, and other important devices for the operation of the programmed system, as presented by the following authors [13, 16] and other authors.

3 Results and Discussion

From the results obtained by working with the software LabVIEW for graphical programming, it was possible to create the speed of a conveyor belt controllers for laboratory, making it possible to vary at different speeds and distances.

The program issued in LabVIEW for the control of the speed of the conveyor belt has the block diagram shown in Fig. 3 and the front panel related to the conveyor belt, Fig. 4.

Next, a constant is created in the block panel that will be a time with 500 ms that will allow an average speed of the conveyor belt and a stop button for the conveyor belt on the front panel, Figs. 5 and 6.

Next it will be necessary to connect the case structure, Fig. 7, that encloses the program of the case structure.

This allows the modeling and simulation of the following actions; when the Ok button is pressed, true must be executed, that is, the program must start working, and when the button is not pressed, nothing is executed in the program.

Now, it is necessary to enclose the entire program in the case structure while loop, as shown in Fig. 8, and then, we create a time control with 100 ms for the entire system.

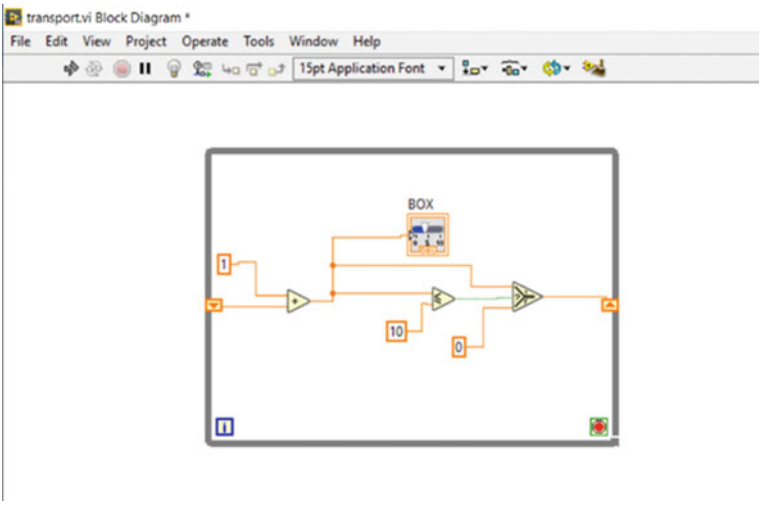

Fig. 3 Block diagram panel

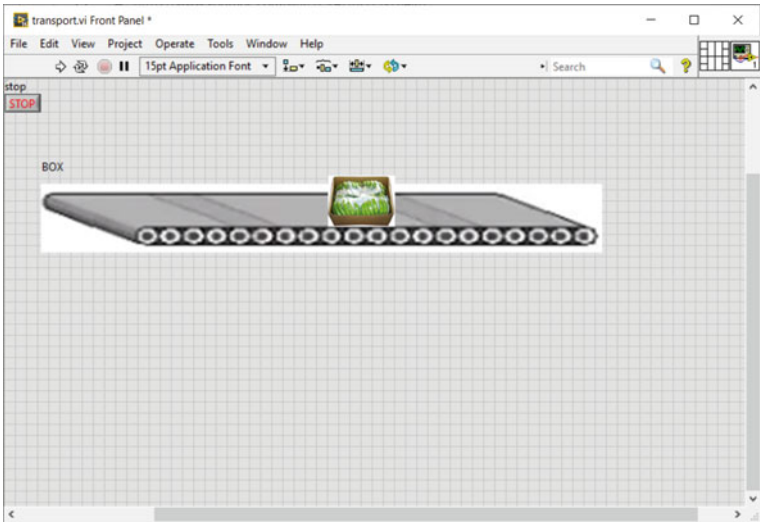

Fig. 4 Front panel with conveyor belt and box

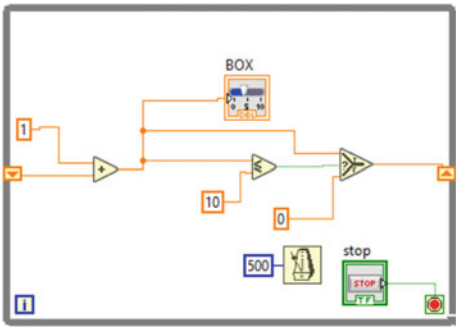

Fig. 5 Block diagram panel with time

On the front panel, we place the start button, the stop button for the conveyor belt, and the emergency stop button for the entire system, as we can see in Fig. 9.

Where:

Start button allows us to start the departure of the conveyor belt system.

Stop button allows us to stop the conveyor belt.

Emergency stop button allows us to stop the entire conveyor belt system.

The results of the tests or tests carried out in the modeling and simulation of speed in the conveyor belt under study, in which the movement of a box on the conveyor belt with the time parameters for 100 ms was observed (fast speed), have been carried

