

Lecture Notes in Electrical Engineering 1115

Rabindra Nath Shaw · Pierluigi Siano ·  
Saad Makhilef · Ankush Ghosh ·  
S. L. Shimi *Editors*

# Innovations in Electrical and Electronic Engineering

Proceedings of ICEEE 2023, Volume 2

 Springer

# Lecture Notes in Electrical Engineering

## Volume 1115

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Saad Makhilef · Ankush Ghosh · S. L. Shimi  
Editors

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ISSN 1876-1100                      ISSN 1876-1119 (electronic)  
Lecture Notes in Electrical Engineering  
ISBN 978-981-99-8660-6              ISBN 978-981-99-8661-3 (eBook)  
<https://doi.org/10.1007/978-981-99-8661-3>

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# Preface

This book features selected high-quality papers presented at 4th International Conference on Electrical and Electronics Engineering (ICEEE 2023), jointly organized by Chitkara University, Himachal Pradesh, India, and ADSRS Education and Research, India, during August 19–20, 2023, in online mode. The conference got overwhelming response and received more than 200 papers from all around the world. All submitted papers have gone through single-blind review process on an average three reviews per paper. The acceptance rate is less than 25%. The presented papers are published in this book chapter. The book focuses on current development in the fields of electrical and electronics engineering. The book one covers electrical engineering topics—power and energy including energy distribution and transmission, renewable energy, power electronics and applications, control, robotics, and automation and instrumentation, and book two covers the areas of robotics, artificial intelligence and IoT, electronic devices, circuits and systems, wireless and optical communication, RF and microwaves, VLSI, and signal processing. The book is beneficial for readers from both academia and industry.

We are thankful to all the authors that have submitted papers for keeping the quality of ICEEE 2023 at high levels. The editors of this book would like to acknowledge all the authors for their contributions and the reviewers. We have received invaluable help from the members of the International Program Committee and the chairs responsible for different aspects of the workshop. We also appreciate the role of Special Sessions Organizers. Thanks to all of them, we had been able to collect many papers on interesting topics, and during the conference, we had very interesting presentations and stimulating discussions.

We hope that these volumes will provide useful information to professors, researchers, and graduated students in the area of electrical engineering, electronics and communication engineering, and computer science engineering, along with AI

and IoT applications, and all will find this collection of papers inspiring, informative, and useful. We also hope to see you at a future ICACIS event.

Mohali, India  
Fisciano, Italy  
Melbourne, Australia  
Mohali, India  
Chandigarh, India

Rabindra Nath Shaw  
Pierluigi Siano  
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Ankush Ghosh  
S. L. Shimi

# Contents

|  |    |
|--|----|
| <b>Safeguarding Justice Employing Blockchain-Enabled Secure Chain of Custody Framework for Digital Evidence</b> .....                                    | 1  |
| Karan Singh Thakur and Rohit Ahuja   |    |
| <b>Future of Cryptography in the Era of Quantum Computing</b> .....  | 13 |
| Balvinder Singh, Md Ahatshaam, Abhisweta Lahiri, and Anil Kumar Sagar  |    |
| <b>Traffic Optimization and Optimal Routing in 5G SDN Networks Using Deep Learning</b> .....   | 33 |
| Piyush Kulshreshtha and Amit Kumar Garg  |    |
| <b>Optimization of Cloud Migration Parameters Using Novel Linear Programming Technique</b> .....   | 43 |
| Shahbaz Afzal, Abhishek Thakur, and Pankaj Singh   |    |
| <b>A Novel Approach on Deep Reinforcement Learning for Improved Throughput in Power-Restricted IoT Networks</b> .....                                    | 63 |
| E. Sweety Bakyarani, Navneet Pratap Singh, Jyoti Shekhawat, Saurabh Bhardwaj, Shweta Chaku, and Jagendra Singh   |    |
| <b>Complex Social Networks: Dynamics, Domains, and Dimensions</b> .....  | 77 |
| Suruchi Gera and Adwitiya Sinha  |    |
| <b>Enhancing Road Safety and Efficiency in Vehicular Ad-Hoc Networks Through Anomaly Detection and Traffic Prediction Using Big Data Analytics</b> ..... | 87 |
| Uday Singh Kushwaha, Neelesh Jain, and Abhishek Anand  |    |
| <b>Benchmarking Facial Emotion Recognition Models Using Deep Learning: A Comparative Study</b> .....   | 97 |
| Ekta Singh and Parma Nand  |    |



|   |     |
|---|-----|
| <b>A Novel Approach to Minimize the Energy Consumption Using Task Scheduling in Cloud Data Centers</b> .....                                    | 105 |
| J. Praveenchandar, V. JaganRaja, V. Prabhu, and G. Kumaran  |     |
| <b>The Impact of Antidepressants in Tech Industry by Medical History and Interpersonal Factors: A Systematic Review and Meta-analysis</b> ..... | 117 |
| Diya Gandhi, Manishka Pareta, Samarth Varma, and Pratiksha Meshram  |     |
| <b>Artificial Neural Networks for Enhancing E-commerce: A Study on Improving Personalization, Recommendation, and Customer Experience</b> ..... | 141 |
| Kamal Upreti, Divya Gangwar, Prashant Vats, Rishu Bhardwaj, Vishal Khatri, and Vijay Gautam   |     |
| <b>New Paradigm of Marketing-Financial Integration Modelling for Business Performance: An IMC Model</b> .....                                   | 155 |
| Tejasvini Alok Paralkar, Adheer A. Goyal, Mustafizul Haque, Neha Ramteke, Kamal Upreti, and Samiksha Shukla                                     |     |
| <b>Eagle Eye: Enhancing Online Exam Proctoring Through AI-Powered Eye Gaze Detection</b> .....  | 173 |
| Jagendra Singh, Amit Kumar Mishra, Leena Chopra, Gunjan Agarwal, Manoj Diwakar, and Prabhishek Singh  |     |
| <b>Fusing Management and Deep Learning to Develop Cutting-Edge Conversational Agents</b> .....  | 187 |
| S. M. P. Gangadharan, Subhash Chandra Gupta, Blessy Thankachan, Ritu Agarwal, Rajnish Kumar Chaturvedi, and Jagendra Singh                      |     |
| <b>Water Quality Classification Using Machine Learning Techniques</b> .....   | 197 |
| Minu Kumari and Sunil Kumar Singh   |     |
| <b>IoT-Based ML Model to Sense Selection of Seed Crops in Changing Climatic Conditions of Punjab</b> .....                                      | 215 |
| Chhavi Sharma and Puneet Kumar  |     |
| <b>A Firebase-Based Smart Home Automation System Using IoT</b> .....  | 229 |
| Pramod Kumar Goyal, Saurabh Verma, and Moksh Giri   |     |
| <b>EnRaFS: An Ensemble Ranking-Based Feature Selection Approach for Grading Gallbladder Cancer Using Radiomic Analysis</b> .....                | 239 |
| Nitya Jitani, Vivek Kumar Verma, and Rosy Sarmah  |     |
| <b>Unmasking Deepfakes Advancements, Challenges, and Ethical Considerations</b> .....   | 249 |
| Usha Kosarkar and Gopal Sakarkar  |     |

**Identification of Height and Gender Using Deep Learning Application** ..... 263  
 Arju Malik, Garima Shukla, Dolly Sharma, Sofia Singh, and Srinivas Singh

**Enhancing Healthcare Security Using IoT-Enabled with Continuous Authentication Using Deep Learning** ..... 275  
 Navneet Pratap Singh, R. Ravichandran, Soumi Ghosh, Priya Rana, Shweta Chaku, and Jagendra Singh

**Cross-Project Defect Prediction: Leveraging Knowledge Transfer for Improved Software Quality Assurance** ..... 291  
 Prachi Sasankar and Gopal Sakarkar

**Multilingual Toxic Comment Classification Using Bidirectional LSTM** ..... 305  
 Md. Nazmul Abdal, Md. Azizul Haque, Most. Humayera Kabir Oshie, and Sumaya Rahman

**Review of Phishing Attacks’ Effects on AI-Powered IoT Systems** ..... 321  
 S. D. Mohana, D. Rafiya Nusrath, S. P. Shiva Prakash, and Kirill Krinkin

**An Extensive Approach for Inter-Frames Video Forgery Detection** ..... 333  
 Neha Dhiman, Hakam Singh, and Abhishek Thakur

**Blockchain Empowered IVF: Revolutionizing Efficiency and Trust Through Smart Contracts** ..... 347  
 Kamal Upreti, Mustafizul Haque, S. S. Patil, Samiksha Shukla, Ashish Kumar Rai, and Prashant Vats

**IoT-Based Smart Door Lock System with Face Recognition Using ESP32 CAM and Android App** ..... 365  
 Pramod Kumar Goyal, Moksh Giri, and Saurabh Verma

**IoT-Based Smart Home Automation** ..... 377  
 Ishu Gaur, Srishti Rai, Utkarsh Tiwari, and Anil Kumar Sagar

**An Intelligent Diabetes Predicting Model for Diverse Ethnicities** ..... 399  
 Suruchi Dive, Gopal Sakarkar, Trupti Kularkar, Sankalp Dhote, and Vaishnavi Deulkar

**Detection of Punjabi Newspaper Articles Using a Deep Learning Approach** ..... 409  
 Atul Kumar and Gurpreet Singh Lehal

**Artificial Intelligence-Enabled Smart Parking System** ..... 419  
 Tanya Singh, Ridhima Rathore, Kush Gupta, Eshita Vijay, and R. Harikrishnan

|   |     |
|---|-----|
| <b>Performance Measurement and Analysis of Partial Cloud-Dependent Application Hosting</b> .....                            | 437 |
| Shantanu Chaturvedi, Sanjoy Das, Subrata Sahana,<br>Tanya Lillian Borges, and Ankush Ghosh                                  |     |
| <b>Advancing Collaborative AI Learning Through the Convergence of Blockchain Technology and Federated Learning</b> .....    | 449 |
| Devadutta Indoria, Jyoti Parashar, Shrinwantu Raha, Himanshi,<br>Kamal Upreti, and Jagendra Singh                           |     |
| <b>Detection of Adulteration in Clarified Butter by Using Machine Learning</b> .....  | 465 |
| Vijay Kumar Sinha, Praveen Kantha, Manish Mahajan, Navneet Kaur,<br>and Fitri Yakub   |     |
| <b>AI Enabled Face Detection Approach and Comparison with PCA Technique</b> .....   | 475 |
| Vijay Kumar Sinha, Praveen Kantha, Manish Mahajan, Latika Kakkar,<br>and Fitri Yakub  |     |
| <b>Automatic Disease Detection for Various Plants Leaf Using Image Processing Techniques and TensorFlow Algorithm</b> ..... | 487 |
| Devyani Shende, Laxman Thakare, Rahul Agrawal,<br>and Nikhil Wyawahare  |     |
| <b>Contribution Unveiling Cutting-Edge Machine Learning Techniques for Image Segmentation</b> .....                         | 501 |
| Nazeer Shaik, Ankur Gupta, Sunita Bhati, Jaideep Kumar,<br>Jagendra Singh, and Ishan Budhiraja                              |     |
| <b>Empowering Elderly Safety: 1D-CNN and IoT-Enabled Fall Detection System</b> .....  | 513 |
| Rahul Modak, Koushik Majumder, Santanu Chatterjee,<br>Rabindra Nath Shaw, and Ankush Ghosh                                  |     |
| <b>Anticipating Graduate Program Admission Through Implementation of Deep Learning Models</b> .....                         | 555 |
| Nazeer Shaik, Jagendra Singh, Ankur Gupta, Dler Salih Hasan,<br>N. Manikandan, and Radha Raman Chandan                      |     |
| <b>Optimizing Fertilization Through IoT: A Smart Approach for Agriculture</b> .....   | 567 |
| Hakam Singh and Ramamani Tripathy   |     |
| <b>Study of Deep Learning-Based Segmentation and Classification of Brain Tumors in MRI Images</b> .....                     | 577 |
| Sonia Arora, Gouri Sankar Mishra, and Manali Gupta  |     |
| <b>Ubiquitous Computing: A Comprehensive Review</b> .....   | 591 |
| Manoj Wadhwa and Utpal Shrivastava  |     |

**Deep Learning Tools for Covid-19 Pneumonia Classification** ..... 601  
 Ngonidzashe Mathew Kanyangarara, D. R. Soumya, Subrata Sahana,  
 and Sanjoy Das

**Security in Cloud Computing Using Blockchain: A Comprehensive Survey** ..... 609  
 Sagnik Jana, Rahul Modak, Koushik Majumder, Anurag Dasgupta,  
 Rabindra Nath Shaw, and Ankush Ghosh

**IoT-SyringeX: A Cutting-Edge Solution for Automated Injection Pumps** ..... 633  
 Komal Ashok Dhone, Sonali Joshi, and Sandeep Sonaskar

**Enhanced Change Detection Analysis of Urban Land Use and Land Cover in Vijayawada City: Integrating Artificial Neural Networks and Mahalanobis Distance Classification** ..... 647  
 K. Pavan Venkat and Vidhya Lakshmi Sivakumar

**Stochastic Performance of CNTFET with High ‘k’ Dielectric Material Over Conventional Silicon Devices in Optimization of Drain Current** ..... 663  
 Sathish Gajendran and Radhika Baskar

**Explainable Machine Learning for Drug Classification** ..... 673  
 Krishna Mridha, Suborno Deb Bappon, Shahriar Mahmud Sabuj,  
 Tasnim Sarker, and Ankush Ghosh

**Deep Learning-Based Intrusion Detection System for Internet of Things Networks for Enhancing Security Against Cyber Attacks** ..... 685  
 Preeti Sharma, Dler Salih Hasan, T. Marthandan, Jagendra Singh,  
 Shweta Chaku, and Mohit Tiwari

**Author Index** ..... 701

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# Safeguarding Justice Employing Blockchain-Enabled Secure Chain of Custody Framework for Digital Evidence



Karan Singh Thakur and Rohit Ahuja 

**Abstract** A subfield of forensic science called “digital forensics” focuses on the examination and recovery of digital evidence from digital devices discovered at crime scenes. The gathered evidence must be securely stored to avoid manipulation or tampering. To ensure justice and make wise decisions, the integrity of the evidence is essential. Blockchain, a new technology, is used to preserve papers in a decentralized setting to address this problem. Blockchain creates a tamper-resistant ledger system by offering a safe and unchangeable chain of data, where each record is cryptographically connected to the one before it. In order to keep evidence in a dependable storage medium, this study suggests a safe chain of custody framework that makes use of blockchain. Only authorized persons can access or possess the evidence since every transmission of it is recorded on a private Ethereum blockchain from the moment it is seized. A digital evidence system that uses smart locks to physically store and secure the evidence is smoothly linked with the framework. The key to unlock the evidence is only in the possession of the Admin, an authorized entity, in order to maintain the integrity of the evidence submission and retrieval process. Multiple parties, including law enforcement organizations, attorneys, and forensic specialists, will benefit from our framework’s secure approach for maintaining the admissibility and integrity of the evidence.

**Keywords** Blockchain · Smart contract · Crime · DApp

## 1 Introduction

Crime refers to behaviors or actions that violate the laws and regulations of a society or jurisdiction, being considered harmful, immoral, or offensive to community values. It encompasses a wide range of forms, including violence, theft, fraud, corruption,

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R. N. Shaw et al. (eds.), *Innovations in Electrical and Electronic Engineering*, Lecture Notes in Electrical Engineering 1115, [https://doi.org/10.1007/978-981-99-8661-3\\_1](https://doi.org/10.1007/978-981-99-8661-3_1)



and drug trafficking that can lead to legal repercussions such as imprisonment, fines, or other penalties [1]. Evidence is the means by which an alleged fact, whose truth is subject to scrutiny, is established or disproved. It can be anything that can be used to prove something, such as the evidence presented in a trial [2]. Physical, circumstantial, and digital evidence are the three types of evidence. For instance, if an unpleasant photograph is transmitted to your phone via a messaging service, the authorities may be able to use phone forensics to recover it as evidence [3].

The handling and storage of criminal evidence is essential to maintaining the fairness of the criminal justice system. The following things can be ensured with proper evidence management and storage:

- Evidence is protected: Proper storage and management of evidence help to ensure that it is protected from contamination, tampering, or loss. This can help to prevent the evidence from being compromised, which can ultimately result in a mistrial or an incorrect verdict.
- Evidence is admissible in court: If evidence is not properly stored or managed, it may not be admissible in court. This can significantly undermine the prosecution's case and lead to a wrongful acquittal.
- Evidence can be used in future investigations: In some cases, evidence may be relevant to future investigations. Proper storage and management of evidence can ensure that it is available for future use.
- Chain of custody can be established: The chain of custody refers to the documentation of the custody, control, transfer, analysis, and disposition of evidence. Proper storage and management of evidence can help to establish a clear and complete chain of custody, which can help to ensure its reliability and admissibility in court.

Society has been substantially impacted by the rise of digitalization and improvements in information technology. "Blockchain" is one of the remarkable technologies that has attracted a lot of attention, especially in the IT and financial services industries [4, 5]. We describe a system made to safely store and handle digital evidence using a trustworthy and open blockchain in response to this trend. Our method preserves the transparency of digital evidence by creating a chain of trust for its sharing and dissemination by taking use of the interconnected blockchain nodes.

Various solutions have been proposed to address the challenge of secure evidence tracking and management. The Blockchain of Evidence system [6, 7] allows authorized entities to upload evidence onto the blockchain while providing read-only access to others. Another solution, the Blockchain-Based Chain of Custody for Evidence Management in Digital Forensics [8], utilizes a private and permissioned blockchain to ensure that only authorized access is granted. In a different approach, a framework presented in [6] enables a fact-based confidence rating of digital evidence. Additionally, blockchain-based systems such as Blockchain-Based Chain of Custody (B-CoC) [9], Blockchain-Based Criminal Record Management System (CRAB) [10], and the Secure Digital Evidence (Block-DEF) framework [11, 12] offer secure and scalable solutions for managing digital evidence by leveraging blockchain technology. These systems store the evidence securely while recording

relevant information in the blockchain. Another notable solution is the Digital Evidence Cabinet based on Blockchain for Evidence Management (B-DEC) [13, 14]. Lastly, an approach for digital evidence management using blockchain involves participants gathering evidence information and storing it in the blockchain.

In the area of managing digital evidence, several solutions have been put forth, yet many of these systems are overly complicated [8, 11]. Our emphasis is on security, and we take a different, more straightforward decentralized storage strategy. For instance, in the research article titled “The Use of Blockchain within Evidence Management Systems (BoE),” the proposed system is simplistic and lacks implementability, especially owing to difficulties with authentication while accessing evidence. The majority of currently used systems for digital evidence rely on centralized structures with tamper-resistant safeguards such as secure hardware, software, or hybrid methods. These systems are, nevertheless, prone to the security dangers, single points of failure, and scalability problems typical with sizable centralized file/storage systems.

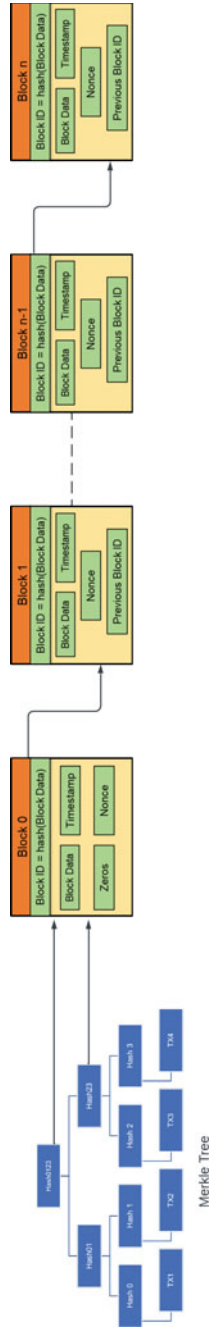
The possibility for damage and manipulation of virtual evidence throughout the criminal investigative process is a problem with the existing digital evidence management system [12, 15]. An essential function in the field of law enforcement is played by inspecting police officers (IOs). Unfortunately, departments frequently adopt practices and procedures that commonly tamper with evidence in cases involving honest law enforcement officials and targeted defendants as a result of dishonest officers giving in to pressure from higher-ranking authorities. The authors of a Texas State University study titled “Case Deconstruction of Criminal Investigative Failures” (National Institutes of Justice 2014-IJ-CX-0037) discovered that when police misbehavior is reported, the criminal justice system frequently falls short of conducting a sufficient investigation. In contrast to responses to an aviation accident, systemic evaluations of these shortcomings are uncommon. As a result, crucial procedural adjustments and policy upgrades are frequently disregarded.

## 2 Preliminaries

This section reviews blockchain, smart contract, and types of blockchain solutions available.

### 2.1 *Blockchain*

Blockchain is a distributed, transparent, immutable, and shared ledger in which numerous nodes participate over a shared network as depicted in Fig. 1. It is a subset of the Distributed Ledger Technology (DLT), with a growing list of records of transactions stored in the blocks. The transactions happen in a peer-to-peer format, and this information is publicly available. These blocks are interlinked using cryptographical hashes of the previous and the subsequent blocks, making them completely secure



**Fig. 1** Blockchain

and non-disruptable. A block essentially consists of the previous block’s hash, i.e., the previous hash, hash of the next block, timestamp (to prove the recorded transaction), and the data is stored in the leaf nodes of a structure like the Merkle tree.