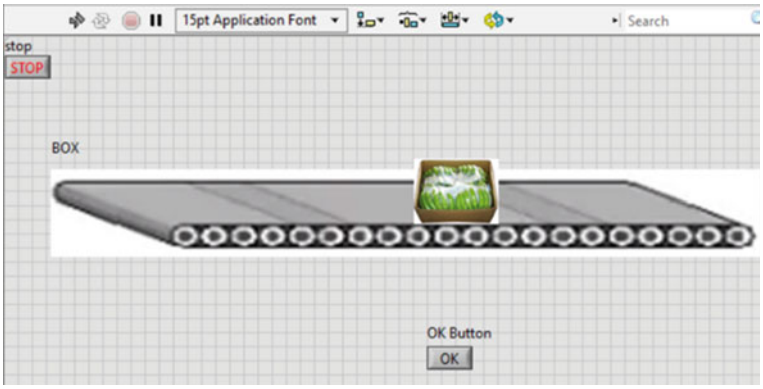

Fig. 6 Front panel with button and stop

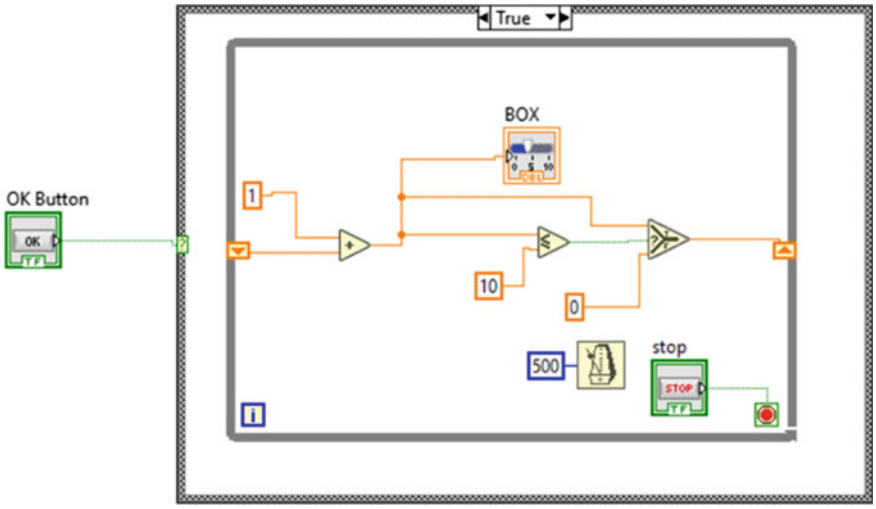

Fig. 7 Block diagram with case structure

out, 500 ms (medium speed) and for a time of 1000 ms (slow speed) as shown in Table 1. The lower the time in milliseconds the speed of the conveyor belt is faster, and for a longer time in the system the speed will be more slow.

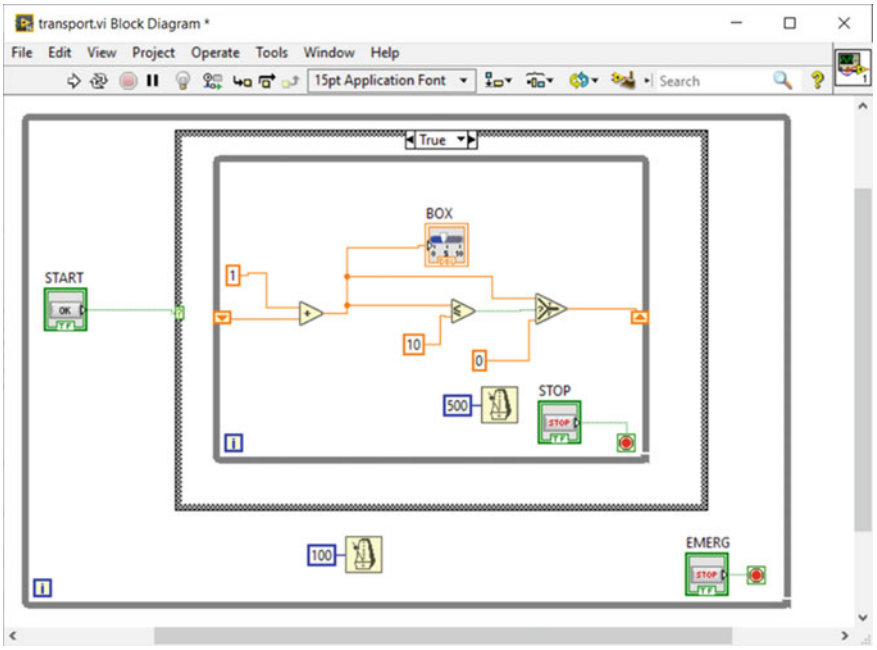

Fig. 8 Entire system or program is enclosed in the while loop case structure

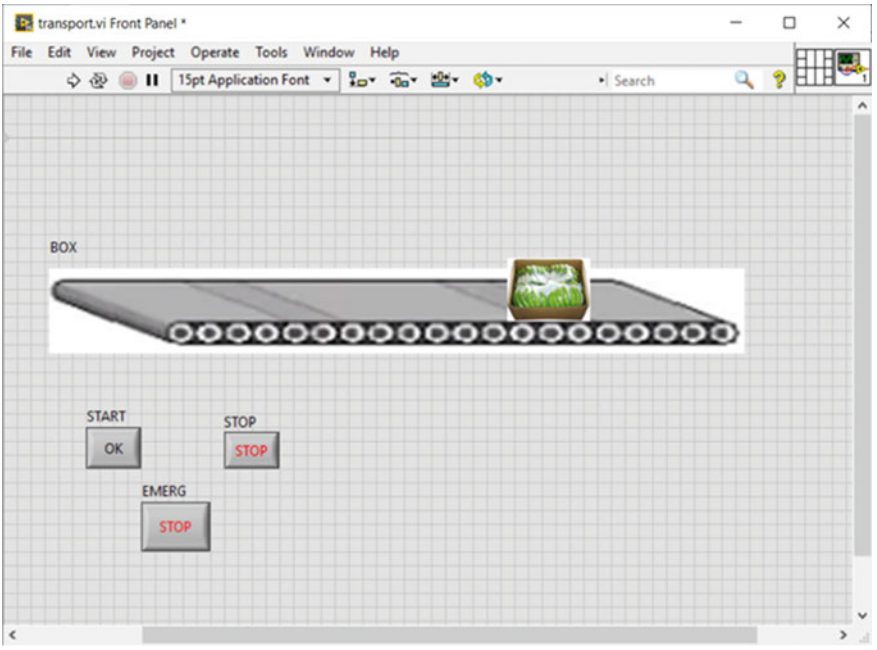

Fig. 9 Front panel with start button, stop button, and emergency stop button

Table 1 Simulation data for conveyor belt length of 10 linear meters (speed in s/ 10 m)

Tests	Speed 100 (S)	Speed 500 (S)	Speed 1000 (S)
1	1.15	4.32	9.51
2	1.16	4.50	9.03
3	1.14	4.06	9.82
4	1.16	4.27	8.75
5	1.12	4.33	8.84
6	1.14	4.22	9.02

4 Conclusión

With the application of the LabVIEW software, it was possible to carry out the graphic programming for the modeling and simulation of the speed of a conveyor belt, obtaining a very fast speed, a medium speed, and a slow speed, with the possibility of making other speed alterations.

With this research work of modeling and simulation of the speed of the conveyor belt with the support of the LabVIEW software, it was possible to show its application in the industry as well as for research in different areas. It is also suggested as a future investigation of filling boxes with different products that move on a conveyor belt.

With the modeling and simulation of the speed of the conveyor belt, using graphical programming, we can quickly generate the different operations of the conveyor belt for any type of product.

In the modeling and simulation of the speed in the conveyor belt, the expected results of a fast, medium, and quite slow speed were obtained.

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Cognitive and Neurocognitive Indicators of Perceived Emotions: Implications for Rehabilitation

Gagandeep Kaur, Bishakh Bhattacharaya, and Maya Dimitrova

Abstract The paper presents the results of a study of human perception of emotional stimuli within the valence-arousal theory of emotion. The study involved 2 stages—EEG recording during viewing of images of 4 valences: happy, sad, excited, and angry. After each image, the participant identified the emotion first and then responded to a Likert scale on the intensity of the emotionality of the picture, defined as cognitive processing. The main result revealed a tendency toward significant difference in the assessment of the emotion intensity by the male and the female participants for 3 of the valences—happy, excited, and angry, but not for the sad. Neurocognitive indicators of brain activation—alpha and theta waves—are discussed in the context of possible novel approaches to rehabilitation in both genders.

Keywords Emotional stimuli · Cognitive indicators · EEG · Likert scale · Gender differences

1 Introduction

The impact of short-term and long-term physical disability on emotional well-being is an important factor in rehabilitation. The interventions for rehabilitation should ac-count for such emotional alterations to optimize the functioning and quality of life of the affected people. The present study is designed to facilitate the understanding of emotional states for this purpose. In this study, the methodology combines the psychological perception of the participants along with the changes captured by their

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brain signals using EEG records while they were exposed to visual stimuli [1–3]. This novel methodological alteration protects us from absorbing data that resulted from misinterpreted valence from the participant.

It is common to assume the emotion in the given pictorial stimulus and check if the participant response is corresponding, but what if the participant perceives a different emotion? To attend to this opacity, our study is designed so that the participant perception of emotion and its intensity are recorded on a 7-point Likert scale immediately after each picture exposure, while simultaneous EEG is recorded for the entire session. Post data acquisition, the behavioral response of the participant is considered prior to the observation of the EEG response, thus taking into cognizance the participant's unique perception of emotion which may assist in the observation and analysis of the corresponding electrophysiological response.

Studies on human emotions have been documented since the later part of the nineteenth century [4]. The diverse schools of psychology have developed multiple theories and models representing the mechanisms of human emotions. These theories were based on different assumptions—physiological that would describe emotions as manifestation of responses within human body [5], neurological theories [6] that describe emotions as expression of actions within the brain, and theories based on mentation [7]. Further, the respective models have been proposed to assess the perception and representation of the diverse individual experiences, associated with given emotions.

The categorical and dimensional models have been well known, and the valence-arousal model has been prevalent [8]. It represents each emotion along a positive–negative dimension and its intensity on an orthogonal axis to the previous dimension to reflect the underlying level of cognitive activation with some probable neural manifestation. However, when viewing emotional images, mapping the self-report on the nature and intensity of the experienced emotions was difficult and not always definitive.

This study aims to identify possible factors that can determine the peculiarities of the observed neural activations in EEG frequency maps. One of these factors may be gender. It is possible to observe differing patterns in male and female participants in respect to valence. It is also possible to observe different intensity of the experienced emotion. The results of this study will have a significant impact on rehabilitation approaches that can be undertaken in the future through brain monitoring technology.

2 The Experimental Study

The aim of the study is to determine whether it is possible to retrieve patterns of emotions from the electrophysiological and verbal responses while the participant attends to a visual stimulus. A stimulus was designed using pictures from the publicly available OASIS database [9].

Participants. Data from three female (F) and seven male (M) participants, who took part in the experiment, is used in the present paper. The participants were without any significant physical health issues related to vision (e.g., color blindness) or musculoskeletal problems. The participants were not familiar with the study context until before the study.

Ethics. The study was approved by the Institutional Ethics Committee (IEC), IIT Kanpur. All procedures conformed to the IEC guidelines for research involving human subjects. The participants were provided written information about the study and a consent form which they had to sign for their approval to take part in the study.

Hardware. This experiment was done using a g.Nautilus wearable wireless EEG signal acquisition system [10]. It has 16 active EEG electrodes g.SAHARA (G.Tec), each sampled at 500Hz with flexible electrode positioning option in compliance with the 10–20 electrode placement system. The acquisition system was integrated with the MATLAB Simulink environment [11] and an external TTL [12] circuit to mark the events. The common reference configuration was in place while setting up the electrode arrays. The EyeLink 1000 eye tracker system [13] was used to capture the gaze pattern and pupil dilation while the participant was attending to the visual stimulus. This data is not discussed in this paper, and this information is mentioned for the sake of reporting the framework of the study.

Stimulus. Forty-two pictures depicting four unique emotional states were randomly presented to the participants as visual stimuli. These images were sourced from the OASIS database and were rated on the valence-arousal scale for four emotional states which were happy, sad, anger, and excitement. Example images are presented in Fig. 1.