### 2.2 Smart Contract

A smart contract is a program/piece of code that runs on the blockchain when a pre-defined condition is met. It is a combination of the functions of the code and the data representing the state of the smart contract, which is stored at a specific blockchain address. Smart contracts are a type of account that can store balances and be the target of transactions. They cannot be handled by the users but are deployed on the network and run as a program. The smart contract’s code is immutable once deployed, and the interactions with them are irreversible.

### 2.3 Types of Blockchain-Based Solutions

An e-commerce application that uses various technologies which include blockchain and smart contracts can become a viable solution in current scenario for the digital warranty system. There are 4 primary types of blockchain solutions as depicted in Fig. 2 that can be employed:

1. Public Blockchain: A public blockchain is the one where anyone is free to join in the ledger over a network, and they can participate in the core activities of the

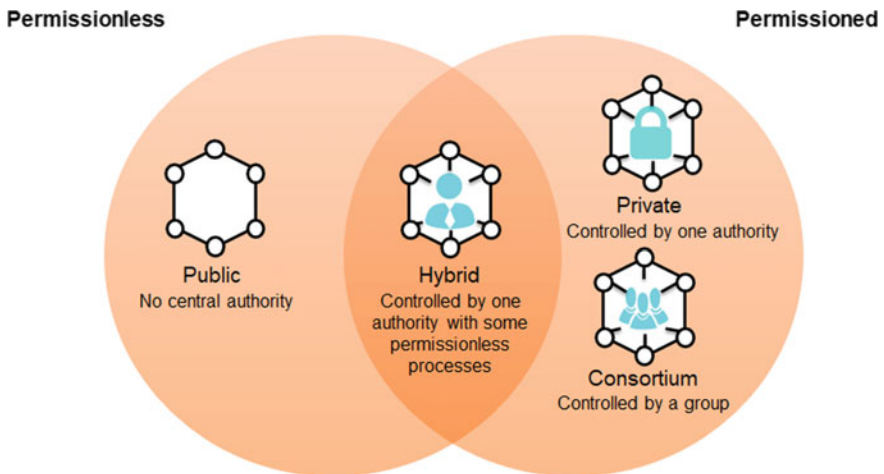


Fig. 2 Types of blockchain

blockchain network. Anyone can read, write, and audit the ongoing activities on a public blockchain network, which helps achieve the self-governed, decentralized nature often touted when blockchain is discussed. Public blockchains offer a precious solution from the point of view of a truly decentralized, democratized, and authority-free operation.

2. **Private Blockchain:** Private blockchains make sure only those users are allowed to participate in the network, which the controlling authority allows. The private nature of the blockchain could control which users can execute the consensus protocol that decides the mining rights and rewards. Additionally, only select users might maintain the shared ledger. The validation is done by the network operator or by a clearly defined set protocol implemented by the network through smart contracts or other automated approval methods. Private blockchains prioritize efficiency and immutability—the state of being unable to be changed. These are essential in supply, logistics, payroll, finances, accounting, and many other enterprise and business areas.
3. **Hybrid Blockchain:** Hybrid/permissioned blockchain is the mixed content of the private and public blockchains, where some organization controls some part, and others are made visible as a public blockchain. It is a blend of both the public and private blockchains. Both, the permission-based and permissionless systems are used, and the user accesses information via smart contracts. Even if a primary entity owns a hybrid blockchain, it cannot alter the transaction.
4. **Consortium Blockchain:** Consortium blockchain, also known as federated blockchain, is a creative approach that solves the organization's needs. This blockchain validates the transaction and also initiates or receives transactions. This blockchain helps organizations to find solutions together and save time and development costs. Some part of this is public, and some part is private. In this type, more than one organization manage the blockchain.

### 3 Proposed Framework

The proposed blockchain-based solution removes any central authority from the system, all the entities involved in the system can view the records, while the authorized entities are allowed to update the crime evidence. Ethereum blockchain will be used to create our blockchain-based digital evidence management system. Smart contracts are written in Solidity and create user interfaces in Html, Css, and ReactJS and at backend Web3.js that will further interact with the Ethereum blockchain. The proposed framework comprises three *Admin, Judge, lawyer<sub>i</sub> : {i ∈ {1, 2}}*, *Police* using blockchain service of the proposed framework.

*Entity Registration:* Prior to register a case, entities should be registered in the system using Algorithm 1 to register himself.

**Algorithm 1** EntityReg: Entity Registration.**Require:** Entity Name  $E_{Name}$ , email  $E_{mail}$ , phone No  $E_p$  address  $E_{Addr}$  gender  $E_g$  of entity  $E$ .**Ensure:** Entity Registered.

---

```

1: Admin  $\xleftarrow{Input} [\xi] Entity : \xi = (E_{Name}, E_{Role} E_{mail}, E_p, E_{Addr}, E_g)$ 
2: Entity  $\xleftarrow{OTP} Admin$ 
3:  $verify(OTP) \leftarrow Admin$ 
4: if ( $verify(OTP) = 1$ ) then
5:   Admin verifies role
6: else
7:   Wrong OTP entered
8: end if
9: Admin  $\xleftarrow[Input]{E_{Name}, pswd} Entity$ 
10: if ( $E_{Name} == Unique \ \&\& \ Criteria(Pswd) == 1$ ) then
11:    $E_{Id}$  is generated
12: else
13:   password and username doesn't match the criteria
14: end if

```

---

*Case Registration:* To register a case Admin calls Algorithm 2 and enters Case Type  $C_{Type}$ , Petitioner lawyer  $P_{lawyer}$ , Respondent lawyer  $R_{lawyer}$ , Investigating officer  $C_{IO}$ . lawyer.

**Algorithm 2** CaseReg: Case Registration.**Require:**  $C_{Type}$ ,  $P_{lawyer}$ ,  $R_{lawyer}$ ,  $Case_{IO}$ .**Ensure:** Case Registered Successfully & Case No.  $C_N$  generated.

---

```

1: if ( $verify(P_{lawyer}) = 1$ ) then
2:    $E_{Portal} \xleftarrow[Input]{P_{lawyer}} Admin$ 
3: else
4:   EXIT
5: end if
6: if ( $verify(R_{lawyer}) = 1$ ) then
7:    $E_{Portal} \xleftarrow[Input]{R_{lawyer}} Admin$ 
8: else
9:   EXIT
10: end if
11:  $C_{IO} \xleftarrow[Fwd]{IO\_UName IO Pswd} Admin$ 
12: Case is registered successfully &  $Case_{Id}$  is generated

```

---

*Add Evidence:* To add a digital evidence Investigating officer (IO) calls Algorithm 3. lawyer.

---

**Algorithm 3** AddEvid: Add Digital Evidence.
 

---

**Require:**  $C_{Id}$  and array of evidence Evid[T].

**Ensure:** Evidences Added Successfully and unique Id is generated.
 

---

```

1: if ( $verify(C_{Id}(IO\_UName \& \& IO\_Pswd)) == 1$ ) then
2:   for  $i \in EvidT$  do
3:      $E_{Portal} \xleftarrow[Evid[i]]{1}, C_{Id} C_{IO}$ 
4:      $Evid[id] : \forall id \in \{1, \dots, T\}$  with  $C_{Id}$  is registered.
5:   end for
6: else
7:   Investigating officer not registered with this case
8: end if

```

---

*View Evidence:* To view a digital evidence only associated lawyers, i.e., Respondent lawyer  $R_{l\_Id}$ , Petitioner lawyer  $P_{l\_Id}$ , and Judge  $J_{C\_Id}$  associated with case  $C_{Id}$  can call Algorithm 4.

---

**Algorithm 4** ViewEvid: View Digital Evidence by Authorized Entities only.
 

---

**Require:** Case Id  $C_{Id}$ .

**Ensure:**  $J_{C\_Id}, R_{l\_Id}, P_{l\_Id}$  can view evidence.
 

---

```

1:  $E_{Portal} \xleftarrow[E_{Name,pswd}]{C_{Id}} Entity$ 
2: if ( $verify(Entity) == 1$ ) then
3:   Entity can view  $Evid[i] : \forall i \in \{1, \dots, T\}$ 
4: else
5:   View Restricted
6: end if

```

---

The working of proposed framework is depicted in Fig. 3.

## 4 Experimentation Implementation Results

### 4.1 Algorithmic Approaches Used

We have used the Ethereum blockchain for running our smart contracts. Ethereum blockchain works on an algorithm called proof of work. The verification process for smart contracts and blockchain works on an algorithm of asymmetric cryptography which lodges the public key into the ledger and is traceable. We have used public key cryptography for the encryption of the evidence.

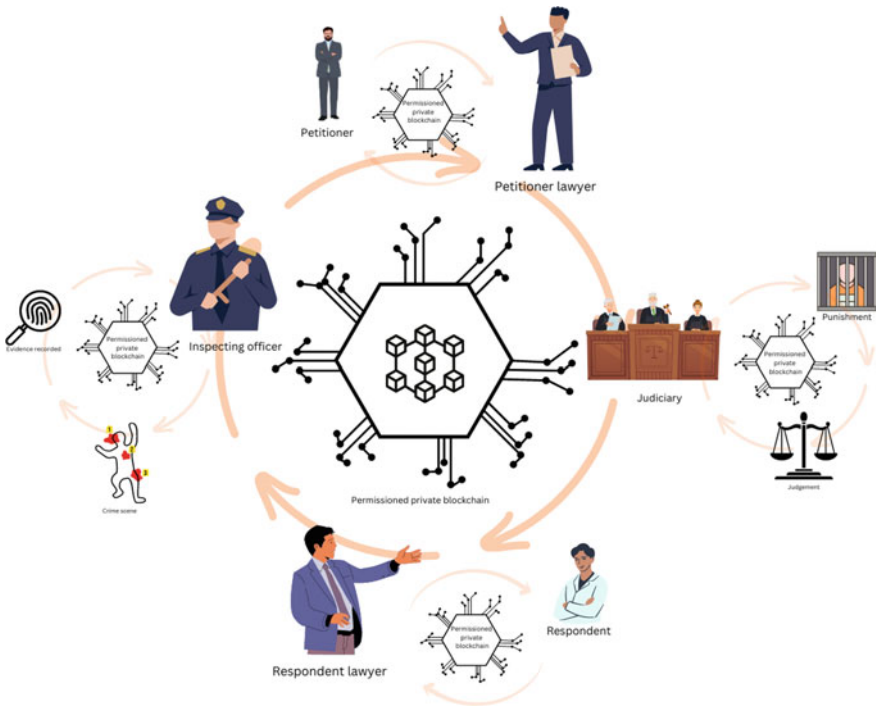


Fig. 3 Proposed system

### 4.2 Project Deployment

InterPlanetary File System (IPFS), a peer-to-peer network and protocol for storing and distributing data in a distributed file system, was used for hosting. To identify each file in the global namespace that links all computing devices, IPFS uses content addressing. The data is all kept on IPFS.

### 4.3 Designing Smart Contract

Smart contracts are designed to execute tasks involved in user registration and verification, land registration and verification as well as land transfer in a flawless manner. Smart contract is made up of four basic functionalities using logic to meet all the requirements. Storing document, such as images/files, will be expensive due to which we store it on IPFS which in turn provides us a hash which is stored on blockchain. Pinata is employed to increase the security of documents stored on IPFS by pinning that document so that no node could delete that particular document.



Our smart contract mainly contains these functions (other than some helper functions).

1. Register lawyer: Whenever a new Lawyer is added to our smart contract register-Lawyer function is called. And to maintain this a new Lawyer Object is pushed into our lawyers array.
2. Register Judge: Whenever a new Judge is added to our smart contract register-Lawyer function is called. And to maintain this a new Judge Object is pushed into our judges array.
3. Add new case: Whenever a new Case is added to our smart contract register-Lawyer function is called.
4. Upload evidence: Whenever a new Evidence is added to our smart contract registerLawyer function is called and evidence case ID is updated with File Hash and the File Type.

## 5 Conclusion

With the help of blockchain and the use of smart contracts using Solidity as our programming language and Ethereum, we aim that all digital evidences used in a case are tamper-free so that no innocent person should be accused due to corruption and manipulation in the evidence. In this project, we have used smart contracts that are stored on a blockchain that is trust-less and completely secure. It majorly helps us in removing any third party involved in the act of storing digital evidence during the court proceedings. We have learnt about Ethereum which is specifically being used because it supports smart contracts the best out of any other platforms. Smart contracts are also decentralized; therefore, there is no single person operating the whole contract.

*Future Work:* There are many possible directions to extend our proposed approach. We can add in more options involving chain of custody. Slowly, we can build up to a better user interface and also include other features required for managing physical evidence. RFID tags can also be implemented.

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# Future of Cryptography in the Era of Quantum Computing



Balvinder Singh, Md Ahateshaam, Abhisweta Lahiri, and Anil Kumar Sagar

**Abstract** As quantum computing advances, it poses a significant threat to the security of conventional cryptographic systems that rely on mathematical problems. The inherent power of quantum computing threatens to render conventional encryption techniques obsolete, thus prompting the development of post-quantum cryptography. In this work, we investigate the possible effects of quantum computing on current cryptography as well as the need for post-quantum encryption. We talk about how quantum computing is progressing right now and the many algorithms that are being created to address mathematical issues. Additionally, we give a general introduction of post-quantum cryptography and its many methods, including lattice-based, code-based, and hash-based encryption. Finally, we evaluate the strengths and limitations of post-quantum cryptography and its potential to withstand quantum attacks in the future. Our analysis reveals that post-quantum cryptography has the potential to provide robust and secure cryptographic solutions for the era of quantum computing.

**Keywords** Post-quantum cryptographic techniques · Quantum computing · Shor's algorithm · Grover's algorithm · Asymmetric encryption · Symmetric encryption

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## 1 Introduction

In the modern world, cryptography is essential for protecting data storage and technological communication. Symmetric and asymmetric cryptosystems both provide defense against external adversaries. The development of quantum computing, however, poses a serious risk to the current asymmetric cryptography. Even symmetric encryption is susceptible to quantum algorithms, but by expanding the key space, it can be made more safe. The most secure and effective approach, Elliptic Curve Cryptography, is subject to new algorithms that potentially break the current asymmetric cryptosystems that rely on factoring huge prime numbers and the large discrete logarithmic problems. It is therefore necessary to develop new encryption methods that can withstand quantum computing. Hash functions, symmetric cryptography, and asymmetric cryptography are the main topics of this research study. In addition to giving a general introduction of quantum mechanisms and its difficulties of building a genuine quantum computer, it analyzes methods that employ factoring large prime numbers and huge discrete logarithmic problems. The study also examines Shor's algorithm and Grover's algorithm, two important quantum algorithms that have an impact on symmetric and asymmetric encryption, respectively. The study also introduces mathematical-based post-quantum cryptography techniques, such as quantum key distribution, lattice-based, code-based encryption, hash-based signatures, and multivariate cryptography techniques. For anyone interested in learning how quantum computing may affect present cryptography systems and investigating post-quantum cryptographic alternatives, this paper is an invaluable resource.

## 2 Present Cryptography

This research provides a quick analysis of the roles played by hash functions, symmetric algorithms, and asymmetric algorithms in contemporary cryptography. We look at the problems of discrete logarithm issue and huge number factorization, which are the foundation of robust asymmetric ciphers.

### 2.1 *Symmetric Cryptography*

Using the same secret key and encryption procedure between the sender and recipient is known as symmetric cryptography. There is a requirement for safe methods of transferring keys across public networks since the shared secret key must be kept private and known only to the people involved. To address this issue, asymmetric cryptography was developed, which enables the use of various keys for encryption and decoding. The symmetric cryptography technique that is often used includes Data Encryption Standard (3DES) and the Advanced Encryption Standard (AES).

## 2.2 Asymmetric Cryptography

Asymmetric cryptography is a type of encryption that encrypts and decrypts data using two different keys. The public key, which is available to everyone, is one key. The owner, on the other hand, guards the secrecy of the private key. The public key is used to encrypt data, while the private key is used to decode it. This encryption method is particularly secure since it is nearly difficult to separate the private key from the public key. Asymmetric cryptography is frequently used in online banking and e-commerce to secure sensitive data and transactions. Asymmetric encryption frequently employs the RSA, Diffie–Hellman, and elliptic curve algorithms. Digital signatures are frequently created using asymmetric cryptography, also known as public-key cryptography (PKC). PKC allows for the digital signature of a sender using their private key and a recipient using their public key to confirm the signature. PKC’s security is built on computational challenges, like how challenging it is to factor huge prime numbers and how challenging it is to solve the discrete logarithm problem. Because they are simple to compute in one direction but challenging to reverse, these methods are known as one-way functions. Protecting sensitive data and online transactions using PKC is a very safe way. Elliptic Curve Cryptography, Diffie–Hellman, and RSA are common PKC algorithms. Digital signatures are frequently created using asymmetric cryptography, also known as public-key cryptography (PKC). PKC allows for the digital signature of a sender using their private key and a recipient using their public key to confirm the signature. PKC’s security is built on computational challenges, like how challenging it is to factor huge prime numbers and how challenging it is to solve the discrete logarithm problem. Because they are simple to compute in one direction but challenging to reverse, these methods are known as one-way functions. Protecting sensitive data and online transactions using PKC is a very safe way. Elliptic Curve Cryptography, Diffie–Hellman, and RSA are common PKC algorithms [1].

1. *Factorization Problem*—Rivest, Shamir, and Adleman created the well-known public-key encryption method RSA in 1977. Because bi-prime numbers are challenging to factor in, RSA is secure [2]. Although computationally expensive, RSA and other asymmetric algorithms are not meant to take the place of symmetric methods. Instead, RSA is frequently paired with symmetric algorithms like AES, which handle the actual encryption and decryption of data, and is primarily used for end-to-end secure key exchange. Factoring method is created or if computational power significantly increases. In fact, the application of quantum mechanics to computers, or quantum computers, has the potential to significantly boost computing power and jeopardize the security of RSA [3]. Nevertheless, RSA continues to be a well-liked and often employed encryption technique, particularly when paired with other cryptographic algorithms.
2. *Diffie–Hellman (DH) and Elliptic Curve Cryptography (ECC)* are two asymmetric cryptographic techniques that rely on the discrete logarithm problem (DLP). Finding the integer “ $j$ ” that satisfies the equation  $uj = x \pmod p$ , where “ $u$ ” and “ $p$ ” are fixed parameters, and “ $x$ ” is a random number, is the goal of the

DLP. The discrete logarithmic problems of “ $x$ ” to the base “ $u$ ” are referred to as “ $j$ ” and are denoted by the equation  $j = \log u \times \text{mod } p$ .

The DLP is one of the most difficult mathematics problem that gets more difficult as “ $g$ ,” “ $p$ ,” and “ $x$ ” values rise. Due to the practical impossibility of estimating the value of “ $r$ ” for sufficiently large values, DLP-based cryptographic systems are secure. As a result, asymmetric cryptography methods like ECC and DH are regarded as being very secure for shielding private data and online communications.

The Diffie–Hellman algorithm is an asymmetric cipher that uses the aforementioned characteristic to securely transmit keys over a public network. Currently, keys with 2048 bits or more are advised to ensure secure key exchange. Elliptic Curve Cryptography (ECC) is one of the most important public-key methods that is also widely used. ECC is a preferred option for systems with limited computational resources because with shorter key operands than RSA and DLP systems, it offers the same degree of security. ECC uses a set of coordinates  $(i, j)$  that satisfy the formula  $j_2 = i_3 + ai + b \text{ mod } p$  as well as an illustrative point at infinity symbolized by the symbol  $(\theta)$ . In this case,  $a$  and  $b$  are members of  $\mathbb{q}_p$ , and  $4s^3 + 27r^2 \text{ mod } k$  [2]. Elliptic Curve Cryptography requires a cyclic group  $H$  and a pair of elements that have order  $H$  as well as primitive elements. ECC is typically regarded as the most effective and secure asymmetric cryptosystem. However, as we will describe in the next sections, this may alter with the development of quantum computers.

### 3 Quantum Computing Versus Classical Computing

The idea of quantum computing, which makes use of the unusual behavior of particles at the quantum level, was originally proposed by physicist Richard Feynman in 1982. In contrast to ordinary computers, quantum computers use quantum bits, or qubits, that may both be 0 and 1 as opposed to conventional computers which use bits that can only be 0 or 1. When qubits are entangled, it is impossible to describe each one’s quantum state separately. As a result, actual parallel processing is allowed and the number of data that may be handled in a single operation rises exponentially [4].

Quantum computers come in two flavors: universal and non-universal. The creation of universal quantum computers is different from the creation of non-universal quantum computers, which are made to accomplish any task. IBM’s quantum computer is the most advanced universal quantum computer at the moment, while D-Wave’s 2000 + qubits and IBM’s 17 qubits are examples of non-universal quantum computers [5].

Comparing conventional computers with typical transistors and diodes to quantum computers reveals significant design differences [6]. Different designs, including quantum dots and computing liquids, have been tested by researchers. Quantum parallel algorithms must be used in conjunction with quantum computers in order for them to surpass traditional computers.

### ***3.1 Challenges in Quantum Computing***

Numerous difficulties with quantum computing exist today, which researchers are working to solve.