Procedure. The experiment started by recording resting state EEG for a period of 30 sec. It was followed by the task, in which the instructions were guiding the participant. A single trial included a 4sec display of the image, followed by a query, asking the user to mark a radio button to record their own perception of the emotion, recognized in the picture. It was followed by a 7-point Likert scale to record user's perception of the degree of certainty about the identified emotion. Our assumption is that the rating of the certainty in the identified emotion reflects to a certain extent the degree of emotional response to the image, i.e., the intensity of the co-experienced emotion. These two queries were included in the paradigm in order to record the behavioral response of the viewer. It was followed by a 4sec inter-stimulus interval (ISI) followed by the next trial. Cases of a sharp discrepancy of the objective emotion, depicted in the picture, and the subjective report (e.g., sad pictures perceived as happy) were removed from the analysis. A total of 42 such trials were recorded. The EEG recorded the cortical activities during the stimulus presentation. The ISI was selected at 4 sec to account for the retraction period after image exposure.

Fig. 1 Example images of 4 emotions *excited* (top left), *happy* (bottom left), *sad* (top right), and *anger* (bottom right)

3 Results and Discussion

The main pattern of the obtained behavioral results is presented in Fig. 2.

Single-factor ANOVA did not reveal a significant difference between the average values for the male participants and the female participants in the evaluation of the intensity of the perceived emotions, $F(1, 74) = 1, 95$, $p = 1, 67$). However, if the evaluation of the most internalized emotion—sad—is removed, then a tendency revealed as marginally significant difference of the intensity of the perceived emotion is revealed, $F(1, 53) = 3, 26$, $p = 0{,}0769$. It seems that the exteriorized emotions are perceived as more intensive by the female viewers, than the male viewers. Interestingly, this effect applies to the images with humans, but not animals, where female viewers perceive as more intensive all of the emotions, than the male viewers, $F(1, 36) = 3{,}15$, $p = 0{,}0847$.

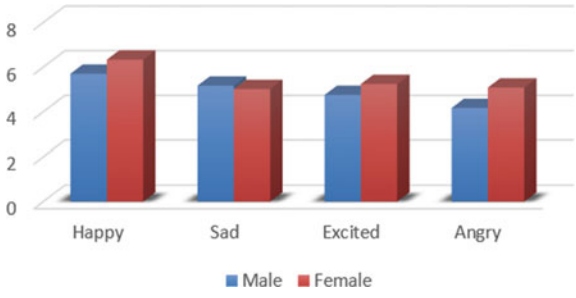

Fig. 2 Difference of the average value of intensity for each image valence (happy, sad, excited, anger) given by the male and female participants.

It might be possible that when the emotion is experienced as an internalized subjective state, such as being sad, there is no gender-related difference in its rating by the subjects. Whereas if emotions are expressed as an externalized, expressive set of psychological reactions, these may be rated as more intensive by the female, than male viewers, reflecting different intensity of the empathic response. This hypothesis needs further tests with a larger sample of participants.

3.1 EEG Study

The observation of EEG activity for the theta and the alpha band for the male and female participants revealed some common, and a few genders unique, brain activities. In our hypothesis, we sought to find the differences between the two genders, when it comes to emotion processing.

Our initial observations (left box in Fig. 3) revealed that for both the male and female participants, exposure to images of happy emotion leads to higher activity in the frontal, temporal, and parietal areas in the theta band. The alpha activity is also common including the frontal and parietal areas extending to the sensory motor areas. The images rated as sad (right box in Fig. 3) produced *some common patterns* in both the female and male participants such as the frontal theta. However, the theta at occipital and the activation toward the right sensory cortex, extending to the temporal area, were unique to the male participant. The alpha activity in the parietal and frontal areas was *common* to both participants in response to exposure to *sad*.

It was observed that, for images associated with excitement (left box in Fig. 4), the temporal and occipital theta activity was high for both the male and female

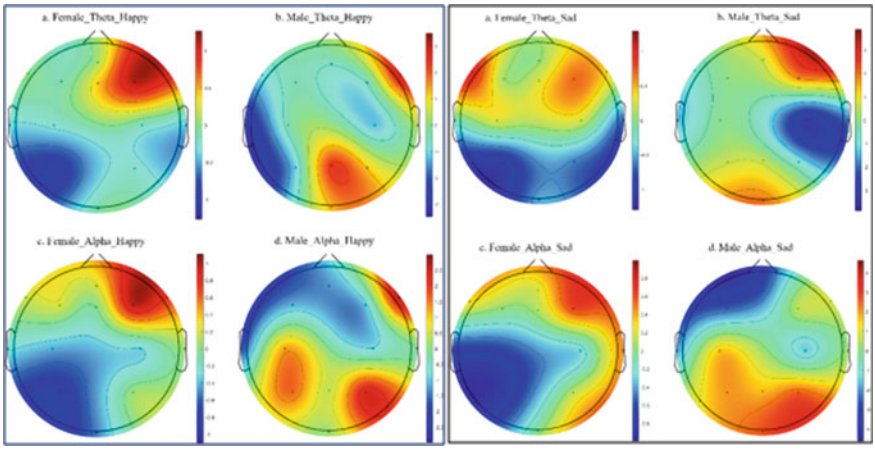

Fig. 3 Brain activation in the theta and alpha band for a female vs. a male participant, viewing happy and sad emotional pictures (see text)

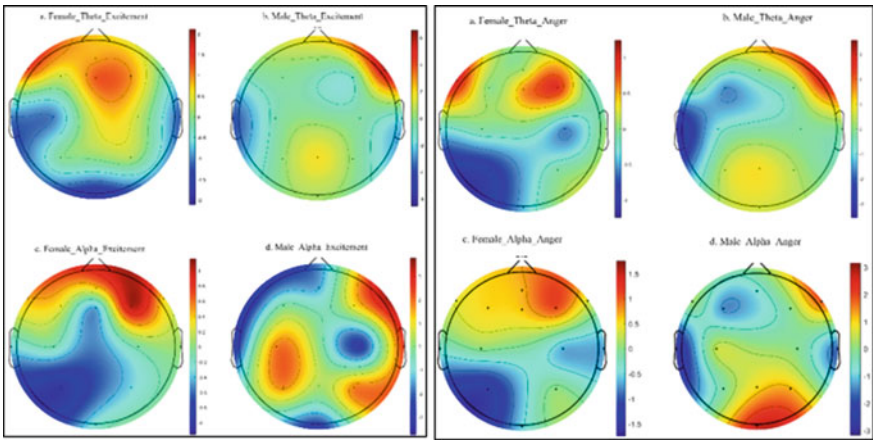

Fig. 4 Brain activation in the theta and alpha band for a female vs. a male participant, viewing excited and angry emotional pictures (see text)

participants. An interesting observation was the unique activity at the parietal area for the female participant and the sensory motor cortex for the male participant present in the alpha band. The pre-frontal alpha was prominent for both the male and female participants during exposure to the excited images. During exposure to images, depicting anger (right box in Fig. 4), the occipital theta activity was prominent for both the male and female participants. A prominent alpha activity at the temporal and parietal areas was present for both the male and female participants. The occipital alpha is more active for the male participant.

The frontal lobe activity was observed in response to the three emotions: happy, sad, and excited, but not for anger. This observation is in alignment with existing reports on emotion perception [14]. In our study, the absence of frontal lobe activity for anger leads us to our first future enquiry. To investigate, if lack of frontal lobe activity in alpha and theta bands has a more conclusive implication on processing high arousal-negative emotion.

The role of amygdala in emotion processing has been well established [15]. The temporal lobe EEG activity observed in the theta and alpha bands for pictures, perceived as happy, anger, and excited, further supports the evidence as the EEG channels over the temporal lobe may capture neuronal activity, originating from the same. Still, it remains to be investigated across a larger sample of data if this activity can be associated with certain bandwidths. The theta activity, reported in our results at the posterior locations, is another observation, which is supported by [16]. The sensitivity of the 3–8Hz frequency band and its activation at various scalp locations is indicated, of which the occipital theta is indicative of affective attention. While the frontal theta, known for activation of working memory centers, was anticipated in our study, the occipital theta in our report is valuable and a lesser investigated aspect of emotion processing.

The current study for emotion detection is a step to collect evidence of emotion perception at conscious level (behavioral response) and at level of mentation (EEG response). Also, emotions are psychological states with physiological manifestations in response to environmental stimuli [17]. Thus, cases wherein participants perceive emotions on a behavioral scale, but do not demonstrate the expected physiological indicators (EEG), can suggest a higher threshold to the emotionally changing environment. More conclusive evidence of emotion processing, using EEG, could be used as a portable, non-invasive alternative among clinical population for treatment of emotion dysfunction.

4 Conclusion

The paper presents the current methodology being implemented to be able to identify factors that can influence the neural processing as reflected in the observed EEG patterns. We formulated the hypothesis about gender differences in processing emotions, which is not entirely conclusive from our data, but it will be explored further in the future studies. Both individual differences and certain regularities were observed in the presented set of EEG data.

The novelty in our method is that the behavioral input has been recorded right after the image exposure wherein the possibility of idiosyncratic influence is minimized due to lack of gap between the picture exposure and the feedback. This also reflects the results of our behavioral data and EEG data where we observed many commonalities between male and female responses and brain activations. These observations would become more crucial when designing personalized EEG-based interventions for rehabilitation such as brain–machine interface systems and special aids.

The observations reported in this paper are part of an ongoing work and are not conclusive yet are in a stage where it is essential to be shared with the broader research community for their vital reviews.

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Printed Circuit Boards at Perspectives: Towards Understanding Useful Data

Ben Malin and Tatiana Kalganova

Abstract Printed Circuit Boards (PCBs) are often the subject of computer vision tasks, within the realms of object detection and classification. This paper provides a new PCB dataset (PCB-P) that has a greater diversity in the range of perspectives and rotations that the images are captured at, as well as a diverse selection of PCBs. These specifications allow for data quality to be identified based on the configuration of the captured image. This dataset is tested on a small range of popular image classification architectures, finding Inception V3 to be the best-performing. Additionally, configurations of reducing various perspectives and rotations are tested. This work finds there to be diminishing returns from increasing training image quantity.

Keywords Data reduction · PCB · Dataset · Image classification

1 Introduction

Printed circuit boards (PCBs) and all the processes that comprise their production equate to a massive industry, with an estimated size of $54.8 billion as of 2020 [1]. However, for this industry to thrive, a colossal quantity of PCB data is required for the training and testing of the multitude of models that are crucial to its quality control. The production of this data often requires copious man-hours, for the image taking as well as correct labelling. Furthermore, the processing of this data for the various computer vision models that are instrumental in the PCB pipelines requires vast quantities of processing power, causing both economic and ecological repercussions. Minimal research has been conducted on how best to optimise the data collection for PCBs as well as how the training process can be optimised.

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Thus, this paper aims to provide a novel PCB dataset as well as trial data reduction methodologies for suitability in maintaining model performance with a demonstrable reduction in data.

2 Related Work

2.1 PCB Datasets

There are several PCB datasets that are utilised for different purposes, ranging from component detection and defect detection to board classification. This section will explore the design decisions that have been made before for PCB dataset production, as well as how each dataset is suited for its purpose.