- The probabilistic nature of quantum algorithms, which causes a quantum computer to return numerous solutions in a single operation even though only one of those solutions is the right one, is one of the fundamental difficulties. Because of this, measuring and validating the right response require trial and error, which reduces the speed advantage of quantum computing [3].
- Qubits are prone to blunders as well and may be impacted by elements including heat, outside noise, and errant electromagnetic couplings. Qubits are subject to bit-flips and phase mistakes, unlike conventional computers, which are not. It is best to avoid doing a direct error check because doing so could result in the value collapsing and losing its superposition state.
- Another issue with quantum computing is coherence, where qubits can only maintain their quantum state for a brief length of time. Two distinct forms of qubits, a phosphorus atom and an artificial atom, have been produced by researchers and placed in tiny silicon (silicon 28) in order to minimize the magnetic noise that makes qubits prone to mistakes. It takes the phosphorus atom 35 s to remain in superposition [7]. And it is the world record and has a 99.99% accuracy rate, accounting for one inaccuracy every 10,000 quantum processes [8]. However, in order to achieve lengthy coherence, qubits must be kept in temperatures approaching absolute zero and isolated from the outside world, which makes it challenging to manage them without introducing further noise [3].

Quantum volume is a new metric IBM suggested in 2017 to gauge a quantum computer's power. The quantum computer's qubit count, the effectiveness of the error correction applied to those qubits, and the total number of simultaneous operations are the three key determinants of quantum volume. A quantum computer's performance may not necessarily be improved by merely adding additional qubits if the error rate on those qubits is high. On the other hand, as it decreases the possibility of errors arising during calculations, better error correction can result in a quantum computer that is more potent. Consequently, quantum volume offers a more thorough evaluation of a quantum computer's capabilities than only counting the qubits [9].

## **4 Cryptosystems That Are Susceptible to Quantum Algorithms**

The impact of quantum algorithms on modern encryption is a significant worry for academics and subject-matter experts. For secure electronic communication, such as email security, password protection, financial transactions, and electronic voting systems, which all need confidentiality and integrity, cryptography is essential [10].

**Table 1** Analysis of the effects of quantum computers on encryption techniques (taken from [12])

| Cryptographic algorithm                   | Type          | Purpose                       | Impact from quantum computer |
|---|---------------|-------------------------------|------------------------------|
| AES-256                                   | Symmetric key | Encryption                    | Secure                       |
| SHA-256, SHA-3                            | –             | Hash functions                | Secure                       |
| RSA                                       | Public key    | Signatures, key establishment | No longer secure             |
| ECDSA, ECDH (Elliptic Curve Cryptography) | Public key    | Signatures, key exchange      | No longer secure             |
| DSA (Finite field cryptography)           | Public key    | Signatures, key exchange      | No longer secure             |

Only those who have traded keys and have permission to do so can decrypt the communication. However, the development of quantum computers poses a threat to the security of every communication system because they can perform computations that traditional computers cannot, making it possible for them to quickly decrypt cryptographic keys by calculating or searching for all secret keys exhaustively. This enables an eavesdropper to infiltrate the sender and receiver’s communication channel, a feat that conventional computers would find computationally impossible [11].

According to the National Institute of Standards and Technology (NIST), the use of public-key encryption will eventually become obsolete due to the development of quantum computers [12]. Table 1, which was modified from NIST, demonstrates how quantum computing will affect current cryptographic techniques. Shor’s algorithm, which weakens discrete logarithm computation and factorization, is one of the most important algorithms in this field. This indicates that encryption techniques that rely on these algorithms are easily cracked by quantum computers. Another significant method is Grover’s, which can search an unsorted database in  $O(\sqrt{N})$  time as opposed to the  $O(N)$  time needed by conventional computers. With a quadratic speedup, this approach can also be used to crack symmetric key encryption.

It follows that it is obvious that quantum algorithms have the ability to significantly alter contemporary cryptography and necessitate the creation of fresh quantum-safe cryptographic techniques.

#### 4.1 *Shor’s Algorithm*

In his paper “Algorithms for Quantum Computation: Discrete Logarithms and Factoring” from 1994 [13], Peter Shor made the case that the factorization of big integers will be substantially altered by a quantum computer. Shor’s method may render modern asymmetric encryption vulnerable since it relies on the discrete logarithm issue or massive prime integer factorization. Take the example of factoring 15 to



demonstrate how Shor's algorithm functions. This calls for a 4-qubit register, equivalent to a regular 4-bit register in a traditional computer. A 4-qubit register is all that is needed to find the prime factors of 15, as the binary representation of that integer is 1111 (or 15). According to Bone and Castro, the calculation done on the register may be interpreted as simultaneous computations for every possible value that the register might hold (0–15) [6]. Only one step needs to be completed on a quantum computer.

Using a quantum computer, Shor's technique can factorize enormous prime numbers in polynomial time. When we want to factorize the number  $n$ , the method operates as follows:

1. Select  $x$  at random so that  $1 < x < n$ .
2. Determine  $x$  and  $n$ 's GCD (greatest common divisor). We have found a factor of  $n$  and are finished if GCD is not equal to 1. If not, move on to the following action.
3. Fill two registers with  $k$  qubits each at startup. The state  $|y\rangle$  will be in the first register, and the state  $|1\rangle$  will be in the second register.
4. On the two registers that are in superposition, use the following function:
5.  $f(y) = n \bmod xy$ .
6. In order to determine the binary value of  $f(y)$ , measure the second register.
7. To find a fraction  $p/q$  that accurately approximates  $f/y$ , use the continuing fractions procedure.
8. If  $f(y)(q - 1)/2 \bmod n = -1$  and  $q$  is odd, then we have identified a factor of  $n$  and are finished.
9. If not, rerun the process with a different random  $x$  value.

In short, Shor's approach finds a period using a quantum Fourier transform in the equation  $f(y) = xy \bmod n$ . The continuous fractions' approach can be used to discover a factor of  $n$  during this time. Since Shor's method factors huge numbers significantly quicker than conventional algorithms, it poses a serious threat to the security of existing public-key encryption techniques.

Discrete logarithm problems can also be solved using Shor's approach. In particular, a new superposition that most likely results in two integers that satisfy an equation can be created by performing a sequence of Fourier transformations starting with a random superposition state of two integers. The value of the unknown "exponent" in the DLP can be calculated using this equation. Vazirani offered a thorough justification of the Shor algorithm's approach to solving DLPs [14]. This poses a serious danger to DLP-based cryptography systems since quantum computers would be able to solve these issues quickly and compromise the security of the system.

## 4.2 Grover's Algorithm in Symmetric Cryptography

For scanning unsorted databases, one can utilize Grover's method, a quantum algorithm [15]. It was developed by Lov Grover in 1996 and has significant cryptographic

ramifications. In a database with  $N$  entries that are not sorted, the approach can find a single entry in about  $N$  searches, but a conventional computer would need  $N/2$  searches to find the same entry. Database searches and optimisation issues are just two areas of computation where this exponential speedup in searching can be highly helpful.

Grover’s method may be used to crack the 56-bit Data Encryption Standard (DES), which uses encryption. Bone and Castro claim that the method only needs 185 searches to discover the secret, rendering DES susceptible to attacks from quantum computers [6]. We presently increase the key bits (bigger key space) to avoid password cracking, which exponentially increases the quantity of searches required. But while Grover’s technique has certain uses in symmetric cryptosystems, it is slower than Shor’s algorithm for discrete logarithm or factorization issues [16].

### 4.3 Asymmetric Cryptography Techniques Affected

Algorithms for public-key encryption are frequently used today to protect online communication. The factorization of huge integers and the computation of discrete logarithms serve as the foundation for these techniques. However, utilizing Shor’s method, quantum computers can quickly resolve both of these issues. Recent elliptic curve algorithms, like ECDSA, utilize a modified discrete logarithm problem, making them similarly susceptible to quantum computers.

According to researchers, data encrypted with ECC can be decrypted using a modified version of Shor’s method [3]. Additionally, ECC is more vulnerable to being cracked by quantum computers due to its smaller key space than RSA. Proos and Zalka claim that breaking 160-bit elliptic curves may be done with a 1000-qubit system, whereas factoring 1024-bit RSA would need a quantum computer with 2000 qubits [17] (Table 2).

Grover’s technique, however, is only a threat to specific symmetric cryptographic algorithms since it can scan unsorted databases. Symmetric cryptography techniques like AES are resistant to quantum computers if the key sizes are large enough. Quantum cryptanalysis is the study of an algorithm’s resistance against quantum computing assaults. The significance of algorithm robustness against attacks from quantum computing has been highlighted by NIST [12]. For the most popular cryptographic algorithms, Table 3 compares the security ratings of classical and quantum systems.

**Table 2** QUBIT register values

|            |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |
|------------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|
| Register 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Register 2 | 1 | 2 | 4 | 8 | 1 | 2 | 4 | 8 | 1 | 2 | 4  | 8  | 1  | 2  | 4  | 8  |

**Table 3** Comparing the security levels of classical and quantum computing

| Crypto scheme | Key size | Effective key strength/security level (in bits) |                   |
|---------------|----------|---|-------------------|
|               |          | Classical computing                             | Quantum computing |
| RSA-1024      | 1024     | 80  | 0                 |
| RSA-2048      | 2048     | 112   | 0                 |
| ECC-256       | 256      | 128   | 0                 |
| ECC-384       | 384      | 256   | 0                 |
| AES-128       | 128      | 128   | 64                |
| AES-256       | 256      | 256   | 128               |

### 4.4 Symmetric Encryption Schemes Affected

Only Grover’s algorithm is now known to threaten symmetric cryptography, which is only slightly at risk from quantum computing. Grover’s method speeds up the typical brute force methods’ square root of the amount of operations required. For an n-bit cipher, for example, a quantum computer can operate on  $(2n = 2(n/2))$ . An AES-128-style symmetric cipher with a 128-bit key length theoretically provides a security level of 256 bits, but in practise only provides 64 bits. It is considered trustworthy to have security at an 80-bit level. When utilized with key sizes of 192 or 256 bits, AES is regarded as a durable cryptographic primitive against quantum computations [18]. The NSA permits the use of the AES cipher to secure confidential information at security levels SECRET and TOP.

### 4.5 Hash Functions

Hash functions have a weakness with symmetric ciphers related to their fixed output length. Grover’s method may be applied to search for collisions in a hash function in an unsorted database. The approach can find a collision in square-root steps of the initial length. A quantum birthday assault can be made by combining this weakness with the birthday paradox [19]. This attack searches a table of size square-root 3N for a collision using Grover’s technique. A hash function must have an output length that is at least three times the desired security level in order to offer a certain amount of protection against Grover’s quantum method. The conclusion is that many hash algorithms in use today are inadequate for use in the quantum era. Though SHA-2 and SHA-3 have longer output lengths, they are still considered to be quantum resistant.

## 5 Post-quantum Encryption

Post-quantum cryptography, often known as quantum-resistant cryptography, aims to develop cryptographic systems that can survive assaults from both quantum and classical computers while remaining compatible with existing communication protocols and networks [12]. In recent years, a variety of post-quantum public-key solutions have been thoroughly studied. In 2016, NIST issued a call for algorithm suggestions that were thought to be resistant to quantum assaults. In 2018, NIST released the findings of the initial investigation, which comprised 82 proposed algorithms, 59 of which were for encryption or key exchange, and 23 of which were for signatures. After 3–5 years of investigation, NIST aims to present its conclusions and a draft of the standards [20]. The NSA has also made plans to switch to post-quantum cryptography for its cryptographic standards [21].

The techniques discussed in this section are different from conventional cryptographic algorithms that rely on the hidden subgroup issue, such as factoring integers or computing discrete logarithms.

### 5.1 *Quantum Key Distribution*

Two parties can safely exchange a cryptographic key across an unsecured channel using a technique known as quantum key distribution (QKD). Based on the basics of quantum physics, which are immune to greater processing power, QKD may be performed using light, lasers, fiber-optics, and free-space transmission technologies. With the creation of the BB84 protocol by Charles Bennett and Gilles Brassard, QKD was first made available in 1984 [22, 23]. Since then, a large number of QKD protocols have been created, primarily taking advantage of two unique qualities.

The Heisenberg Uncertainty Principle, this says that evaluating a quantum state alters it in some way [24], is the foundation of the prepare-and-measure (P&M) techniques. This makes it more challenging for a hacker to snoop on a communication channel. Legitimate exchange parties can calculate the quantity of information intercepted and delete corrupted information in the case of eavesdropping [25]. This characteristic is used by the BB84 protocol.

Entanglement-based (EB) protocols, on the other hand, make use of shared pairs of entangled objects between two parties. A quantum phenomenon called entanglement connects two or more objects in such a way that it is necessary to treat them as a single object. A measurement of one of the things would also have an impact on the other. When two legitimate exchange parties share an entangled pair of objects, anyone who intercepts either object would modify the entire system, indicating the presence of an attacker and the quantity of information acquired. The E91 protocol made use of this characteristic [26].

The two methods previously described are further separated into three families: distributed phase reference coding, continuous variable coding, and discrete variable coding. The type of detecting mechanism employed is the primary distinction between these families. After a detection has actually taken place, the events are post-selected using discrete variable coding and distributed phase reference coding [27].

A single frequency of an oscillating signal's modulation is compared to a reference oscillation using homodyne detection, which is employed in continuous variable coding [27].

Several Quantum Key Distribution (QKD) techniques for discrete variable coding are briefly summarized below:

- BB84: The original QKD technique established secure communication between two parties by employing four non-orthogonal polarized single-photon states, also referred to as low-intensity light pulses [22, 23].
- BBM: A variation of BB84 that uses Bell states and is entanglement-based [28].
- E91: A protocol that builds on the BB84 concept and uses the generalized Bell's theorem and the gedanken experiment [26, 29, 30].
- SARG04: Comparable to BB84, except instead of using states to encode bits, it employs bases. It can withstand an attack using photon number splitting (PNS) better [31, 32].
- A variation of the BB84 called the six-state protocol employs the six-state polarization technique on three orthogonal bases [33, 34].
- The SARG04 coding has six-state variations [32].
- The Singapore protocol is a tomographic protocol that outperforms the six-state protocol in terms of effectiveness [35].
- The B92 protocol employs two non-orthogonal quantum states to encrypt bits for secure communication utilizing low-intensity coherent light pulses [36].

**Protocols for continuous variable coding:**

1. Gaussian procedure

- Continuous variable version of BB84: In a continuous variable variant of the BB84 protocol, bits are encoded using Gaussian states in this protocol [37].
- Continuous variable utilizing coherent states: This protocol establishes secure communication between two parties using coherent states [38].
- The simultaneous quadrature measurements of coherent states are the foundation of the coherent state QKD protocol [39].
- The coherent condition in the QKD protocol, coherent or compressed random distributions are created and sent [40].

2. Protocols for discrete modulation:

- Coherent state-based continuous variable protocol: This protocol substitutes coherent states for compressed states [41].

### **Protocols for distributed phase reference coding:**

1. In the Quantum Key Distribution (QKD) method, differential phase shift (DPS) is utilized. A single photon is used in this method to create a superposition state that consists of three fundamental keys, and the change in stage between two subsequent pulses is used to encode bit data [42, 43].
2. The Coherent One-Way (COW) protocol uses an interferometer on a monitoring line to detect intruders while determining the key via a time-of-arrival measurement on the data line. 2008 saw the release of a version of this protocol [44–46].

The majority of quantum key distribution protocols are currently used in practice, and they use discrete variable coding. However, distributed phase reference coding protocols and continuous variable coding methods concentrate on overcoming practical constraints in experiments. Despite the fact that they might not be used as frequently as discrete variable coding techniques, these are nonetheless significant study topics for the advancement of quantum communication technology.

#### **1. BB84 Protocol**

Due to its demonstrable security, the BB84 protocol is a quantum cryptography system that is frequently used today [47]. It operates by using the polarization of light to generate keys (qubits) at random and transmit them across a quantum channel [48]. This protocol uses base 1 and base 2 as its two distinct bases. Base 1 is made up of photons that are polarized either horizontally or vertically, whereas Base 2 is made up of photons that are polarized at 45 or 135 degrees. Alice starts by launching a photon into one of the two bases with a value of either 0 or 1, which is chosen at random. The photon's value is then measured by Bob using one of the two bases without him being aware of which base Alice used.

They carry on in this manner until they have produced enough bits for their key. Bob divulges to Alice the order of bases he employed, but not the measured values. Any faulty bits are eliminated after Alice determines whether the bases were accurate or incorrect. Alice then encrypts the message and sends it to Bob using the key that was traded. Figure 1 presents a graphic representation of the BB84 protocol.

The BB84 protocol has been shown to be vulnerable to attacks in actual hardware implementations, despite being provably secure. By blinding the APD-based detector (avalanche photodiode), Lydersen et al. [49] successfully breached the protocol by viewing the secret key without the receiver's awareness. However, Yuan et al. have suggested ways to lessen these blinding attacks. One suggested countermeasure is to monitor for exceptionally high photocurrent readings among the proposed upgrades. Despite these upgrades, Lydersen et al. [50] were still able to successfully release the secret key without leaving any evidence [51].

#### **2. Photon Number Splitting Attack**

The security of the system is one of the main issues with quantum key distribution. In practise, laser pulses are used instead of single photons because doing so would be impracticable for the device. The Photon Number Splitting (PNS) attack is a

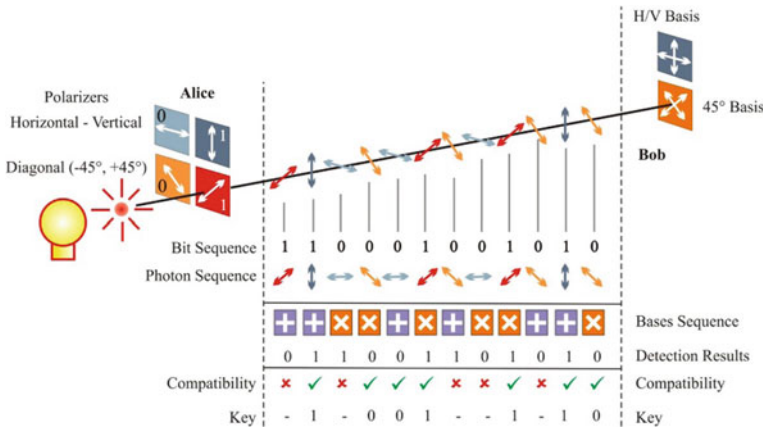


Fig. 1 Implementation of the BB84 protocol’s key exchange using photon polarization (from [68])

weakness brought on by this use of laser pulses. In this method, Eve splits a photon from the signal without altering the polarization of the remaining photons, which are then transferred to Bob, the receiver. While Alice reveals the encoding bases, Bob measures the photons. Then, Eve may undetectably measure all captured photons on the proper bases and learn the secret key from all messages including multiple photons. Researchers suggested employing decoy states to identify PNS assaults to solve this problem [52]. Eve is unable to distinguish between decoyed signals and non-decoyed signals by broadcasting randomly generated laser pulses with a lower average photon number [53]. Both single-photon and multi-photon pulses may be used with this technique [54]. The approach developed by Lo et al. appears to be the most effective way to stop PNS assaults.

### 5.2 Mathematically Based Solutions

Like RSA, DH, and ECDSA, there are a number of mathematical puzzles that can be utilized for public-key cryptography that are resistant to quantum computer assaults [55]. There are various alternatives, including hash-based signatures, code-based, multivariate, and lattice-based encryption [56–59]. These mathematical problems have already been used in public-key cryptography systems and do not depend on the Hidden Subgroup Problem.

The cryptographic techniques that result from the mathematics presented above are not necessarily ideal or faultless. We will give an overview of these additional cryptographic techniques in the following sections.

## 1. Lattice-Based Cryptography

**Lattice-Based Cryptography** is one of the first A more secure alternatives to RSA which is cryptography, a subset of public-key cryptography. Lattice-based encryption uses multiplying matrices rather than prime numbers. Based on the shortest vector problem's (SVP) alleged complexity, lattice-based cryptographic constructs are said to be secure [56]. Finding the shortest non-zero vector in any lattice represented by a given basis is the aim of SVP.

The three primary lattice-based cryptosystems are NTRU [60], Goldreich–Goldwasser–Halevi [61], and Ajtai-Dwork (AD) [62]. After finding a link between the ugliest-case and avg-case complexity of SVP, Ajtai and Dwork claimed in 1997 that their cryptosystem was probably safe [62]. Nguyen and Ster, however, challenged their assertion in 1998 [63]. The AD key that is public is also excessively large, which causes message growth and renders it useless in the post-quantum era. Additionally, the AD public key is too big, which leads to message growth and makes it unworkable in the post-quantum period.

The problem of the closest vector (CVP), which is regarded as being NP-hard, is used in GGH, a 1997 publication. Nguyen demonstrated in 1999 that GGH had a serious vulnerability while being more effective than AD. By resolving CVP instances, you can acquire some plaintext information [64].

The NTRU protocol is used by both digital signature (NTRUSign) and encryption systems (NTRUEncrypt), which Hoffstein et al. [60] disclosed in 1996. It makes use of the fact that some polynomials are challenging to factor, and it is immune to Shor's algorithm. NTRU needs 12881-bit keys in order to provide 128-bit post-quantum security [65]. As of right now, NTRU has not been the target of any attacks.