Table 1 provides reference for the scale of current PCB datasets along with some of the methodology used to procure each dataset. All datasets that have been produced for the purpose of either PCB classification or component detection are of a high resolution and without a need for image pre-processing [2–4].

Table 2 explores the diversity of the datasets, with regards to how the data is gathered and presented. This task is once again highly specific to the dataset's intended function.

The datasets produced by [5–8] are all created for the goal of defect detection and thus require a different methodology of data collection and pre-processing for the greatest effectiveness of the dataset. Commonly, defect detection datasets are presented in a binarised form as the defects that are desirable for detection are typically related to erroneous copper trace and solder [5, 6]. The use of binarisation clearly segments the solder/trace from the background—allowing for superior defect detection.

PCB-METAL [2] and FICS [3] aim to detect components present on a PCB. This makes thresholding less relevant, due to the increased complexity of component classification compared to solder/trace defects, which are typically defined by shape. Whilst components have more complicated structures as well as colour information often being important. Additionally, these datasets have not incorporated artificial features like the defect datasets have done. This is due to the massive difference in quantity between components on a board compared to defects that would typically be found on a PCB.

Finally, the remaining dataset by [4] focuses exclusively on PCB classification, with the emphasis being on creating diversity with the images taken, using different viewing angles and rotations. This dataset is most comparable to the one proposed in this work, with similar methodologies being employed. This approach is most relevant in ascertaining the data quality of each image, as images can be discriminated based on objective features such as perspective and rotation.

Table 1 Features of existing PCB datasets

Dataset/ Author	#Images	Resolution	Boards/ Classes	Goal	Pre-processing
FICS Lu et al. 2022 [3]	9,912 total (9,861–microscope, 51–DSLR)	1600 × 1200–microscope 8256 × 5504–DSLR	31	Component detection	N/A
MicroPCB Byerly et al. 2021 [4]	8,125	1956 × 1982	13	PCB classification	N/A
HRIPCB Huang et al. 2020 [7]	1,386	4608 × 3456	10	Defect detection	Grayscale conversion and binarisation
PCB-METAL Mahalingam et al. 2019 [2]	984	'High resolution'	123	Component detection	N/A
Zhang et al. 2018 [8]	1,350	Scaled to 800 × 600	7	Artificial defect detection	PCB image is cropped and scaled. Then divided into 128 × 128 segments
Huang and Wei 2019 [5]	1,386	4608 × 3456	6	Artificial defect detection	Binarisation via adaptive thresholding
DEEPPCB Tang et al. 2019 [6]	1,500	640 × 640	6	Artificial defect detection	Binarisation via thresholding
(Proposed Work)	16,625	4288 × 2848	20	PCB classification	N/A

3 Methodology

3.1 PCB-P Dataset Generation

As identified through related work, the dataset must be produced with sufficient resolution for optimal performance. There must be a high enough quantity of the images so that patterns can be recognised by the system to allow for accurate classification. Shadows and other unwanted features, such as a noisy background, must be eliminated as much as possible. Additionally, images in the dataset will need to be at a multitude of different angles and board rotations, so that in the real-world applications the system can still process the images at these less conventional positions. This will also provide opportunities to evaluate the quality of data at specific perspectives and rotation.

Table 2 Class variations in existing PCB datasets

Dataset/Author	Annotations	Perspectives
FICS Lu et al. 2022 [3]	Six types of components have been annotated, as well as text on the board, for a total of 77,347 annotations	Vertical
MicroPCB Byerly et al. 2021 [4]	Class, perspective and rotation of board	Front, 5 orientations, 25 viewing angles, 5 images per configuration
HRIPCB Huang et al. 2020 [7]	3–5 annotated defects per image across six classes	Vertical
PCB-METAL Mahalingam et al. 2019 [2]	12,240 hand-annotated components	Front, Back, 4 orientations per side
Zhang et al. 2018 [8]	Each 128 × 128 section is annotated with class of defect	Vertical
Huang and Wei 2019 [5]	Six classes of artificial defects have been annotated with bounding box and class information	Vertical
DEEPPCB Tang et al. 2019 [6]	Defects have been annotated across six classes. Some artificial defects have been added	Vertical
(Proposed Work)	Class, perspective and rotation of board	Front, back (for 11 boards), 5 orientations per side, 25 viewing angles. 4 pictures minimum per configuration

3.2 Design and Implementation

A 'Nikon D90 DSLR' camera was selected to be used to photograph the boards. This camera should offer the level of quality necessary for the dataset requirements to be met. To maximise quality, shadows and other unwanted features must be attempted to be minimised to ensure that high-quality images can be taken. This is to be achieved through using four lightboxes surrounding the PCB. Each lightbox produces an 85 W, 5,500 K light. The high-power rating should provide ample illumination on the board so that shadows are not present. The 5,500 K colour temperature is white light and thus should not distort the colours on the boards. To minimise background noise, a white, cotton sheet was fitted over a cardboard structure as shown in Fig. 1 and also shown are the clamps fitted to the corners of the sheet to prevent creases and folds from disrupting the background.

For consistency between the images, as well as to obtain images from different perspectives, a method with which to photograph the boards was selected, as shown in Fig. 1. A tripod was set up above each of the 25 positions shown in Fig. 2, with the photographed board remaining central to the table. Example images can be seen

Fig. 1 (**Left**) Tripod setup (**Top-right**) Board placement example (**Bottom-right**) Clamps used

in Fig. 3, attached to their respective camera perspective. At every camera position, the board is photographed four times and then rotated 36°. This occurs four times, so that a full rotation can be emulated using image augmentation—by duplicating the images and digitally rotating them 180°. Nine boards have multiple identical copies. An additional image was taken of each of these duplicates at every perspective and rotation. A PCB's side refers to either the front or back of the board.

The number of images taken for the dataset can be explained more easily through using the following formulae to calculate an average number of images taken per board:

$$x = \frac{(s \times 4) + (d \times 5)}{t} = \frac{133}{31},$$

where x is the average number of images per position, s is the quantity of PCB sides where only one PCB is available, d is the quantity of PCB sides where multiple are available and t is the total number of PCB sides imaged.

Substituting this value into the formula allows the calculation of the total number of images to be obtained upon completion of the dataset:

$$b \times p \times r \times a = t$$
$$31 \times 25 \times 5 \times \frac{133}{31} = 16,625 \text{ images},$$

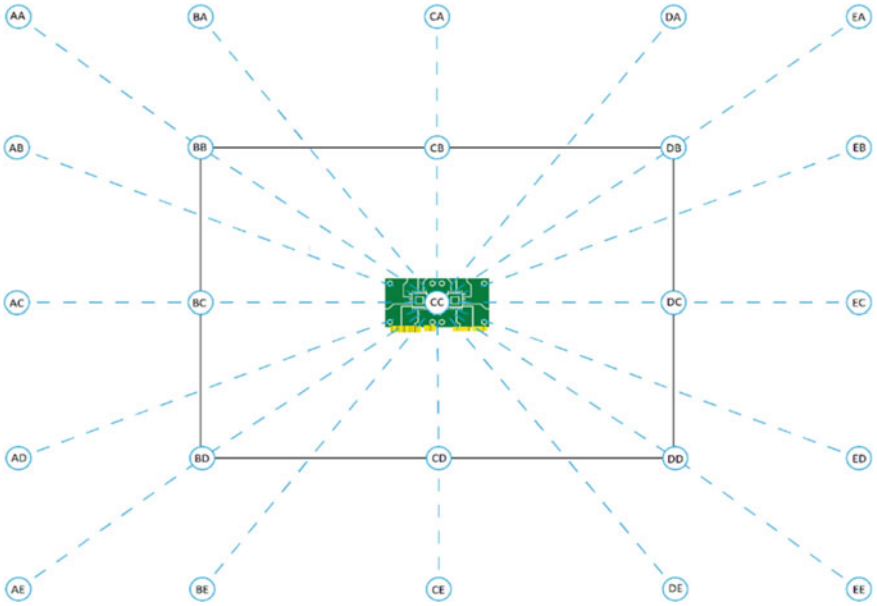

Fig. 2 Camera positioning configurations

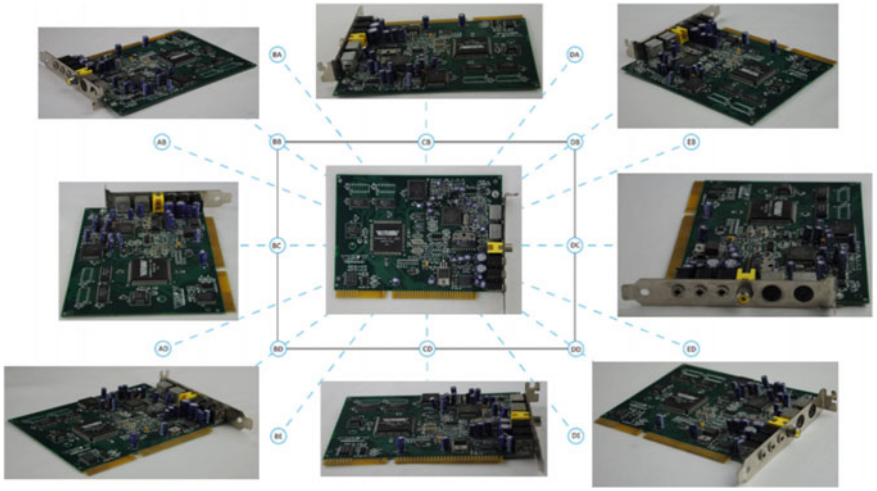

Fig. 3 Camera positioning configurations with example images

where b is the number of relevant PCB sides, p is number of perspectives, r is number of rotations, a is average images per position and t is the total number of images.

This number of images is large enough that an accurate model can be trained to allow for the classification of the PCBs.

Each of these images has been labelled with their corresponding rotation and perspective designation. This dataset can be found at https://www.kaggle.com/dsv/4975464 [9].

4 Experimental Results

Using the PCB-P dataset on a variety of architectures has been done to identify the best-performing architecture for further evaluation. For this architectural analysis, five runs were performed using 12,750 images to train and 3,875 images that were reserved for training (Table 3).

4.1 Perspective Reduction

To ascertain the influence of the various perspectives, categories must be drawn to separate them. Byerly et al. [4] defined the far perspectives as shown above in the 'Perimeter' definition. However, due mainly to the inequality between category sizes present within this definition (the 'Perimeter' definition has 8 perspectives within the 'near' category and 16 within the 'far'), additional definitions were drawn out. These include the 'Even Distribution' definition, whereby the 'far' perspectives only contain the three perspectives within each corner—providing both categories with equal numbers of images. As well as the 'Hybrid' definition whereby the four perspectives that change between definitions are eliminated altogether from the training set (Fig. 4).