The NTRU Prime lattice-based cryptosystem, which Bernstein et al. unveiled in May 2016 [66], employs several, more secure ring configurations to fix the vulnerabilities of multiple lattice-based cryptosystems, including NTRU. In 2013 [67], Stehle and Steinfeld developed SS-NTRU, a provably secure variant of NTRU. In conclusion, NTRU is a strong candidate for the post-quantum era since it is the most efficient and safe algorithm among all the lattice-based cryptosystems mentioned.

## 2. Multivariate-Based Cryptography

The complexity of solving systems of multivariate polynomials over finite fields determines the type of public-key encryption used, or cryptography. It has proven difficult to create a multivariate equation-based encryption system, nevertheless [11]. Several multivariate polynomial-based asymmetric public-key encryption systems have been created; however, many of them are unsafe because their core maps are linked to low-rank quadratic forms [69]. Tao et al. developed the Simple Matrix (ABC), a successful multivariate strategy based on matrix multiplication, in order to remedy this issue. Multivariate cryptosystems may also be used to establish digital signatures; the most promising signature methods are Unbalanced Oil and Vinegar



(UOV) and Rainbow. Due to the large ratio of variables to equations in UOV, signatures and public-key sizes are longer. In contrast, Rainbow employs lower ratios, resulting in reduced digital signatures and key sizes [10].

### 3. Hash-Based Signatures

Leslie Lamport created the Lamport signature scheme, a digital signature algorithm, in 1979 [16]. It creates a digital signature for a message using a secure hash algorithm. The intended security level of the system is specified by the parameter  $b$ , with SHA-256 being regarded as the best option for a 128-bit  $b$  security level.

Two hundred and fifty-six random number pairs are produced using a random number generator, each with 256 bits, for a total of  $2 \times 256 \times 256 = 16$  KB, in order to construct a private key. The private key has an  $8b^2$  bit length. The private key's produced numbers are independently hashed into 512 distinct hashes of 256 bits each to produce the public key. The public key consists of  $8b^2$  bits.

The hashed message is being processed in order to sign it. One number is selected from each pair that makes up the private key for each bit, yielding a string of 256 numbers. The digital signature, which is also released with the plaintext message, is this string of digits. The remaining 256 numbers from the pairs should be deleted, and the private key should never be used again.

As part of the verification process, the hash of the received message is calculated, and the proper hash from the public key is then chosen for each bit of the hashed message. The sequence of hashed values generated after each number of the sender's private key is hashed should correspond to the recipient's appropriately chosen public-key values [16]. The only time the private key is used, which makes it impossible for an opponent to obtain more than 50% of the private key and create a new valid signature, is what gives this system its security.

Other hash-based signature methods have been created that are more effective than Lamport's, like the one-time signature (WOTS) described by Winternitz, and chaining can be included for signing numerous messages [70]. However, due to the fact that they can only be used once, they are not appropriate for widespread use. With the Merkle Signature Scheme, Winternitz's OTS and binary trees are combined in a novel way. Each node in a binary tree, which together constitutes a tree and is referred to as nodes, has the hash value of the concatenation of the child nodes. Each leaf node stores a Winternitz's OTS for signature, while the root node of the tree has the real public key that can validate the OTSs stored in the leaf nodes [71].

In 2013, Hulsing enhanced the security and efficiency of the WOTS algorithm, even when using collision-free hash function resistance [70]. The XMSS, a stateful signature scheme, and stateless practical Hash-based has been incredibly great collision-resilient signatures, which is a stateless signature method, are both now being worked up for standardization [72, 73].

### 4. Based on Code Cryptography

Based on codes, error-correcting codes are a form of cryptographic technique used in cryptography. These algorithms' security is predicated on how challenging it is to decode linear codes, and when key sizes are four times larger, it is thought to

be resistant to quantum attacks. According to Buchmann et al. [16], the decoding problem can be resolved by converting it into a Low-Weight-Code World Problem (LWCWP), although it is thought to be impossible to resolve a LWCWP with vast dimensions.

Examining the original code-based public-key encryption scheme developed by McEliece [16] can help one comprehend code-based cryptography. The security parameter in this system,  $b$ , is a power of two, with the values of  $n = 4b \log b$ ,  $d = \log n$ , and  $t = 0.5 n/d$ . For instance,  $n = 512 \log 2(128) = 3584$ ,  $d = 12$ , and  $t = 149$  if  $b = 128$ .

A dtn matrix  $K$  having coefficients  $F_2$  works as the recipient's public key in this approach. The content of the message  $m$  is multiplied by  $K$  to encrypt it, and the message must have precisely  $t$  bits set to 1. The receiver generates a public key using a secret Goppa code structure (error-correction code) to enable Patterson's algorithm decoding or other speedier techniques. Two reversible matrices which are utilized to decipher the encrypted text and acquire the information  $t$  have an effect on the code's generating matrix  $K$ .

The use of code-based cryptography entails an agreement among effectiveness and safety, much like other forms of cryptosystems. Cryptographic system provided by McEliece employs speedy and incredibly straightforward encryption and decryption procedures, although these procedures call for the usage of huge public keys (between 100 kilobytes and several gigabytes in size).

## 6 Conclusion

In the information-driven world of today, the safe transmission and storage of data are essential. However, the threat presented by quantum computers to symmetric key algorithms like 3DES and AES as well as established public-key algorithms like RSA, ElGamal, ECC, and DSA necessitates the development of more secure cryptographic systems. As fully operational quantum computers, capable of executing potent quantum algorithms like Shor's and Grover's algorithms, become increasingly probable, current public-key techniques could no longer be practical. To address this problem, several solutions have been proposed, including the BB84 protocol, a quantum key distribution method, and mathematically based alternatives including lattice-based cryptography, hash-based signatures, and code-based encryption.

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# Traffic Optimization and Optimal Routing in 5G SDN Networks Using Deep Learning



Piyush Kulshreshtha  and Amit Kumar Garg 

**Abstract** 5G networks use a network architecture based on SDN due to the efficiency, low cost, ease of management, and scalability provided by SDN. However, SDN has the issue of determining the routes and traffic optimization centrally. The problem of traffic optimization and routing in 5G networks has been solved through the use of deep learning algorithms such as Deep Deterministic Policy Gradient (DDPG). DDPG provides good results but suffers from the problem of overestimation bias and runs the risk of becoming unstable. These issues have been solved by an alternative deep learning algorithm called Twin-Delayed Deep Deterministic Policy Gradient (TD3). One of the changes in TD3 is training the agent with two Q value functions instead of a single Q value function and taking the minimum of two values. TD3 also uses delayed policy/target updates and smoothing of target policy. There is no mention of TD3 in literature for solving the problem of SDN routing, so this paper analyzes and compares DDPG (existing approach) and TD3 (proposed approach). A simulation environment consisting of the Omnet++ discrete event simulator was used to simulate a 5G network with SDN routing. Two different simulation runs were used—with DDPG and TD3. It was demonstrated that the TD3 approach provided a much better performance with lower latency.

**Keywords** 5G network · Mobile network · Software-defined networks (SDNs) · Machine learning · Deep learning

## 1 Introduction

Wireless communication networks have evolved with the advancements in technology to their fifth generation which supports much faster data rates, is ultra-dense, and provides lower latency. The 5G networks use a lot of emerging technologies and innovations to achieve these capabilities. Software-defined networks are one such

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technology deployed in 5G networks to reduce latency as well as cost. SDN architecture separates the data plane from the control plane in the network and provides a centralized network control. The routers in the traditional network are replaced with high-speed switches that have limited control plane capability. The routing functionality is shifted to the centralized SDN controller that shares the routing information with the switches. Standard protocols like OpenFlow are used for this communication between the SDN controller and the switches. The routing decisions are communicated to the switches by the SDN controller through this standard protocol. The centralized control of routing eliminates the overhead of routing from the network and also allows a centralized policy to be enforced. SDN networks provide much higher reliability and scalability compared to the traditional model of distributed routing.

The use of SDN architecture improves the performance of the networks significantly and also provides much more scalability compared to conventional routing protocols. Rego et al. [1] demonstrated a performance improvement when OSPF routing was used in an SDN network as compared to traditional distributed networks. There was a significant reduction seen in packet delays as well as jitter in video streaming applications in SDN networks as compared to OSPF routing networks. Zhang et al. [2] demonstrated that SDN routing is much more scalable and routing convergence is faster in the case of large networks with higher link delays. The OSPF networks provided better response time as compared to SDN networks in the case of small, 16-node topology. However, the response time of SDN networks was 20% faster as compared to conventional OSPF networks in the case of large, 120-node topology. Gopi et al. [3] compared the routing convergence time of conventional routing networks and SDN networks. It was demonstrated that in an 80-node topology, conventional networks took 3 times more to converge as compared to SDN networks.

This architecture, however, requires the routing function to be implemented in the SDN controller and merely shifts the problem from routers to the SDN controller.

An alternative to the use of routing protocols in the control plane is to use machine learning techniques for traffic optimizations and learning routing paths in SDN networks. Machine learning techniques can be used for capturing multiple features such as bandwidth, delays, energy efficiency, QoS in routing. The overheads of traditional routing algorithms can be eliminated through the use of machine learning.

## 2 Existing Work in This Area

The existing literature includes work in the area of using machine learning techniques for learning of routing in SDN networks. Reinforcement learning is one of the commonly used techniques used for this purpose.

Lin et al. [4] proposed a QoS-aware adaptive routing for SDN networks based on reinforcement learning. The specific RL algorithm used by them was State-Reward-Action-State-Reward (SARSA). SARSA is conservative and learns a near-optimal policy as opposed to optimal policy learning in Q learning.

Tang et al. [5] suggested the use of deep CNN-based learning for automatically learning routing information in SDN networks. The deep learning approach was found to be faster compared to traditional routing. At a packet generate rate of 480 Mbps, the packet loss in deep learning was 50% of the rate observed in traditional routing. Deep learning, however, has the overhead and drawbacks of supervised learning and is not dynamic.

Stampa et al. [6] proposed the use of a deep reinforcement learning approach for learning routing information from the network using the Deep Deterministic Policy Gradient (DDPG) algorithm. It was demonstrated that the algorithm provided optimal delays in the network as compared to an initial benchmark. DDPG has a problem of overestimation bias which also needs to be addressed.

Yu et al. [7] also experimented with the DDPG algorithm to optimize routing in SDN networks. Minimization of delay was used as a performance metric and the benchmark used for comparison was OSPF routing data. Under a 70% traffic load condition, the delay performance of the proposed algorithm improved by 40.4% as compared to OSPF.

Xu et al. [8] integrated the DDPG learning algorithm into the routing process of SDN to facilitate routing. A comparison was made with the traditional OSPF routing protocol.

Tu et al. [9] also used the DDPG algorithm to take real-time routing decisions in SDN networks. The reward was set chosen as a function of bandwidth, delay, jitter, and packet loss. A comparison was also done with the OSPF routing protocol and significant improvement was seen in the case of DDPG-based routing.

Pham et al. [10] proposed a knowledge plane in SDN networks to manage the routing decisions. This knowledge plane used the DDPG algorithm to learn QoS-aware routing decisions. Latency and packet loss rate were considered as the criteria for optimizing routing. Improvement in packet loss rate as well as latency was observed in the case of the DDPG algorithm as compared to traditional routing mechanisms.

Kim et al. [11] implemented a DDPG-based deep reinforcement learning agent (DRL) for routing in SDN networks. DDPG-based agents demonstrated better performance compared to Naive methods.

Sun et al. [12] proposed Time-Relevant Deep Learning Control (TIDE) algorithm based on DDPG for QoS guarantee in SDN networks. TIDE took less time for running as compared to Shortest Path (SP) algorithms and provided better results.

The DDPG algorithm, used by several researchers, has the problem of over-estimation bias. Any error is propagated through Bellman equations and can make the algorithm unstable, making it miss the target value or find a local optimum.



### 3 DDPG and TD3 Deep Learning Algorithms

Lillicrap et al. [13] proposed a deep learning algorithm for continuous spaces and called it Deep Deterministic Policy Gradient (DDPG). DDPG is an off-policy, model-free, online learning algorithm that uses the Actor-Critic method for learning. The DDPG agent looks for an optimal policy that maximizes the cumulative long-term reward. It uses four function approximators—Actor, Target Actor, Critic, and Target Critic for learning. The Actor takes the action to maximize the reward, and the Critic returns the expected value of the long-term reward. Targets are used to improve the stability of the optimization. DDPG uses a replay buffer to randomly sample past actions.

DDPG also uses soft updates through target networks for both Actors and Critics. This means that all the weights are not copied from the target networks to the main networks, but a fraction of the weights are copied to provide stability.

This can be mathematically shown as:

$$\theta'_i \leftarrow \tau\theta + (1 - \tau)\theta'_i, \quad (1)$$

$$\phi' \leftarrow \tau\theta + (1 - \tau)\phi', \quad (2)$$

where  $\theta$  and  $\phi$  are the weights of the networks and  $\tau$  is the parameter used for the soft update. The value of  $\tau$  is less than 1 (typically around 0.999).

The DDPG algorithm, however, still suffers from an overestimation bias problem and can become unstable or may lead to a local optimum. To avoid this problem, several changes have been suggested in an alternative to DDPG known as Twin-Delayed Deep Deterministic Policy Gradient or TD3 algorithm. The changes from DDPG to TD3 are:

A TD3 agent learns two Q values instead of a single value used by DDPG. The minimum of these two values is used by the algorithm for updates.

Unlike DDPG, the policy is not updated after every iteration in TD3 but is updated less frequently (usually every two or three iterations of Q values).

During policy updates, the TD3 agent adds noise to the target action. This ensures that any high values are not exploited by the agent. The noise used in TD3 is Gaussian noise.

#### TD3 Algorithm

Initialization:

Two critic networks  $Q_{\theta_1}$  and  $Q_{\theta_2}$ .

are initialized with random parameters  $\theta_1$  and  $\theta_2$ .

An Actor network  $\Pi_\phi$  is initialized with random parameter  $\phi$ .

Target networks are initialized  $\theta'_1 \leftarrow \theta_1, \theta'_2 \leftarrow \theta_2, \phi' \leftarrow \phi$ .

The replay buffer  $\mathcal{B}$  is also initialized.

for  $t$  in range (1, T):

Select an Action with exploration noise  $a \sim \pi_\phi(s) + \varepsilon, \varepsilon \sim N(0, \sigma)$ .

Watch the reward  $r$  and new state  $s'$ .

Save the transition values  $(s, r, a, s')$  in the replay buffer.

Pick up  $N$  random transitions  $(s, r, a, s')$  from Replay Buffer

$$\tilde{a} \sim \pi_{\phi'}(s) + \varepsilon, \varepsilon \sim \text{clip}(N(0, \sigma), -c, c)$$

$$y \leftarrow r + \gamma(\min_{i=1,2} Q_{\theta_i}(s', \tilde{a}))$$

Update the critics

$$\theta_i \leftarrow \arg \min_{\theta_i} N^{-1} \sum (y - Q_{\theta_i}(s, a))^2$$

if  $t \bmod d$ :

update  $\phi$  using the Deterministic Policy Gradient

$$\nabla_{\phi} J(\phi) = N^{-1} \sum \nabla_a Q_{\theta_i}(s, a) | a = \pi_{\phi}(s) \nabla_{\phi} \pi_{\phi}(s)$$

Update the target networks

$$\theta'_i \leftarrow \tau \theta_i + (1 - \tau) \theta'_i$$

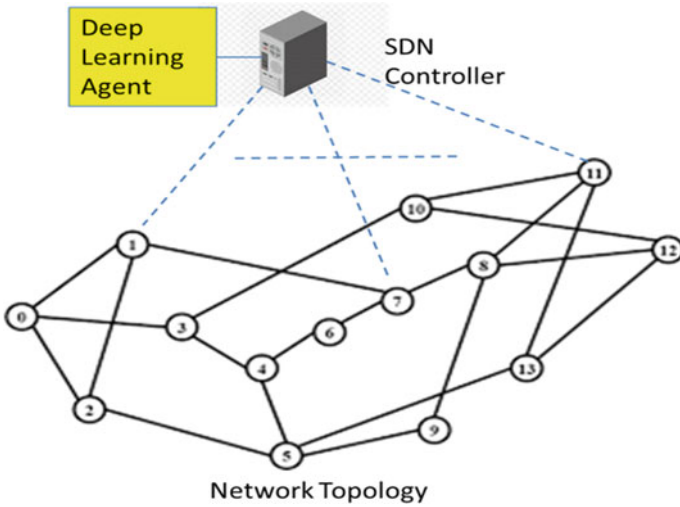
$$\phi' \leftarrow \tau \phi + (1 - \tau) \phi'$$

## 4 Experiments and Results

The experiments were carried out using the Omnet++ simulator which is a discrete event simulator written in C++ and also provides support for Python. The hardware environment consisted of an  $8 \times$  NVIDIA A100 System with 40 GB GPUs (5 GB GPU Memory allocated for this setup). The network topology simulated using Omnet++ was the standard 14-node NSFNet topology with 21 full duplex links as shown in Fig. 1.

The nodes were simple forwarding switches connected to a central SDN controller. The routing decisions were taken by the SDN controller using the OpenFlow control protocol. The central controller application for routing was an agent based on reinforcement learning (RL agent) that controlled the routing entries on all switches. Two versions of RL agents were implemented using TensorFlow libraries in Python. The first version was based on the DDPG algorithm and the second version was based on the TD3 algorithm (Table 1).

A traffic matrix was created for testing the performance with 1000 different traffic configurations. To check the performance of the RL, 100,000 random routing



**Fig. 1** Deep learning agent in SDN network (NSFNet topology)

**Table 1** Parameters used in TD3 algorithm

| Parameter                  | Value  |
|----------------------------|--------|
| Number of episodes (epoch) | 1000   |
| Number of epochs           | 100    |
| Batch size                 | 32     |
| Replay buffer              | 1600   |
| Discount factor            | 0.99   |
| Actor learning rate        | 0.0001 |
| Critic learning rate       | 0.001  |

configurations were used where all nodes were reachable. The same set of routing configurations was used for all the traffic configurations (Fig. 2).

Latency is an important criterion in deciding the QoS as well as congestion. The target is to minimize latency, so negative latency was chosen as the reward function which had to be maximized by the RL agents.

The performance results obtained for the models used are shown in Figs. 3 and 4. Figure 3 compares the latency in the network as the training progresses. It can be seen that beyond 50 epochs, the latency is higher in the case of DDPG compared to TD3. The trend is consistent as the training progresses. This demonstrates the effectiveness of the TD3 algorithm in learning the SDN routing with minimal delay as compared to DDPG algorithm.

Figure 4 shows the runtime performance of the agents after the training is completed. Again, it can be seen that the performance of TD3 is better as compared to DDPG.

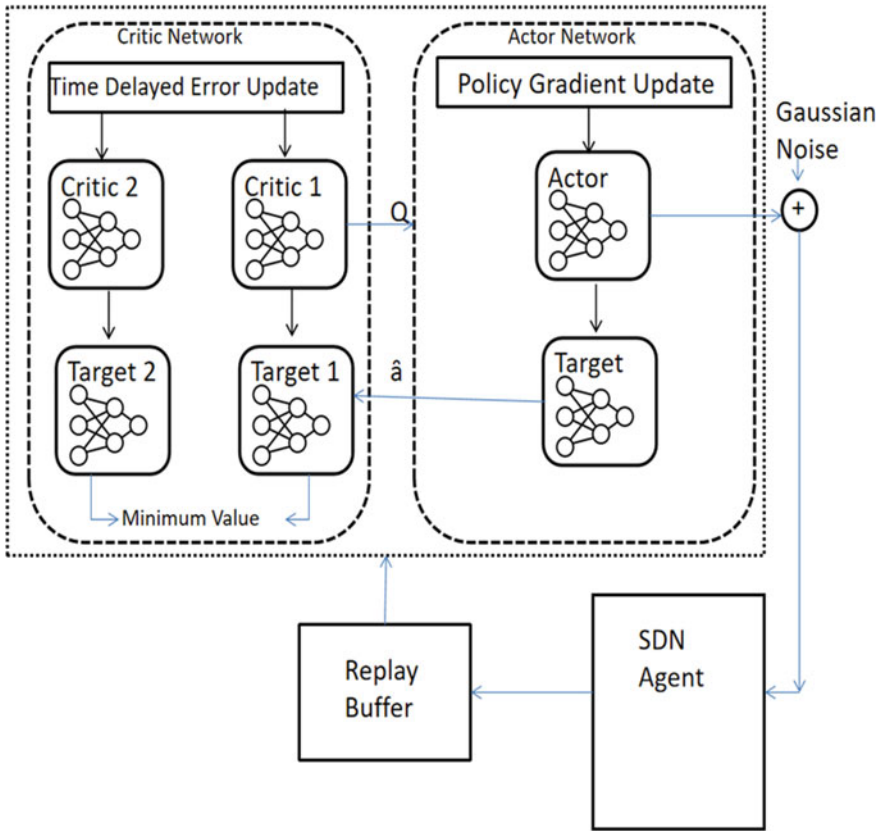


Fig. 2 Block diagram of TD3 RL agent

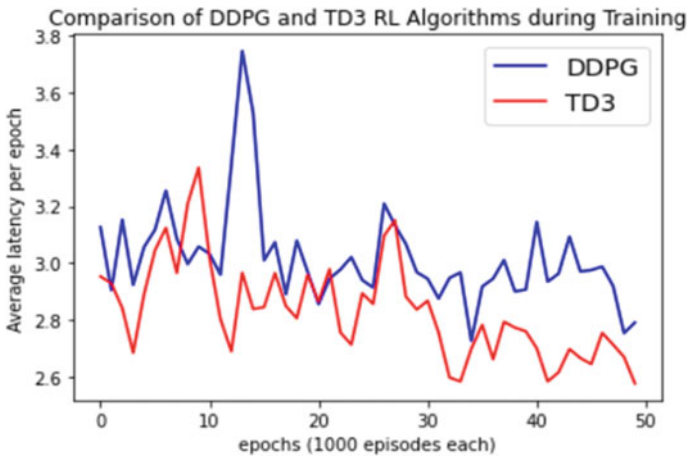
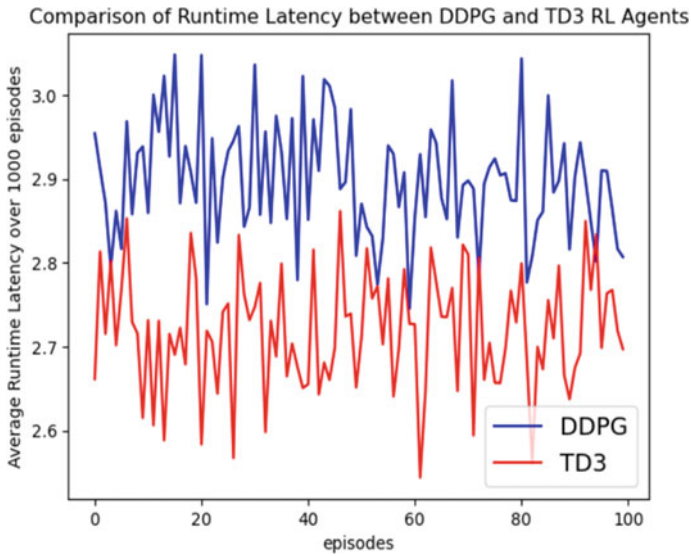


Fig. 3 Comparison of training of DDPG and TD3 RL agents



**Fig. 4** Runtime performance comparison of DDPG and TD3 RL agents

## 5 Conclusion and Future Directions

As demonstrated through the simulation results, TD3 is more effective and efficient in learning the SDN routing in 5G network as compared to DDPG and reduces the overhead of a routing protocol in the network. It is therefore preferable to use an RL agent based on TD3 for SDN routing in 5G networks.

This study has focused on static network topologies, where learning takes place in a fixed network environment. In case of any changes in the topology, the training may need to be repeated. A subject for future study is to explore transfer learning for using the current models even in case of any changes in the network topology.

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# Optimization of Cloud Migration Parameters Using Novel Linear Programming Technique



Shahbaz Afzal, Abhishek Thakur, and Pankaj Singh

**Abstract** The work presents a linear programming-based transportation model approach known as improved modified distribution load balancing algorithm (IMDLBA) to enhance the migration parameters. IMDLBA is a part of reactive load balancing mechanism that relies on the process of migration to deal with workload imbalances across the virtual resources. The important migration parameters considered in this work are migration cost, degree of balance, number of task migrations, and number of machines required for migration. The model has been reviewed with respect to existing meta-heuristics—improved weighted round robin (IWRR), honey bee behavior load balancing (HBB-LB), dynamic load balancing (DLB), and HDLB algorithms, in terms of above cited parameters which come under the class of quality of service (QoS) metrics. Experimental analysis and evaluations from IMDLB algorithm revealed the significant reduction in migration cost and improvement in balance factor—a metric that define the degree of balance if VMs. A balance factor of around 31% has been enhanced compared to the existing methods. The IMDLB algorithm also works by performing one time migration on a given set of tasks. The IMDLB algorithm reduces the number of task migrations by 28.5, 51.25, 58.33, 75.16, and 75.19% with reference to IWRR (time-shared), IWRR (space-shared), HBB-LB, DLB, and HDLB respectively. Further the minimum number of machine combinations required for performing load balancing is also achieved. The research article takes into consideration five UN sustainable development goals namely SDG7, SDG 8, SDG 9, SDG 11, and SDG 12.

**Keywords** Cloud computing · Virtual machines · Migration process · Load balancing · Migration parameters · Quality of service · Scheduling · Optimization · Improved modified distribution load balancing algorithm · Transportation model

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# 1 Introduction

The present day Information Technology evolved from standalone mainframe computers to personal computers, ascended through the steps of network, and Internet computing (cluster, grid, and utility computing). Cloud computing occupies top level in the stack of computing paradigm hierarchy [1]. The computing paradigm alignment from centralized to de-centralized to distributed computing with the essentials of ubiquity, utility, and commercialization being introduced in its later stages as depicted in Fig. 1. The advancements in hardware technologies featuring Moore’s law flooded the electronics market with different computing devices. Meantime the breakthrough in Internet and web technologies with peaking data speeds has gained much attention toward data communications. Cloud computing is a means of sharing and accessing virtualized computing resources through Internet governed by certain service level agreements and business models. NIST originally [2] described three service delivery models and four deployments models for cloud computing, but with the period of time both the models evolved into others types.

As a massive distributed computing platform, cloud computing deliver and manage data, information, applications, web services, IT infrastructure, and other services on a global scale over Internet. This makes it good choice to handle high velocity and voluminous data. Infrastructure clouds and infrastructure as a service (IaaS) deliver IT resources in form of virtualized containers known as virtual machines (VM). These containers act like independent machines with their own

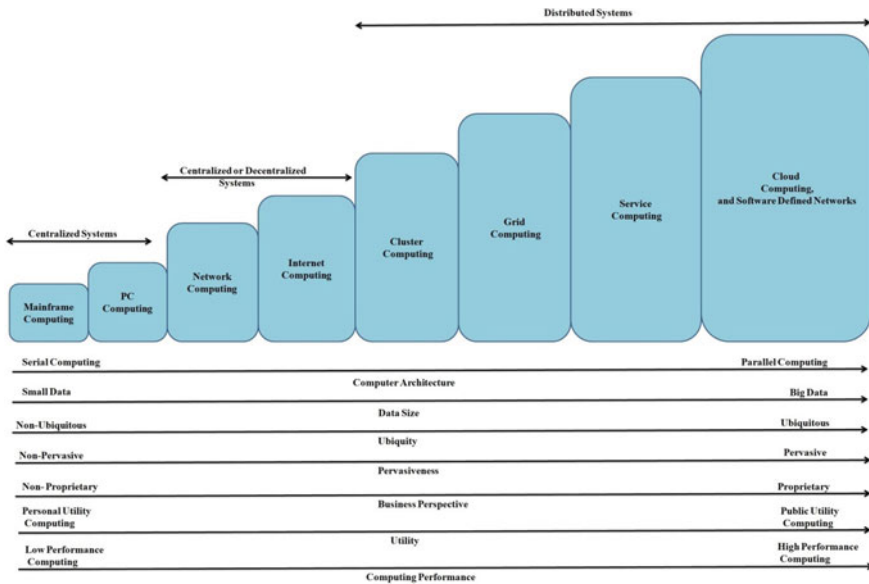


Fig. 1 Computing paradigms



resource sets and that can be created and destroyed anytime depending what a situation demands. A virtual machine is the basic building block of infrastructure cloud environment that can be shared among multiple users one at a time in a multi-tenancy manner.

The evolution of cloud computing as a business enabled computing platform has paved the way for global online utility mode of computing that transformed the world of ‘computing driven business’ into a customizable and pervasive computing. With its powerful computing capability and versatile service delivery models, cloud computing can practically serve all types of user demands in the form of web services irrespective of user time or location using some business model. The rapid shift toward cloud computing by individual and corporate businesses, government sector, academia, online businesses, research and development, finance, banking and insurance, healthcare, entertainment, and much more, with the services being supported by few IT giants have put a tremendous pressure on service providers to deal with different aspects of workload and resource management.

Workload imbalances across the provider datacenters is a critical issue that adversely affect the performance of the cloud systems due to the implications in QoS metrics. In view of the user time zone, geo-location and geospatial distribution, the CSP face the problem of when to scale up and scale down the resources, resulting in imbalanced datacenters. To counter the negative effects of load imbalances the cloud datacenters are equipped with load balancing features in the scheduling algorithm that ensure the fair dissemination of user tasks to suitable resources. However, the existing load balancing approaches being reactive in nature rely heavily on migration process involving the movement of tasks or VM’s. While these approaches suffer from inherent limitations where number of VMs required for migration process, number of task migrations, migration cost, and migration time has to be evaluated.

The demand for data (Data as a service) [3] has increased by huge magnitudes progressing with time. The recent outbreak of Corona virus pandemic (Covid-19) across the globe witnessed a tremendous shift of workforce to online mode primarily backed by cloud computing and its services [4]. This also caused the heavy pressure on cloud datacenters. Also because of the unpredictable nature of user tasks, time zone of a cloud user and geospatial location of cloud user that leaves behind the unbalanced datacenters. However, the blame cannot be put on cloud users as and when they can access the service from a cloud provider, it is solely the responsibility of cloud provider to manage its infrastructure and deliver guaranteed services to its customers.

It is the VM that is actually executing the user jobs inside cloud datacenters or on a higher level the physical machines that contain these virtual machines. So, when a datacenter gets overloaded or under loaded, it is actually VM or PM facing this situation. The question is why it happens and who is responsible for this cause. The answer lies in the scheduling and allocation policies implemented in cloud datacenters. The scheduling and resource allocation algorithm that runs inside a datacenter is the real cause behind this scenario. The inefficient scheduling and allocation policies give birth to workload unbalanced VMs that are over provisioned or under provisioned.

Unbalanced nodes in cloud datacenters has become a challenging factor for service providers in delivering performance-based services. Unbalanced nodes gives rise to resources wastages, low quality of service, unexpected completion times, energy wastages, degraded performance, service level violations, reduced throughput, and economical losses [5]. To deal with this problem in cloud datacenter, load balancing policies play an essential role in resource management of service provider datacenters. The varying nature of cloud user tasks in terms of resource requirements in addition to the NP hardness property of scheduling and resource allocation strategies emphasis the need to implement a balanced traffic management policy at the CSP datacenters.

Load balancing or workload distribution within the cloud datacenters is a two level process performed by level 2 and level 1 load balancers at VM level and PM level, respectively. Figure 2 shows the two level load balancing model in cloud computing. Most of the load balancing algorithms focuses on VM level load balancing, because when all the VMs of a particular physical machine are balanced, the physical machine itself goes into balanced state. In case of reactive approaches, the load balancing at VM level is performed by either movement of VM or tasks but not both simultaneously. In VM load balancing [6, 7], the uneven VMs are drifted across the physical machines, while in task load balancing [8], the surplus tasks are moved across the unbalanced VMs. Now, the load balancing in infrastructure cloud computing is defined as the process of distributing (in proactive load balancing) or redistributing (reactive approaches) the user tasks and datacenter resources among virtual machines so as to avert load unbalancing situation and to guarantee the desired service quality to users at each point of time without compromising the quality of service at both the sides, i.e., user side and provider side.

Because of the serious consequences of load unbalancing phenomena on service delivery quality which may include low throughput, high response time, delayed execution, high makespan, starvation, deadlock, energy wastages, resource wastages, and high SLVs. Apart from this the provider will also suffer from economic losses. Therefore there arises a need to adapt load balancing strategy at datacenter to avoid this grim situation.

IMDLB algorithm is a proposed load balancing algorithm where the load balancing is performed through task migration. The work presents a reactive-based load balancing approach that optimizes some of the migration related metrics to improve the overall performance and service quality of the cloud systems.

## ***1.1 Objectives of the Study***

The following sub section highlights some of the research contributions accomplished in this work:

- I. An ideal degree of balance is achieved among the virtual machines chosen for task migration.

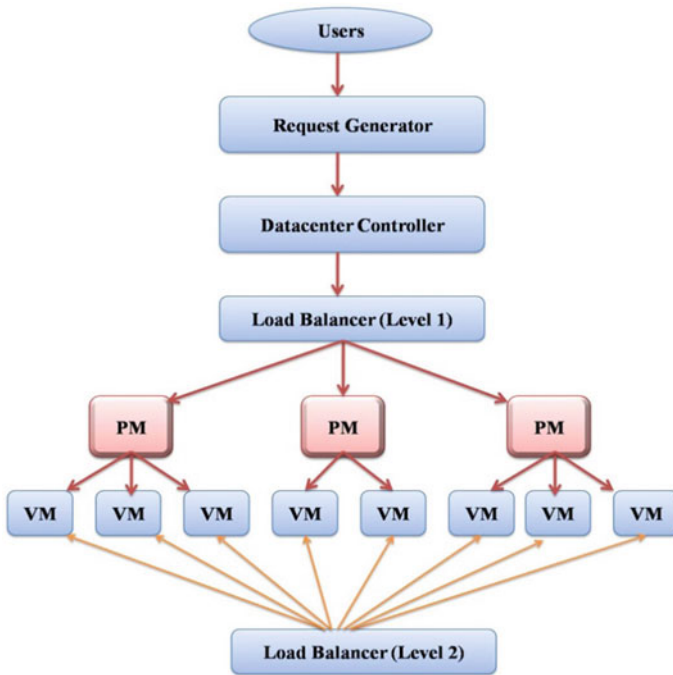


Fig. 2 Two level cloud load balancing model [5]

- II. The IMDLB algorithm selects the unbalanced machines in such a way that the number of migrations for tasks takes place only once and is the global minimal optimal value for migration process. With one time migration, the migration time also reduces drastically. However in the existing approaches the minimum number of task migrations has not been achieved.
- III. The IMDLB algorithm balances the load in unbalanced virtual machines by choosing the minimum number of virtual machines for performing task migration among them. As a result the IMDLB algorithm yields the optimal setting of virtual machine combinations for performing load balancing against a complex range of machine combinations. It is because of the optimal setting of machines that the proposed algorithm selects, the number of migrations is achieved one.

### 1.2 Application of the Study

IMDLB algorithm can prove to be an effective optimization technique in cloud computing for reactive-based load balancing process that heavily rely on migration policies to optimize different migration process parameters like migration cost, migration time, degree of balance, number of migrations (VM or task), number of

machines required for migration process. IMDLB algorithm can also find application in network load balancing to balance the network traffic among different nodes. Utilizing IMDLB algorithm as a reference level can help researchers in developing efficient reactive-based load balancing algorithms and to deal with migration process effectively in cloud computing. However, IMDLB algorithm cannot help in evaluating the cloud computing performance metrics to a great extent but is suitable for migration parameters only.

The rest of the paper is organized as follows. Section 2 discusses related works, Sect. 3 presents a theoretical background on migration enabled load balancing process in cloud computing. The methodology of IMDLB algorithm is explained in Sect. 4, while results are discussed in Sect. 5. Section 6 highlights some of the weaknesses in the IMDLB algorithm. Section 7 concludes our work and points out some future directions.

## 2 Related Works

The fundamental aim of introducing the scheduling and allocation policies in any computing environment is to provide an efficient quality of service while dealing with task-resource problem. Using the scheduling and allocation techniques, task are first scheduled and then allocated on the relevant resources for execution. Scheduling and allocation policies are sufficient to handle the workloads of lower order in simple systems; however for complex systems where the workloads are of higher orders, scheduling and allocation policies are not self-sufficient to handle the workload. In the cloud computing systems where the data centers have to handle millions of user tasks, there is a prerequisite of load balancing assisted scheduling and allocation. NP hardness property exist both in scheduling and load balancing policies in cloud computing due to some controlled and uncontrolled factors.

A survey on load balancing showed that load balancing approaches broadly fall under proactive and reactive approaches [5, 9]. The study further illustrated that proactive approaches are best when compared to reactive approaches [5]. This is because the reactive approaches solely rely on migration process. A study showed that most of load balancing approaches falls under the category of reactive approaches where migration process is necessary in achieving the overall balance of the data-center. Implementing the reactive approaches at datacenter demands improving some of the additional metrics which are involved in reactive process like migration cost, migration time, number of migrations required for load balancing, number of VMs chosen for migration process, etc. Migration cost has been minimized using IMDLB algorithm by Shahbaz and Kavitha [10]. A number of load balancing techniques have been proposed to minimize the migration time.

Workload imbalance is one of the serious concerns faced in cloud datacenters that demands strong attention while dealing with QoS, SLA, energy and resource utilizations. In response to this a lot of load balancing approaches [11–15] have been suggested by researchers with the course of time to deal with load unbalancing

situations in order to preserve QoS along with different qualitative and quantitative metrics from both user and provider perspective. Most of the load balancing algorithms falls under reactive approaches which depend upon the migration process. However, majority of the load balancing algorithm are dynamic in nature and multi-objective based that try to enhance more than one objective function at a time [16]. One of the fundamental limitations of reactive-based approaches is that apart from improving the different QoS metrics, the algorithm need to enhance migration associated metrics. As of today there exists no ideal load balancing technique which optimizes all the QoS metrics in a single algorithm because of the different dependencies among the metrics and consequently if a particular metric is enhanced some of its allied metric will diminish if there existed an inverse relation between the two.

Chitra Devi and Uthrairaj [17] suggested a hybrid reactive-based load balancing approach called as improved weighted round robin (IWRR) algorithm to schedule non-preemptive dependent tasks in a cloud system. The advantage of IWRR algorithm is that it schedule tasks to the most appropriate VMs. This allows fair distribution of workload among cloud resources with minimal load imbalances. The overall task completion time and number of task migrations are the two performance metrics evaluated using this method. However, the authors did not consider other migration parameters like migration cost, migration time, degree of balance and number of machines required for migration. Dinesh Babu and Venkata Krishna [18] modeled the foraging behavior of honey bees and proposed a dynamic reactive-based load balancing approach to deal with task scheduling and workload balancing in cloud computing for non-preemptive independent tasks. The QoS metrics assessed using HB-LBB algorithm are user priorities, execution time, response time, makespan time, degree of balance, number of task migrations, and number of migrated tasks. One of the limitations of this work is that some prominent migration metrics have not been evaluated like migration time, migration cost, and number of machines required for migration. One more drawback of this work is that it considers only independent tasks while a cloud computing system can have mixture of tasks. Also, the datasets used for experimental set up are small in magnitude. Jena et al. [19] implemented a dynamic load balancing strategy in cloud computing environment based on the hybridization of two meta-heuristic approaches namely modified PSO and improved Q-learning algorithm. Load balancing is achieved by reassigning the workload among appropriate virtual machines. The work aims at optimizing different cloud performance metrics like makespan, energy consumption, degree of balance, throughput and number of migrated tasks. Despite, the work follows the migration process as the prime principle of workload balancing among nodes, the work does not studied the migration parameters except number of migrated tasks. Also, the study has been conducted on independent tasks only. Keng et al. [20] proposed a dynamic VM scheduling approach using the joint operation of two meta-heuristic algorithms namely ACO and PSO to balance the load among cloud servers. The work undertakes makespan and degree of balance as the two important metrics for evaluation. Like previous studies, this work also suffers for not computing migration parameters. Adhikari and Tarachand [21] developed a heuristic load balancing algorithm for IaaS clouds with heterogeneous VMs where tasks are mapped to suitable VMs by finding

the best VM configurations. The main aim of the paper is to improve the performance metrics in terms of waiting time, makespan, and resource utilization. Gamal et al. [22] developed a hybrid optimization technique governed by the concepts of osmotic behavior from osmotic computing, and hybrid Artificial Bee colony and ACO from bio-inspired computing to tackle the load unbalancing problem in infrastructure cloud computing. Load balancing is performed by live migration of VMs among physical servers by mimicking the osmotic computing. The key performance indicators evaluated in the work are energy consumption, SLA violations, and number of VM migrations. Sommer et al. [9] proposed a load balancing in cloud computing through proactive live VM migration policy. Load balancing is achieved by modeling the time-series analysis of VMs with the help of prediction and ensemble techniques to determine the future state of a VM. The work guarantees the performance of the cloud system by enhancing SLA violations, number of VM migrations, and energy consumption as the main QoS parameters.

Abdelmabud et al. conducted a survey on QoS approaches in cloud computing where it was found that majority of resource management-based QoS approaches have been implemented at IaaS (48%), SaaS (36%), CSP (10%), CSC, and PaaS each with 3%. Moreover, in IaaS the thrust areas of QoS optimization falls in resource management and performance monitoring. Resource management in infrastructure cloud computing is an assignment problem which deals with the task—VM scheduling and allocation, such that QoS levels are maintained and SLAs are not violated [15, 23–25].

### **3 Migration Enabled Load Balancing in Cloud Computing—Theoretical Background**

The current state of the art load balancing algorithms in cloud computing are broadly classified into reactive and proactive-based approaches, that fall at the top level in the hierarchy when it comes to the classification of load balancing approaches [5]. Reactive mechanisms of load balancing in cloud computing operates under the working principles of migration process. Migration process is a key phenomenon while dealing with workload distribution for a reactive approach in infrastructure cloud computing. Based on the type of entity being migrated while performing load balancing, migration is of two kinds: task migration also called as workload migration and VM migration. Further on the basis of state behavior as how the migration process is invoked, migration is of two types: live migration or online migration, and offline migration [23]. To be more precise, it is concluded that migration enabled load balancing is a characteristic of reactive approaches. Whether a reactive approach is a static, dynamic or hybrid, the algorithms of this variant suffer from a serious limitation of improving migration parameters while dealing with QoS parameters. In a migration enabled load balancing, apart from enhancing cloud QoS metrics, the algorithm should be able to perform well with migration related metrics also.