No definitions were required for the rotations as the rotations were unanimously defined with 'Neutral', 'Shallow' and 'Extreme'. With 'Neutral' being the centre-most image out of the five rotations, 'Shallow' being one rotation either side of that

Table 3 PCB-P architectural comparison

Architecture	Mean test accuracy (%)	Max test accuracy (%)	Validation accuracy (%)	Validation loss
Inception V3	99.95	99.97	99.88	0.0035
ResNet V152V2	99.89	99.92	99.79	0.0077
VGG19	99.90	99.95	99.77	0.0073
DenseNet169	97.93	99.97	97.69	0.1009

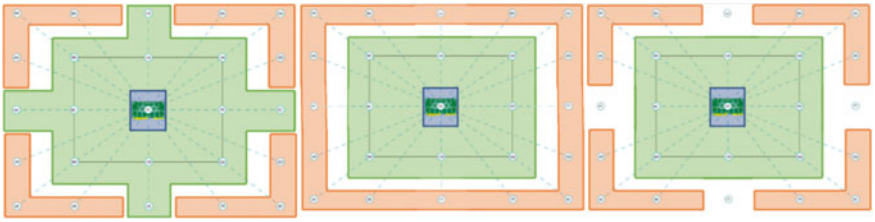

Fig. 4 (**Left**) Even distribution, (**Middle**) Perimeter distribution, (**Right**) Hybrid

Table 4 PCB-P experimental configurations

No	Neutral rotation reduction (%)	Shallow rotation reduction (%)	Extreme rotation reduction (%)	Neutral perspective reduction (%)	Near perspective reduction (%)	Far perspective reduction (%)
E1	100	100	100	100	100	100
E2	100	100	100	100	100	0
E3	100	100	100	100	0	0
E4	100	100	0	100	100	100
E5	100	100	0	100	100	0
E6	100	100	0	100	0	0
E7	100	0	0	100	100	100
E8	100	0	0	100	100	0
E9	100	0	0	100	0	0

and 'Extreme' comprising the final rotations that are farthest from 'Neutral' (Table 4).

With the definitions drawn out, each experiment has a unique configuration of perspectives and rotations (shown in Table 5) and was performed five times to help reduce the influence of random variance.

Initial testing was done just using E1–E9, for comparability with the results shown by [4], and the methodology used within their paper was followed for E1–E9.

4.2 PCB-P Results

Table 5 shows the full set of averaged results, across the five test runs, when various dataset configurations were trialled. Figure 5 shows this data simplified, losing the intricacies offered by the experimental configurations but clearly showing the trend that accuracy follows as training data is removed. PCB-P contains 31 classes compared to the 13 classes assessed within the 'MicroPCB' dataset, yet the logarithmic decline of accuracy still occurs at a similar point—approximately 70% [4].

Table 5 PCB-P experimental results

No	PCB-P Even distribution			PCB-P Perimeter distribution			PCB-P Hybrid definition		
	Mean	Max	# Images	Mean	Max	# Images	Mean	Max	# Images
E1	0.999	1.000	12750	0.999	1.000	12750	0.999	1.000	12750
E2	0.971	0.984	6630	0.906	0.920	4590	0.906	0.920	4590
E3	0.301	0.363	510	0.301	0.363	510	0.301	0.363	510
E4	0.993	0.997	7650	0.993	0.997	7650	0.982	0.990	6426
E5	0.927	0.972	3978	0.853	0.876	2754	0.853	0.876	2754
E6	0.236	0.294	306	0.236	0.294	306	0.236	0.294	306
E7	0.884	0.917	2550	0.884	0.917	2550	0.801	0.825	2142
E8	0.639	0.705	1326	0.609	0.671	918	0.609	0.671	918
E9	0.045	0.098	102	0.045	0.098	102	0.045	0.098	102

However, this point is only qualitatively assessed for both sets of results, yet it does show some degree of consistency between models when data is reduced in a similar fashion.

Unsurprisingly, E1 (which contains all the available training data, from all perspectives and rotations) performed the best. However, the returns are diminishing with the addition of substantial quantities of training data. This is shown by comparing E2 (which has removed the Extreme Perspectives) with the model trained on all the training images. This model performs with approximately 0.3% weaker accuracy than the full model when trained with approximately half of the data. However, when the definition on what an extreme perspective is changed, this accuracy starts to fall. This suggests that the perspectives that are at sharp angles, but in-line with the PCB, are of a higher quality than rotation data. Rotation data appears

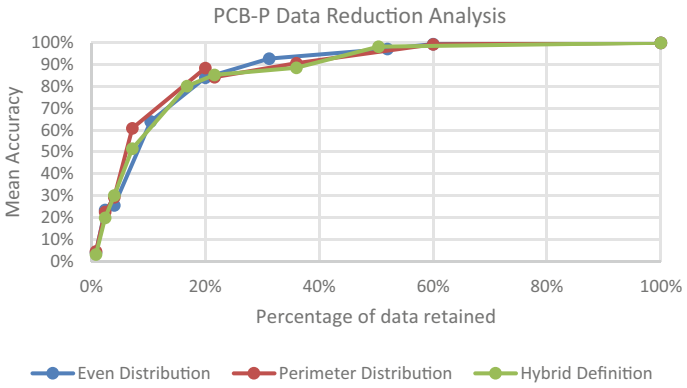

Fig. 5 PCB-P classification performance against data reduction

to be of a lesser quality due to E4 and E7 which have extreme rotations removed and all rotations removed, respectively. This results in a 40% reduction and an 80% reduction in training images, respectively. Despite this large quantity removed, the accuracy drops by only 0.6% in the first instance and 11.5% in the second.

5 Conclusion and Future Work

We present a new PCB dataset that contains a greater diversity of both image perspectives and PCBs. A minor architectural comparison was performed and found Inception V3 to be the best-performing architecture for this dataset and thus was used for further analysis. This further analysis was focused on the reduction of the dataset with regards to both perspectives and rotations, with findings that show depreciating gains as training data is added. The results also suggest that there is disparity between the quality of data at different perspectives and rotations, with additional rotation data contributing minimally to the overall performance of the network once some rotation data has been included. Finally, these results also suggest that images taken at extreme perspectives, yet still in-line with the PCB, are of higher quality than those at extreme perspectives but not in-line. Thus, with the desire to collect data in an efficient manner, certain data collection configurations can be removed with a limited performance impact—saving man-hours as well as computational power.

Additional, more intelligent data reduction techniques can be performed to further and more quantitatively identify the quality of data, in the aim of minimising computational processing and data collection time.

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