However, at no point of time, the QoS and migration parameters will go hand in hand and there is an urgency to develop separate QoS-based load balancing algorithm and migration related load balancing algorithm or hybrid of these two. Some of the prominent migration parameters which need to be optimized while performing load balancing are degree of balance, migration cost, migration time, number of migrations, and number of machines used for migration process.

A lot of migration enabled reactive approaches have been suggested in the literature for workload balancing in cloud computing under the banner of heuristic, meta-heuristic and optimization techniques. The literature for migration enabled load balancing approaches features the algorithms from broad spectrum of classical, mathematical derived, evolutionary, stochastic, bio-inspired and, nature inspired techniques. From this vast spectrum of available algorithms, a standalone algorithm can never achieve the job of improving parameters on both perspectives. This forces the researchers to consider the optimization of migration parameters independently. A standalone algorithm or a hybrid from above mentioned techniques can help in fine tuning the QoS parameters but cannot succeed in improving the migration parameters. So, it is essential to develop and consider a standalone algorithm for migration process and integrate it with workload distribution algorithm for effective treatment to load unbalancing problem for migration enabled approaches. Some of the insights from load balancing policies which prove the essence of developing a standalone migration enabled load balancing algorithm to evaluate migration parameters:

1. A load balancing algorithm which cannot provide an optimal degree of balance has no practical significance.
2. A load balancing policy which incurs huge migration cost is not a desired option for a cloud provider.
3. A load balancing algorithm which takes longer times to perform migration cannot be considered a practical approach.
4. A load balancing strategy which performs repeated and frequent migration of entities among virtual machines or physical servers is not a good candidate for a service provider.
5. A load balancing approach which takes into account a number of machines for migration process is also not an ideal one for service provider.

With this study in mind, the authors proposed an operation research borrowed concept called as modified distribution method of transportation model to deal with the migration process and to enhance the migration enabled process parameters. The authors experimentally validated the effectiveness of IMDLB algorithm in mitigating the migration process parameters.

## **4 Migration Enabled Load Balancing in Infrastructure Cloud Computing Using Transportation Model-Based IMDLBA Approach**

Transportation model is a well-known linear integer problem in operation research that deals with the shipment of physical entities from many sources to many destinations in such a way that the cost of transportation should be minimal optimal [24]. Load balancing performed through migration process can be viewed as a transportation problem with associated supply and demand. Figure 3 shows the transportation model-based migration enabled load balancing algorithm in cloud computing. Generally load balancing in cloud computing performed through reactive methodology involves the following activities.

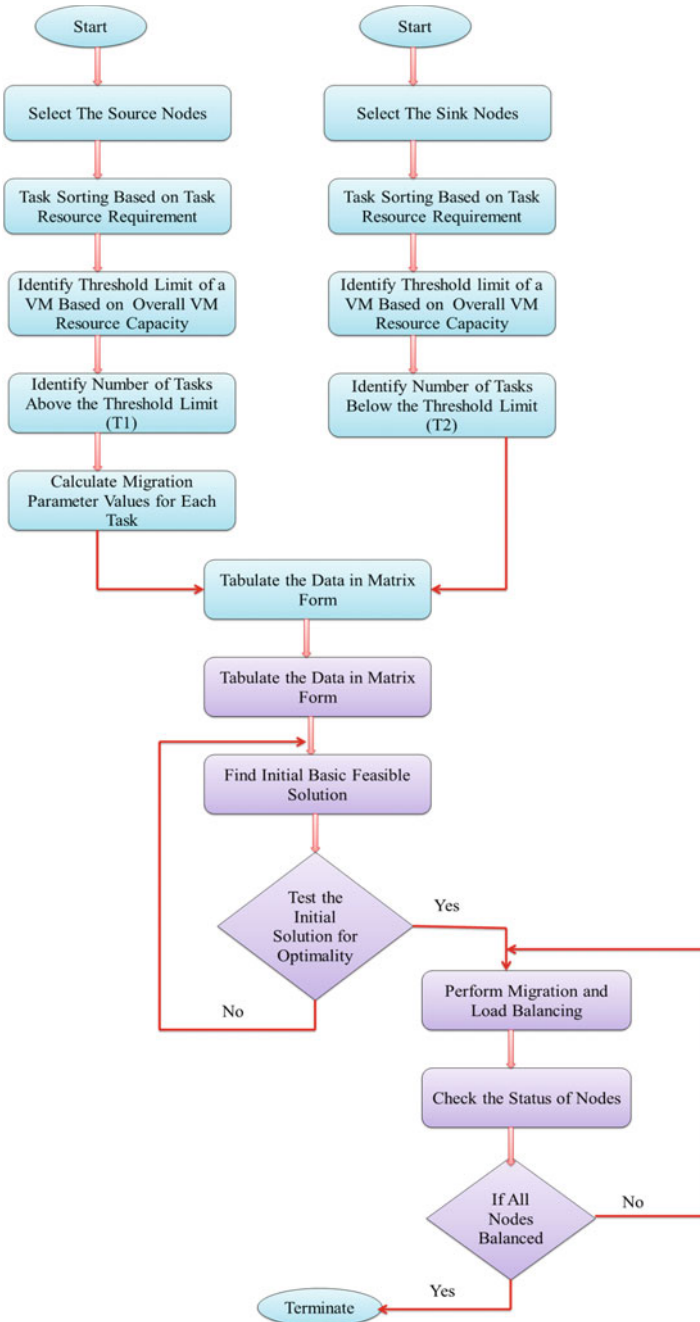
### ***4.1 Identification of Source and Sink Nodes***

This phase selects the unbalanced virtual machines for migration process where tasks have to be migrated from over provisioned machines (called as Source Nodes) to the under provisioned machines (called as destination nodes or sink nodes) as shown in Fig. 3. Load balancing takes place due to the movement of tasks from overloaded machines to under loaded machines until all the nodes get uniform distribution of workload. The load balancing algorithm may select source and destination nodes any number of times, but the efficient load balancing algorithm is one which chooses a given VM for least number of times during migration. This phase is also called as resource discovery phase where the unutilized resources are discovered for future execution of tasks. Based on some threshold limit value, the nodes are identified as being balanced, under loaded, or overloaded.

### ***4.2 Selection of Tasks from Source Node***

Once the source and destination nodes are identified and chosen, the next step is the selection of tasks planned for migration process from source nodes. It is necessary to determine the resource requirements of these tasks that will specify whether the destination node can accommodate all or few of these tasks and which later on are going to be scheduled on the destination nodes. A good load balancing algorithm selects minimum number of virtual machines for minimum task migrations during migration process. Tasks are sorted in each virtual machine to find the deviation from a higher threshold level or a lower threshold level. A simple sorting technique can be applied to perform sorting operation on the basis of task resource information which is handled by the datacenter controller. Task sorting is performed in both over





**Fig. 3** Transportation model-based IMDLBA with migration enabled load balancing in cloud computing

utilized and underutilized nodes to find out the number of tasks from the respective threshold levels as presented in Fig. 3.

The next step is to estimate the migration parameter values from all source nodes to all destination nodes and tabulating the data. Before performing the actual migration process, the tabulated data is analyzed and processed to find the desirable candidate sets for task migration. This is achieved by enforcing two linear programming techniques. The first technique deals with the evaluation of initial basic feasible solution which is achieved by Vogel's approximation method (VAM). The next phase is to test the optimality of initial basic feasible solution using modified distribution (MoDi) method. After the optimal solution of tabulated data is obtained, the information regarding the best candidate set is provided to the load balancing algorithm in datacenter controller. The load balancing algorithm performs the migration process among the given nodes until the status of each node is set to be balanced.

### ***4.3 Task Rescheduling, Migration, and Resource Reallocation***

Once the tasks are selected and their resource requirements are identified, the surplus tasks have to be rescheduled on unallocated resources of destination machines based on some scheduling principle. After task rescheduling, the selected tasks are moved from source virtual machine to destination virtual machine. This movement of tasks from source node to destination node is known as task migration. During the task migration process the unallocated resources of destination node(s) are allocated to rescheduled tasks and the process continues until the source and destination nodes reach the balanced state.

### ***4.4 Optimization Using Modified Distribution Algorithm***

From a set of unbalanced VMs, let there be ' $\alpha$ ' number of over utilized VMs,  $VM_1, VM_2, \dots, VM_\alpha$  as source nodes with  $\lambda_i$  units of supplies to be distributed among ' $\beta$ ' number of underutilized nodes  $VM_1, VM_2, \dots, VM_\beta$  with  $\mu_j$  units of demand.

$$i = 1, 2, \dots, \alpha$$

$$j = 1, 2, \dots, \beta$$

If  $\eta_{ij}$  represent the number of tasks to be migrated from over utilized VM ' $i$ ' to underutilized VM ' $j$ ' with an average migration cost of  $\theta_{ij}$  per task, satisfying supply and demand.

The objective function can be expressed as;

$$\text{Minimize (total migration cost) } Z = \sum_{i=1}^{\alpha} \sum_{j=1}^{\beta} \theta_{ij} \eta_{ij} \quad (1)$$

Subject to constraints

$$\sum_{j=1}^{\alpha} \theta_{ij} = \lambda_i \text{ (supply constraints)} \quad (2)$$

$$\sum_{j=1}^{\alpha} \eta_{ij} = \mu_i \text{ (demand constraints)} \quad (3)$$

$$\eta_{ij} \geq 0 \text{ for all } i \text{ and } j$$

Figure 4 shows the working principle of modified distribution method and forms an important component of IMDLB algorithm shown in Fig. 3. The modified distribution algorithm provides the best candidate set of VMs satisfying supply and demand constraints in terms of tasks.

## 5 Results and Discussion

The following computational results are obtained using IMDLB algorithm that is shown in Figs. 3 and 4.

### 5.1 Task Migration Cost

Task migration cost may be defined as the cost incurred by a cloud provider while migrating the tasks from over utilized VMs to underutilized VMs and should be practically low. From an in-depth survey conducted on reactive load balancing algorithms, the authors could not find the evaluation of migration cost in the existing literature. This work presents the minimum migration cost achieved through the implementation of IMDLB algorithm. Figure 5 shows the comparison of migration cost achieved through using three initial basic feasible solutions namely North-West corner method, Least-Cost method, and Vogel's approximation method (VAM) with the optimal solution by IMDL algorithm.

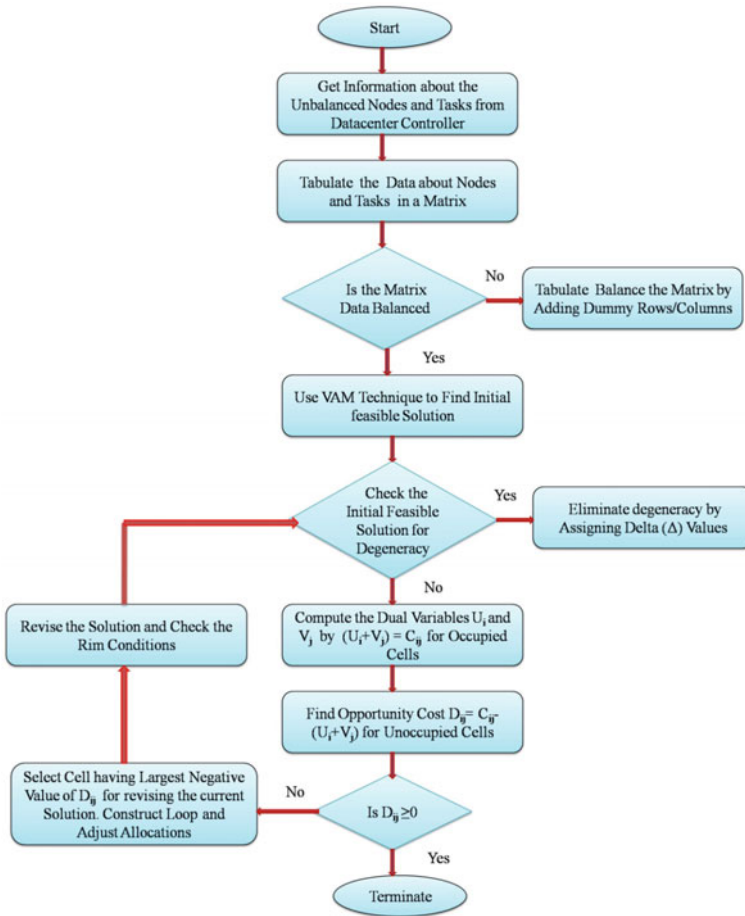


Fig. 4 A modified distribution algorithm to find optimal migration cost

### 5.2 Degree of Balance

Degree of balance in this work refers to the number of unbalanced machines balanced after performing migration enabled load balancing. IMDLB algorithm not only selects the best candidate VM set for migration but also aims to fulfill supply and demand at source and destination VMs, respectively. As a result the IMDLB algorithm ensures the overall balancing of over provisioned and under provisioned VMs. Once the task migration is performed, all the VMs that have been selected for migration process by IMDLB algorithm establish a balanced state. The degree of balance of IMDLB algorithm for a migration process involving ‘*m*’ over provisioned VMs and ‘*n*’ under provisioned VMs is calculated as:

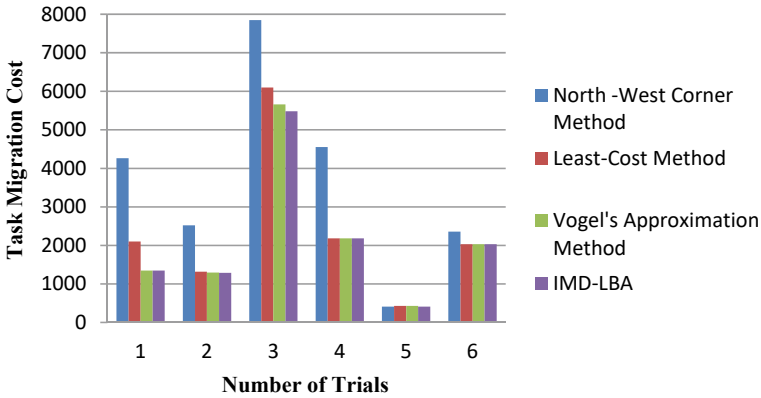


Fig. 5 Migration cost using initial feasible solution and optimal solution

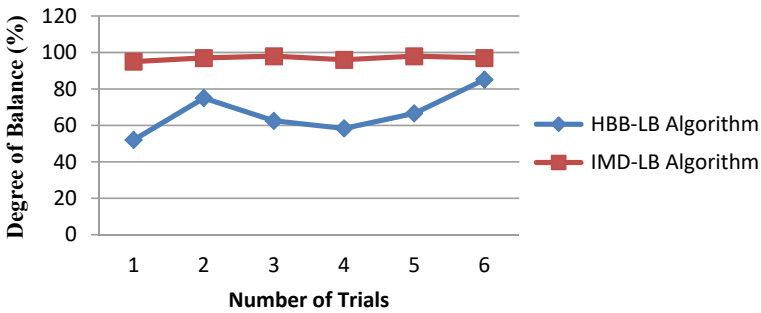


Fig. 6 Comparison of degree of balance between HBB-LB and IMDLB

$$\text{Degree of Balance} = m + n \tag{4}$$

In terms of percentage contribution toward degree of balance, IMDLB algorithm ideally provides 100% degree of balance among unbalanced machines. Figure 6 illustrates the comparison between the Improved Modified Distribution method (IMDLB) and the Honey bee behavior inspired load balancing algorithm (HBB-LB) and concludes that the proposed model is 31.2% more efficient than the existing model. The HBB-LB algorithm is efficient than the FCFS, WRR, and DLB methods so, there is no need to compare our work with these models.

### 5.3 Number of VMs Required for Migration

An ideal load balancing algorithm should perform the task migration with minimum number of VMs and IMDLB algorithm is best to operate under these conditions. For

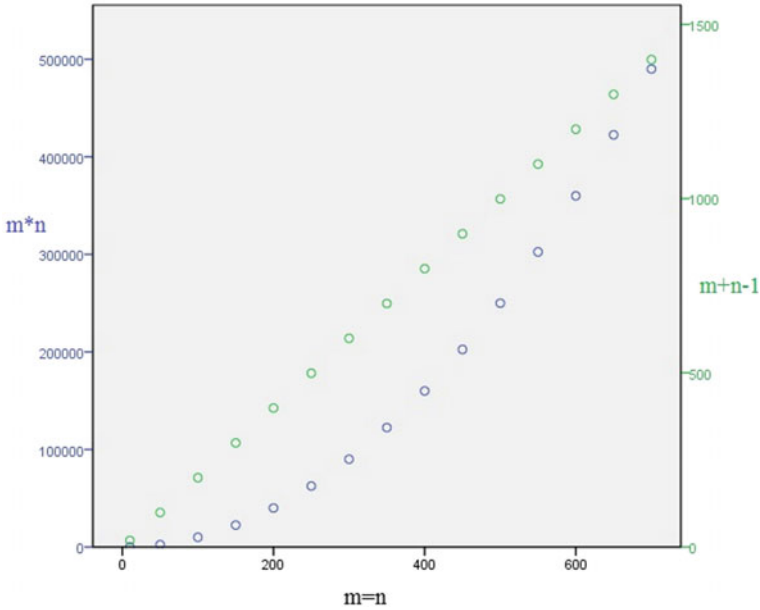


Fig. 7 Overall VM combinations and minimum VM combinations

‘ $m$ ’ number of over loaded VMs and ‘ $n$ ’ number of under loaded VMs, there exists  $m * n$  possible VM combinations to perform task migration, but using the IMDLB algorithm, the required VM combinations for migration process is reduced to  $m + n - 1$  as shown in Fig. 7.

### 5.4 Number of Migrated Tasks and Number of Task Migrations

Number of migrated tasks and number of task migrations are two different migration parameters that need to be calculated in a migration load balancing approach. Numbers of migrated tasks represent how many tasks are transported from source VMs to destination VMs. In IMDLB algorithm the number of migrated tasks is equal to the supply units at source VMs. Number of task migrations refers to how many times a particular task is migrated from source to destination VM. This should be usually low. In the existing approaches, tasks are moved among VMS multiple times, however using IMDLB algorithm the task migration is done on one time basis.

Figure 8 depicts that the IMDLB algorithm is 28.5% efficient than IWRR (time-shared) and 51.25% efficient than IWRR (space-shared) respectively based on the number of task migrations. Figure 9 compares the IMDLB with the existing algorithms of HBB-LB, HDLB, and DLB on the basis of number of task migrations

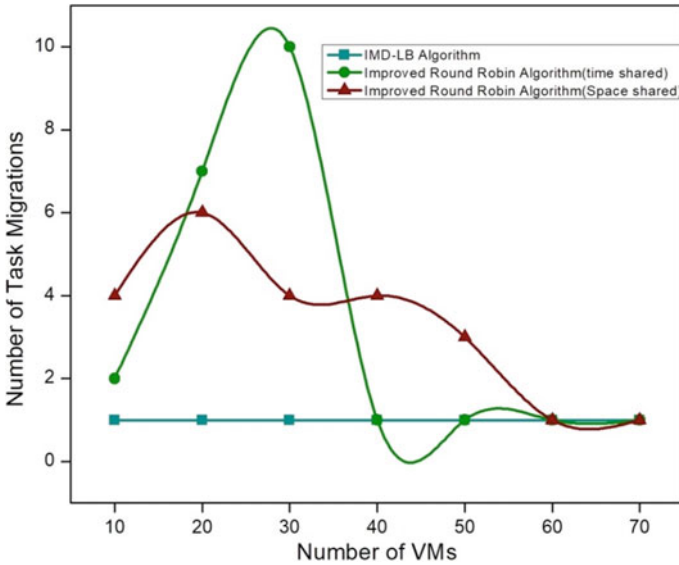


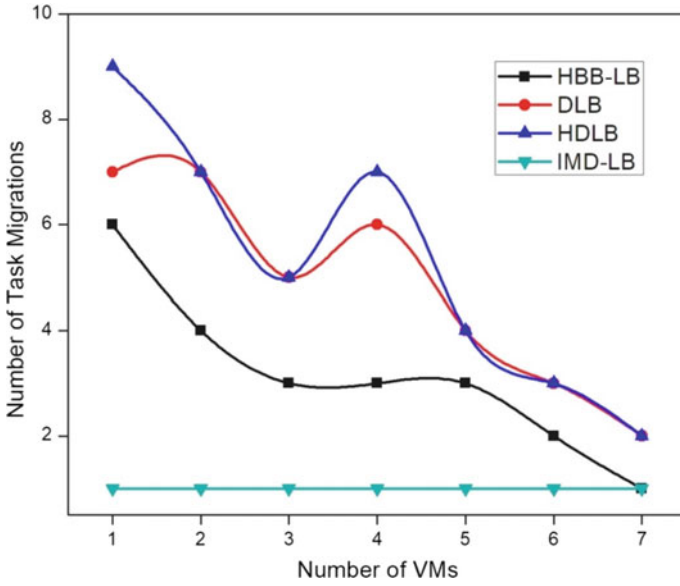
Fig. 8 Comparison of IMDLB algorithm with improved round robin algorithm

vs. number of VMs. The comparative graph in Fig. 9 interprets that IMDLB algorithm is 58.33, 75.16, and 75.95% more efficient than HBB-LB, DLB, and HDLB algorithms respectively on the basis of total number of task migrations vs. number of VMs. Hence the IMDLB algorithm is best in comparison with the existing algorithms in cloud load balancing. Figure 10 shows the comparison of existing algorithms with the proposed algorithm for a set of 10, 20, 30, and 40 respectively tasks on the basis of number of task migrations vs. total number of VMs. algorithm based on the parameters given in the table.

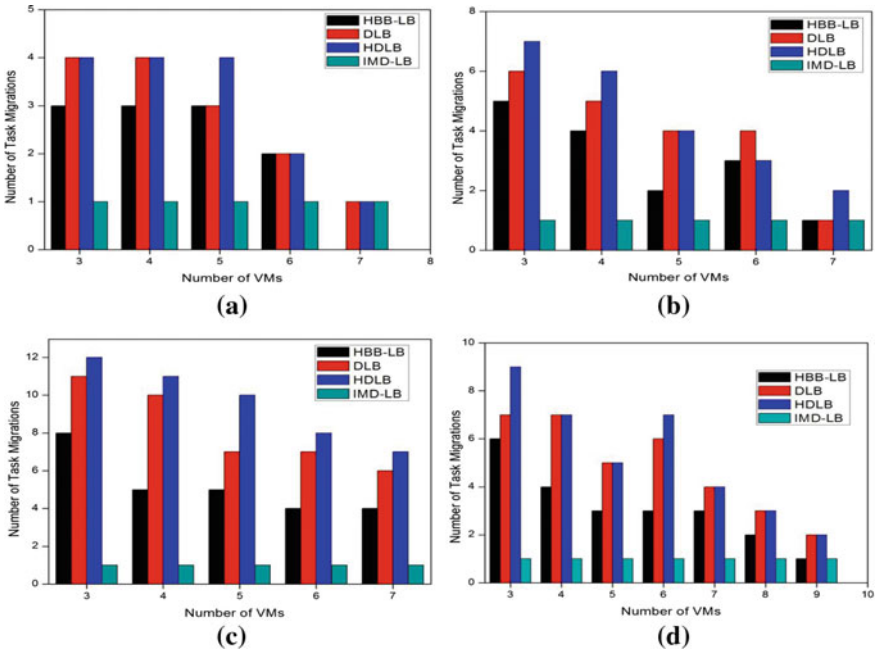
Table 1 represents the comparison between the existing load balancing algorithms with the IMDLB algorithm. Migration cost and minimum number of machine combinations have not been considered so far in the literature. Also, the degree of balance is not considered in WRR and IWRR algorithms.

## 6 Limitation of the Work

The study considers the migration of tasks as the means of performing migration enabled load balancing process in infrastructure cloud computing to evaluate the migration parameters like migration cost, degree of balance, number of tasks migrations, number of migrated tasks, and number of VMs required for migration, except migration time. However the study does not take into account the evaluation of QoS parameters post migration process.



**Fig. 9** Comparison between algorithms (IMDLB, HDLB, DLB, and HBB-LB) based on the number of task migrations



**Fig. 10** Comparison between algorithms (IMDLB, HDLB, DLB, and HBB-LB) based on the number of task



**Table 1** Comparison of existing algorithms based on migration parameters

| Method | Metric         |                |  |                           |
|--------|----------------|----------------|--|---------------------------|
|        | Balance factor | Migration cost | Minimum number of machine combinations | Number of task migrations |
| HB-LBB | Yes            | No             | No                                     | Yes                       |
| DLB    | Yes            | No             | No                                     | Yes                       |
| HDLB   | Yes            | No             | No                                     | Yes                       |
| WRR    | No             | No             | No                                     | Yes                       |
| IWRR   | No             | No             | No                                     | Yes                       |
| IMDLB  | Yes            | Yes            | Yes                                    | Yes                       |

## 7 Conclusion and Future Work

The work presents a transportation model-based IMDLB algorithm to enhance the migration parameters in cloud computing datacenters. The performance analysis showed that IMDLB algorithm is best while dealing with load balancing migration parameters in comparison with the existing migration enabled load balancing approaches. As a part of future work, the IMDLB algorithm will be integrated with any heuristic or meta-heuristic technique to evaluate the QoS-based load balancing parameters in cloud computing.

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# A Novel Approach on Deep Reinforcement Learning for Improved Throughput in Power-Restricted IoT Networks



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**Abstract** The rapid expansion of the Internet of Things (IoT) has stressed the importance of energy-efficient communication protocols, particularly in networks operating under power constraints. This paper presents a unique approach for managing communication in energy-limited IoT networks using a deep reinforcement learning (DRL)-based communication protocol. By integrating Sparse Code Multiple Access (SCMA), Code Division Multiple Access (CDMA) techniques, and the Combined Experience Replay Deep Deterministic Policy Gradient (CER-DDPG) algorithm, we developed a novel protocol to improve the throughput of power-constrained sensors in an IoT network. Through comprehensive simulations, we compared the proposed protocol's performance with benchmark systems like traditional DDPG and stochastic algorithms. The results reveal superior energy efficiency and throughput with the proposed protocol, establishing its potential to significantly enhance the performance of energy-constrained IoT networks.

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**Keywords** Deep reinforcement learning · Energy-constrained IoT networks · Communication protocol · Sparse Code Multiple Access (SCMA) · Combined experience replay deep deterministic policy gradient (CER-DDPG)

## 1 Introduction

The Internet of Things (IoT) has had an impact on numerous industries, including transportation, health care, and others. The Internet of Things (IoT)'s potential to globally connect billions of devices, ranging from simple sensors to sophisticated machinery, is revolutionizing how data is acquired, processed, and utilized for informed decision-making [1]. One of the key aspects impacting the success and efficiency of IoT is the communication protocol used within the network. Protocols for communication are critical, especially with the emergence of Industry 4.0 and the consequent expansion of industrial IoT. Because these networks usually operate under power constraints, they rely largely on sensors to allow communication. Traditional communication methods struggle to manage such energy-constrained devices; therefore, IoT networks function poorly [2, 3].

The Sparse Code Multiple Access (SCMA) and Code Division Multiple Access (CDMA) algorithms were introduced as a critical first step in resolving this issue. These technologies, when combined, have successfully enabled autonomous sensors to communicate effectively over networks. Maintaining optimum throughput and optimizing energy usage are difficult issues even with current solutions. We study how deep reinforcement learning (DRL) might be integrated with these approaches to improve the performance of IoT networks with limited energy resources in response to these difficulties. The primary purpose of our research is to create and implement a one-of-a-kind deep reinforcement learning-based communication protocol based on the combined experience replay deep deterministic policy gradient (CER-DDPG) technique. We are particularly interested in how effectively this protocol boosts the throughput of autonomous, power-restricted sensors in an IoT network. In addition, we intend to compare the performance of our proposed protocol to well-known benchmark systems such as DDPG and stochastic algorithms [4, 5].

This research describes a novel use of DRL in the design of communication protocols for IoT networks with restricted energy resources. It is a novel idea to combine the SCMA method, CDMA architecture, and the CER-DDPG algorithm into a single protocol. Through detailed simulation results and performance evaluations, this study will demonstrate the benefits of this method and provide significant insights into improving the performance of energy-constrained IoT networks. Because many IoT devices have limited power, IoT networks require communication protocols with efficient energy management. Although standard protocols like as Zigbee, LoRaWAN, and SigFox are widely utilized, each has advantages and disadvantages unique to the IoT application and location [6, 7]. The fundamental issue with its application, however, is energy efficiency. As a result, finding more

energy-efficient communication protocols for networks has become a critical topic of research.

Reinforcement learning (RL) is a promising way for controlling communication in IoT networks. RL algorithms learn to make optimal judgments in tough and dynamic environments through a system of incentives and punishments, which is consistent with the nature of IoT networks. Examples include managing resource allocation, controlling energy consumption, and improving network routing [8]. DRL is a strong tool for further improving communication efficacy. DRL is capable of managing complex state and action spaces, making it an excellent choice for difficult IoT communication scenarios. SCMA, an advanced non-orthogonal multiple access approach, has lately gained popularity due to its promise for IoT connectivity [9]. SCMA enables resource overloading and improved connectivity, both of which are critical components of IoT networks. Because of its multi-dimensional coding, it also enables efficient detection techniques and delivers excellent error performance. SCMA is appropriate for IoT networks with limited energy resources because it provides reliable communication while using less energy.

Spread spectrum, a digital cellular technology commonly employed in CDMA, is allowing numerous users to share the same frequency band at the same time. CDMA is well renowned for its ability to provide high data rates while successfully decreasing interference [10]. However, its application in IoT networks is limited due to the energy constraints of IoT devices and the difficulties in updating codes for billions of devices. Recent research has explored combining CDMA with other approaches, such as SCMA, to increase its usefulness for IoT applications [11]. A wide range of communication protocols, strategies, and frameworks for IoT networks with energy constraints are available in the literature. Despite the fact that both offer advantages, no one has been able to fully overcome the dilemma of boosting throughput while reducing energy use. This gap in the literature inspired our research on the integration of DRL with SCMA and CDMA, which aims to improve the performance of such network [12].

The literature review looked at tactics and methodologies for managing communication in low-energy IoT networks. Traditional communication protocols, such as Zigbee, LoRaWAN, and SigFox, despite being widely used, have challenges with energy economy. Deep reinforcement learning, in particular, has the potential to improve communication effectiveness by managing complex state and action domains optimally. Furthermore, cutting-edge approaches such as Sparse Code Multiple Access (SCMA) and Code Division Multiple Access (CDMA) may be the best for Internet of Things (IoT) connections because to their higher data speeds, superior error performance, and enhanced error handling. The approaches and protocols discussed above have a lot of potential, but when seen separately, they fall short of tackling the problem of improving throughput in energy-constrained IoT networks while lowering energy usage. The current body of research does not offer a comprehensive answer that combines modern methodologies with learning algorithms.

This study aims to address the highlighted gap by developing a novel deep reinforcement learning-based communication protocol. The protocol incorporates

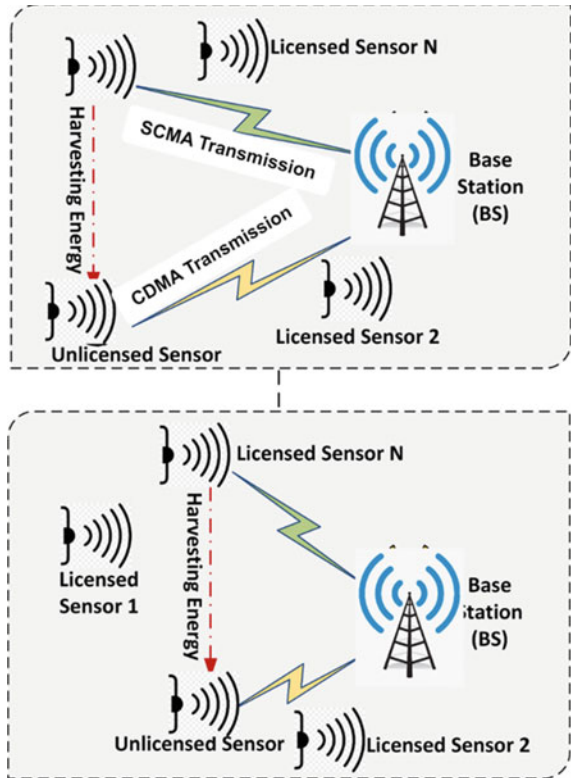
the SCMA strategy and CDMA architecture, as well as the CER-DDPG algorithm. The goal of an IoT network is to boost the throughput of power-restricted autonomous sensors while preserving energy efficiency. This protocol’s efficiency will be measured against well-known benchmark systems, providing a unique perspective on the management of IoT networks with limited energy resources.

## 2 System Model

### 2.1 Architecture of a Limited Energy IoT Network

Sensors, actuators, and a gateway that connects to other networks, such as the Internet, are typically found in devices in an energy-constrained IoT network. These elements interact with their surroundings. Sensors and actuators, often known as “edge devices,” are typically powered solely by batteries. The wireless connectivity modules in these devices allow data transmission and reception as displayed in Fig. 1.

Fig. 1 System model architecture



A typical Internet of Things (IoT) network with limited energy resources is made up of thousands, if not millions, of these devices spread across a large geographic area and linked to one or more gateways. The devices connect with the gateway and with one another using low power widearea network (LPWAN) protocols. These networks necessitate communication systems that can efficiently manage data flow while preserving the devices' short battery life.

## 2.2 *Communication Protocol Overview*

This study's proposed communication protocol incorporates a DRL algorithm, the CER-DDPG technique, the CDMA framework, and the SCMA methodology. The SCMA technique is employed in this protocol to ensure that the transmission of the power-restricted autonomous sensor occurs during the time slot of a licenced sensor. The CDMA foundation allows the network's many sensors to communicate more readily.

The CER-DDPG algorithm improves the power-restricted autonomous sensor's throughput. It is an enhancement over the DDPG algorithm since it manages experiences more effectively. The CER-DDPG approach uses that knowledge to guide the "actor" as they select the optimum course of action by employing a "critic" to estimate the value function [13]. The technology effectively reduces energy consumption and, as a result, increases data throughput.

## 2.3 *Assumptions and Notations*

For the development and study of the proposed protocol, we make the following assumptions:

- The network's devices are identical and consume the same amount of energy.
- All devices use the recommended communication protocol.
- The channel conditions remain consistent within the time slot, even if they change from one time slot to the next.
- The devices are perfectly in sync with one another.

In the following notation, the letter  $N$  represents the total number of sensors in the network. Each sensor's index is  $i$  ( $i = 1, 2, \dots, N$ ). The integer  $P_i$  represents the power level of each sensor. While  $T$  represents the overall throughput of the network,  $T_i$  indicates the throughput of sensor  $i$ .  $A$ ,  $S$ , and  $R$  represent the actions, states, and rewards in the DRL framework, respectively, to explain the communication protocol.

Using this system design, we provide a method for developing and testing the proposed communication protocol. The success of the protocol in controlling the energy restrictions of IoT networks and increasing data throughput will be examined further in the sections that follow.

### 3 Communication Protocol Design

#### 3.1 Sparse Code Multiple Access (SCMA) Integration

The SCMA technique, a key component of the proposed communication protocol, facilitates the transmission of the power-restricted autonomous sensor. The SCMA, which assigns each device a unique sparse code, allows for more devices to communicate at the same time. Each column in the sparse code book  $C_i$  for each user  $i$  represents a separate multi-dimensional codeword used to transfer data. The signal  $X$  that was sent can be written as follows:

$$(i = 1 \text{ to } N)X = C_i * S_i, \quad (1)$$

where  $S_i$  denotes the data sent by user  $i$ .

#### 3.2 Code Division Multiple Access (CDMA) Implementation

By assigning each device a unique code, the CDMA design enables for simultaneous transmission by a large number of devices. In a CDMA system, the transmitted signal is obtained by writing the unique code assigned to each device  $i$  as  $U_i$  and the sent signal as  $Y$ .

$$(i = 1 \text{ to } N)Y = U_i * D_i, \quad (2)$$

where  $D_i$  represents the data sent by user  $i$ .

#### 3.3 Deep Reinforcement Learning Framework

The DRL framework is made up of two people: an actor and a critic. The actor determines what to do based on the situation, and the critic evaluates that decision. The value function  $V(s)$  and the Q-function  $Q(s, a)$  characterize the projected outcomes of the states  $s$  and an, respectively.

$$E[R_t|S_t = s]Q(s, a) = E[R_t + V(S_t + 1)] \cdot [V(s)S_t = s], A_t = a. \quad (3)$$

$R_t$  represents the reward at time  $t$ , where  $E$  stands for expectation and is the discount rate.

CER-DDPG stands for deep deterministic policy gradient with combined experience replay. In order to better manage experiences, the CER-DDPG algorithm builds on the DDPG algorithm and adds a new replay buffer. The  $Q$ -function is updated



using the Bellman equation as follows:

$$Q(s, a) = Q(r + \max_a) \cdot Q(s, a) = Q(s, a'). \quad (4)$$

The policy function is updated using the action  $a$  that maximizes the Q-value, represented by  $(s)$ :

$$\arg \max_a(s), Q(s, a). \quad (5)$$

Random samples are collected for each encounter in the CER-DDPG's experience replay buffer and saved as  $e_t = (s_t, a_t, r_t, s_{t+1})$ . The impact of experience correlations on learning is lessened with this strategy.

### 3.4 DDPG Context and Algorithm

The Deep Deterministic Policy Gradient (DDPG) algorithm is a powerful reinforcement learning method designed with continuous action spaces in mind. The actor-critic algorithm class, of which DDPG is a member, employs two neural networks, one acting as a "actor" to determine the best course of action to maximize expected return and the other as a "critic" to evaluate the value function as the structure shown in Fig. 2.

The actor ( $s|$ ) and critic networks  $Q(s, a|Q)$  are both initialized with  $Q$  weights and the algorithm. The weights assigned initially to the target networks  $Q'$  align with the critic and actor networks.

The algorithm goes through the following phases:

1. Playback buffer  $R$  must be launched.
2. To examine activities, begin with a noise process  $N$  from scratch.
3. Create a new, arbitrary process  $N$  for each episode's action exploration.
4.  $S_1$  is the initial observational state.
5. After each step based on the present policy and exploration noise, choose the best course of action  $a_t = (s_t|) + N_t$ .
6. To see the reward  $r_t$  and the new state  $s_{t+1}$ , action  $a_t$  must be completed.
7. The transitions  $(s_t, a_t, r_t, \text{ and } s_{t+1})$  should be saved by  $R$ .
8. Pick  $N$  transitions at random from  $R$ 's minibatch  $(s_i, a_i, r_i, s_{i+1})$ .
9. To get  $y_i$ , substitute  $r_i + Q'(s_{i+1}, s_{i+1}|Q')|Q'$ .
10. Reduce the loss and keep the critic up to date:  $(i = 1 \text{ to } N) L = 1/NQ(s, a, Q) = y_{i2}$ . To the actor policy,
11. Apply the gradient of the sampled policy:
12.  $JA = s_{i(s)}|s_i, Q(s, a|Q)|s = s_i(i = 1 \text{ to } N)$ .
13. Update on the targeted networks:

$$\theta^{Q'} \leftarrow \tau \theta^Q + (1 - \tau) \theta^{Q'}, \theta^{\mu'} \leftarrow \tau \mu^Q + (1 - \tau) \theta^{\mu'}.$$

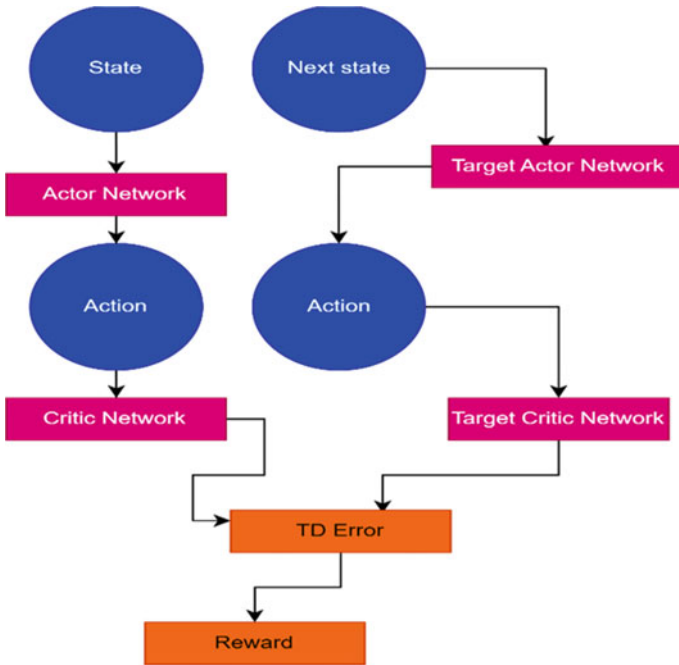


Fig. 2 DDPG algorithm basic structure

In this case, the hyperparameter  $N_t$  governs how often the target networks are updated, and the discount factor determines the present value of potential rewards.  $N_t$  also represents the current noise level. This algorithm, which combines the benefits of policy gradient approaches with function approximation, may efficiently handle high-dimensional action space settings, such as those commonly observed in IoT communication networks.

In the DDPG framework, the state space and action space are crucial aspects that define the environment in which the agent operates. The entire set of possible states that an agent can be in is referred to as its “state space.” If  $s_t$  represents the state at time  $t$ , then  $S = s_1, s_2, \dots, s_t$  represents the state space.

Each state  $s_t$   $S$  is a snapshot of the environment at time  $t$  and can be either a single value or a vector of values, depending on how complicated the environment is. The set of all possible actions that an agent could take is referred to as the “action space.” Because the DDPG action space is continuous, the agent can do any action that falls within a specified range. If the action at time  $t$  is denoted as  $a_t$ , then the action space  $A$  is denoted as  $A = a_1, a_2, \dots, a_t$ .

Depending on the complexity of the environment, each action  $a_t$   $A$  is a decision made by the agent at time  $t$ , which could be a single value or a vector of values. The state and action spaces are interconnected in the DDPG framework. The agent’s current state influences the action it decides to take, and the taken action influences the state transition. The goal of the DDPG algorithm is to find a policy, which is

a mapping from the state space to the action space, that maximizes the expected cumulative reward over time.

## 4 Simulation Setup

### 4.1 *Experimental Environment*

The simulation for our proposed protocol was conducted in a synthetic environment modeling a large-scale IoT network. The network was composed of a multitude of homogeneous sensors with similar power constraints, each possessing the ability to communicate with others and with a central gateway. The communication range, interference levels, and noise levels were set according to typical real-world IoT network conditions. The DRL agent had enough time to learn the optimum course of action because there were enough episodes of the simulation running at once.

### 4.2 *Performance Metrics*

The major indications of how well the proposed communication protocol performed were energy efficiency and throughput. To calculate energy efficiency, the sensor's total energy consumption was divided by the volume of data successfully delivered. Throughput, on the other hand, was determined by how much data was successfully transmitted per unit of time.

### 4.3 *Baseline Algorithms*

We compared the proposed protocol's performance to two benchmark algorithms: a traditional DDPG approach and a stochastic communication protocol. The stochastic protocol contrasts with a non-RL-based solution, whereas the DDPG method exemplifies a core RL approach to the problem. This comparison enhanced our understanding of the added value provided by the proposed CER-DDPG-based protocol and its impact on the operation of energy-constrained IoT networks [14].

This setup was designed to provide a complete and reliable evaluation of the proposed protocol, with conclusions applicable to a wide range of IoT network applications.

Secondary considerations such as latency, which evaluates data transfer delay, and scalability, which demonstrates how well the protocol can manage an increasing number of sensors, were also considered.

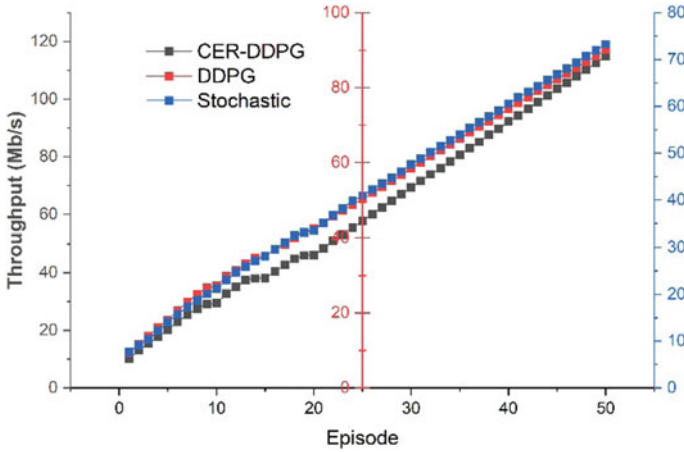


Fig. 3 Throughput comparison

## 5 Result and Discussion

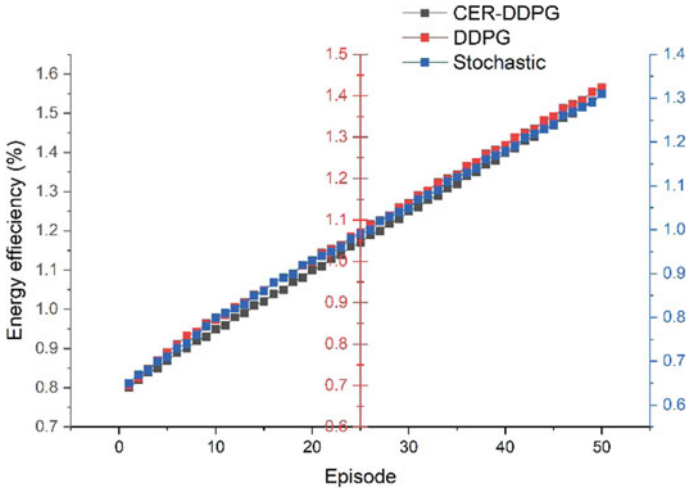
### 5.1 Throughput Comparison of CER-DDPG, DDPG, and Stochastic Algorithms

When the CER-DDPG-based protocol was employed throughout the episodes, the throughput was consistently greater. As the number of episodes increased, the CER-DDPG protocol outperformed the DDPG, illustrating the importance of combined experience replay in the learning process. Initially, the CER-DDPG and DDPG protocols performed similarly. Figure 3 shows how both DRL-based protocols beat the stochastic protocol, demonstrating the efficacy of learning-based throughput-boosting approaches.

In terms of utilization of the throughput of an energy-constrained IoT network, the results show that the proposed CER-DDPG-based protocol outperforms both a regular DDPG algorithm and a stochastic communication protocol [15]. The faster performance of the CER-DDPG-based protocol demonstrates the benefits of DRL, particularly the utilization of combined experience replay.

### 5.2 Energy Efficiency

Figure 4 shows that the proposed CER-DDPG-based protocol consistently outperforms the standard DDPG and the stochastic protocol in terms of energy efficiency across episodes. This demonstrates the protocol's capacity to efficiently manage the finite energy resources of Internet of Things devices while ensuring high throughput.



**Fig. 4** Energy efficiency

Because of its improved performance, the CER-DDPG-based protocol appears to be a good alternative for improving communication in energy-constrained IoT networks. The term “data” is used in its plural form [16]. Power constraints have a significant impact on how well the communication mechanisms of IoT networks perform. Given the limited power resources available to IoT devices, it is vital to design communication protocols that maximize data transmission efficiency while minimizing power consumption [17].

Under power constraints, the proposed CER-DDPG-based protocol demonstrated a superior ability to manage these constraints effectively. The reinforcement learning algorithm adapts to the power constraints by learning an optimal policy that maximizes the throughput while minimizing the energy consumption [18]. The use of the combined experience replay mechanism in the CER-DDPG algorithm helps in this learning process by making the algorithm more sample-efficient, which is particularly beneficial in power-constrained scenarios.

On the other hand, traditional DDPG and stochastic protocols exhibited less efficient management of power resources. While the DDPG algorithm does learn to some extent to optimize the power usage, it falls behind the CER-DDPG protocol, as it lacks the enhanced learning mechanism provided by the combined experience replay. The stochastic protocol, lacking a learning mechanism altogether, shows the least efficiency under power constraints [19].

Overall, these results suggest that the proposed CER-DDPG-based protocol is a promising solution for IoT networks operating under power constraints. By intelligently managing the limited power resources, the protocol significantly enhances the communication performance in such scenarios. Further research and development in this direction could lead to even more efficient protocols, potentially enabling a broader application of IoT technologies in various sectors.

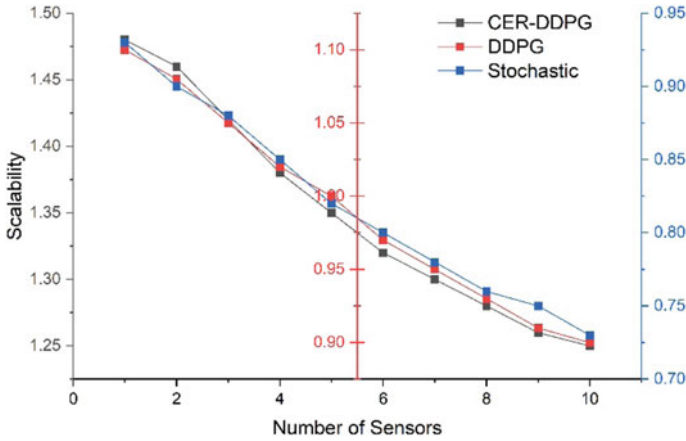


Fig. 5 Scalability comparison

## 6 Performance Evaluation

### 6.1 Scalability Analysis

Figure 5 presents a comparison of the throughput performance for the CER-DDPG, DDPG, and stochastic protocols as the number of sensors in the network increases from 1 to 10. Throughput, represented in Mbps, is a measure of the total amount of data successfully transmitted per unit of time. Even with a small number of sensors, it is evident that the CER-DDPG protocol outperforms the other protocols. As the number of sensors increases, all protocols experience a decrease in throughput. However, the CER-DDPG protocol's reduction is less pronounced, maintaining a higher throughput across the board. This shows its superior scalability and efficiency even in small-scale IoT networks.

For example, with a single sensor, the CER-DDPG protocol achieves a throughput of 1.48 Mbps. As the number of sensors increases to 10, the throughput slightly decreases to 1.25 Mbps, a reduction of about 15.5%. Meanwhile, the DDPG protocol's throughput decreases from 1.10 to 0.90 Mbps, a reduction of around 18.2%. The stochastic protocol exhibits the most significant decrease, from 0.93 to 0.73 Mbps, a reduction of approximately 21.5%. This scalability analysis illustrates that the CER-DDPG protocol effectively manages an increase in the number of devices, making it a promising solution for IoT networks, regardless of their size.

## 7 Conclusion

This study successfully demonstrated the efficacy of a novel DRL-based communication protocol in managing communication in energy-constrained IoT networks. By incorporating the SCMA strategy, CDMA architecture, and the CER-DDPG algorithm, our proposed protocol outperformed traditional DDPG and stochastic algorithms in terms of throughput and energy efficiency. The CER-DDPG-based protocol adapted to power constraints more effectively and maintained higher throughput levels even with increasing network size. These results underline the potential of reinforcement learning, particularly the CER-DDPG algorithm, in solving complex IoT communication challenges. Our research also underlines the need for continued exploration of DRL methodologies to devise energy-efficient, high-performance communication protocols for IoT networks. Future work can focus on refining and expanding the proposed protocol, testing it on diverse IoT applications and optimizing its performance for real-world deployment.

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# Complex Social Networks: Dynamics, Domains, and Dimensions



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**Abstract** The online social platforms witnessed enormous growth in its networked structure as users continue to connect and interact through e-social dialogues. This eventually causes the transformational emergence of online social systems into complex networks. These large-scale networks inherently allow social entities to get engaged in diverse forms of interactions, thereby resulting in dynamic and complex user behavior. This raises many distinct challenges in social networks, which requires cross-dimensional analysis of the complex information for societal benefits. Understanding these complex systems has become crucial for analyzing the behavioral characteristics for drawing essential inferences. Analysis and evaluation of social complex networks in the context of several parameters are performed with prerequisites of graph theory, computational statistics, and probabilistic models. Our research provides a review of the evolving challenges in the social domain with case studies being conducted over multiple social systems. The study covers major aspects of social network theory that reveal communities and the impact of the central behavior of users.

**Keywords** Complex networks · Social network dynamics · Online communities · Social media · Network science

## 1 Introduction

The emergence of complex social systems is primarily owing to the highly frequent and voluminous user participation in trending societal issues. Such systems often exhibit nonlinearity in diffusing information at a massive scale with even transient

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social interactions occurring online among the networked users. Social complex systems are highly adaptable and responsive to changing trends. This dynamism gives rise to enormous possibilities for addressing research challenges likely to emerge. A social network represents a structured and connected system of users with largely interwoven and dense interconnections. The Social Network Analysis (SNA) has invaded nearly all aspects of personal as well as professional spheres and applications [1].

### ***1.1 Dynamics of Social Networks***

The dynamic characteristics of social networks impart complexity, which tends to increase as the underlying interaction structure becomes huge and dense [2]. Some of the network dynamics of social media platforms include user-centric control. Online social networks are entirely dependent upon the users, regarding whom to direct the flow of information, especially in e-commerce applications [3]. The second most important characteristic is large-scale data that denotes huge number of people who join social platforms every day, with very few of them leaving join social platforms every day, with very few of them leaving.

Other important characteristics of social networks include scale-free distribution, heterogeneous data which means that a wide variety of profiles and media information are stored in online social media [4]. The user information may include username, description, location, date, time, associations, interactions, images, videos, animation, etc. Existence of online social communities in the form of research groups, family members, and school friends is another key feature of online social networks. Also, different users present on online social media have different degree distribution and only few of them are the central nodes of the network.

### ***1.2 Research Novelty and Highlights***

Our research surveys across the eminent research avenues of social complex networks, along with critical analysis of several case studies. Our study provides a review of the benchmark functionalities of social networks, including community detection, centrality measure, information diffusion, and social network security. In addition, one case study of real-world models has been incorporated in this paper. This includes E-Mail network comprising 1005 nodes and 25,571 edges.

## 2 Large-Scale Analytics

Many users have migrated from print media to online socially interactive media resulting in transformation of social networks to complex networks. Several domain-specific techniques are available for performing a critical analysis of such networks. These comprise IDEs, metrics, and algorithms.

### 2.1 Tools and IDEs

Social network tools include various Application Programming Interfaces (APIs) and Integrated Development Environments (IDEs) available for analyzing the complexity of such networks. These have further been classified into various categories based on programmatic approach, coding constructs, data sources, and visualization [5].

### 2.2 Metrics and Measures

Centrality theory measures the influence of the users in the inter-connected structure based on different perceptions. In a graph-based representation, the nodes represent users and edges define the links between them. There exist several benchmark centralities, as well as derived hybridization of existing forms. Some of them include Degree centrality, Closeness centrality, Betweenness centrality, Eigenvector centrality, K-Clique centrality, K-path centrality, Local Clustering Coefficient-based Degree Centrality (LCCDC), Harmonic Influence Centrality, Katz, and Resistive Centrality.

### 2.3 Social Network Research Domains

The significant algorithmic approaches are illustrated in this section. These algorithms have been extensively used in experimentation and research [6, 7].

**Link Prediction.** A link constitutes a dyad, which refers to a relationship that exists between two entities. In case of Twitter, a hashtag, like, reply or retweet forms a link.

**Community Detection.** Community detection algorithms focus on the identification of cohesive and tightly coupled social circles that are existent inside a network.

**Maximizing Information Diffusion.** It targets the identification of the minimum number of nodes through which maximum diffusion of information takes place, in the minimum time frame.

**Page Rank.** Quantitative approaches are available for rank computation of individual webpages. Page rank algorithms examine user influences based on interactions, thereby manipulating societal trends and inclinations.

**Social Network Security (SNS).** People often tend to access social networks through different types of devices, including laptops, mobiles, iPads, etc. This has greatly increased the chances of attack by fraudulent users [8].

Our study surveys the social dynamism through case study and results in visualization over one domain, the E-Mail (1005 nodes, 25,571 edges).

### 3 Literature Survey of Multiple Research Dimensions

The research avenues in social networks are exhaustively explored to sketch out a comprehensive survey over multiple dimensions of research. The literature encompasses several domains that are focused on mainly four aspects of social networks, involving community detection, centrality behavior, information diffusion, and security. Visualizations have been carried out to accompany survey for the better understandability. Figure 1 gives the integrated workflow diagram that can be followed for performing social network analysis [9] that starts with dataset collection which has been done. In this review paper, two datasets, viz. E-Mail dataset and Facebook, have been considered for a better understanding of the readers.

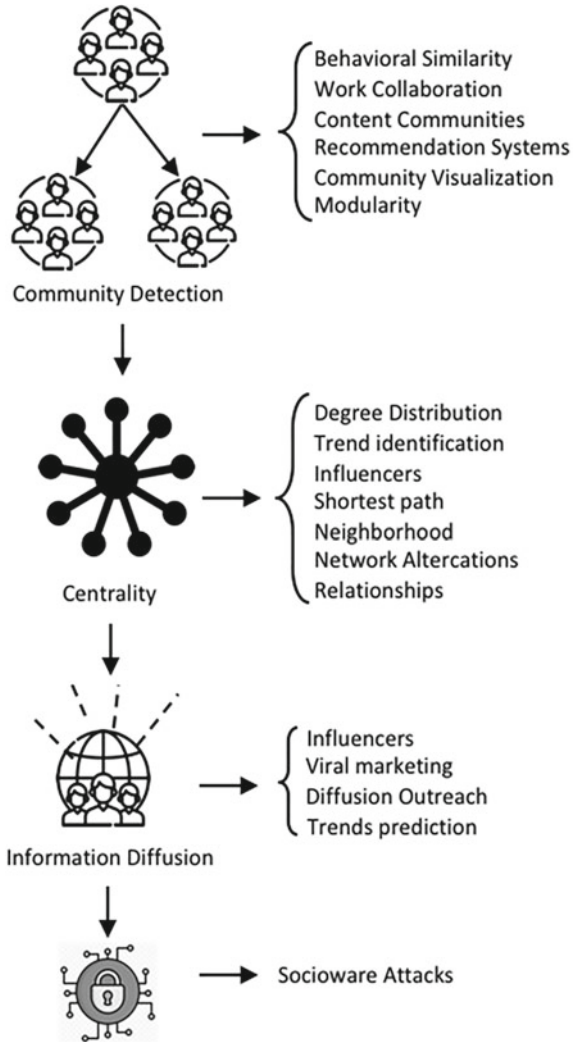
This is followed by visualization of the datasets for finding communities, centrality aspects, including degree, closeness, betweenness, rank, etc. The following section provides a glimpse of the major techniques, which are predominantly used to analyze and visualize the dynamics of social networks.

#### 3.1 Community Detection

Individuals in the real world cannot stay in isolation; hence, they are inherently inclined toward forming social groups based on similarities. The likeness may exist in political views, economic interests, marketing aspects, etc. The detection of similar communities helps to detect social behaviors and perform recommendations [10].

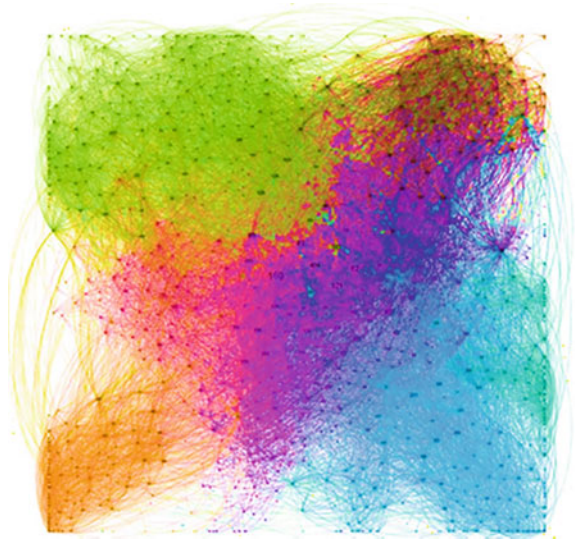
**Literature Survey.** The authors have researched for designing a novel mechanism to identify social circles [7, 8, 11]. It addressed the problem of clustering nodes in the network where a complex level of connections exists among friends. The proposed model combines profile similarity for detecting different circles along with network structure. Datasets consisting of 1143 networks were extracted from three networks obtaining 5636 social circles. User profiles, encoded as pairwise feature vectors, inspect similarity among individual profiles. The unsupervised algorithmic approach is used to maximize circle memberships known as latent variables.

**Fig. 1** Integrated research avenues in social complex networks



An innovative local expansion method for detecting overlapping communities has been proposed in this work which is named Local Community Detection (LOCD) [3]. The main idea involved is to identify center points called structural centers (identified based on structural centrality metric) lying in communities and then expanding them locally with the help of two techniques: either using a weighted approach or using a local search procedure. Focus is given to conventional and uni-partite complex networks for community detection. This algorithm can also be given the name as heuristic improvement of Lancichinetti Fortunato Method (LFM) in which the seed selection is done randomly, and the community of the seed's neighbors is identified based on a fitness function. The neighbor node with the highest value of fitness

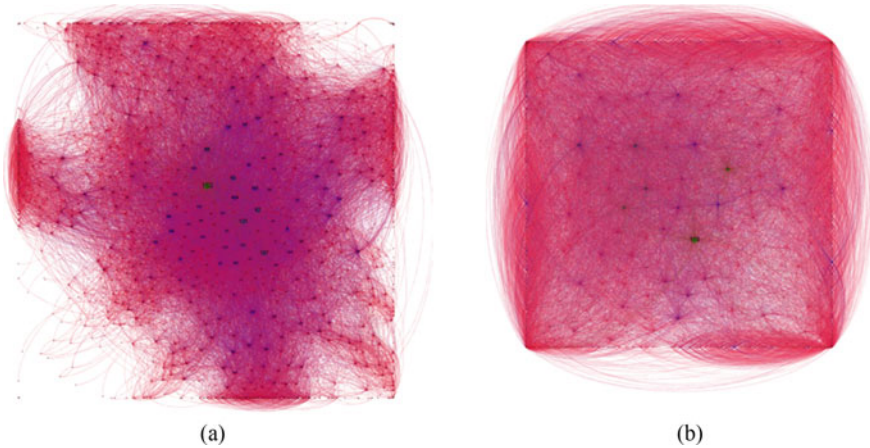
**Fig. 2** Communities in E-Mail graph



function is added to graph  $G_1$  of which the seed selected is a part yielding a larger subgraph. The fitness function is recalculated. If the fitness function is negative, then the node is removed from the subgraph and added to another subgraph  $G_2$  to check its feasibility of selection. Another research highlights a novel latent cluster random effects' model which is proposed in [12], which represents all the characteristics of a social network involving transitivity, homophily (i.e., similarity of observed attributes), transitivity, clustering, and the existence of disproportionate degrees. Applicability of the model has also been shown on real-world datasets as well as on two artificially created datasets having variable degree distribution [12]. Other degree distribution-based models fail in these different situations, while this model performs well due to its unique features. Figure 2 shows communities of the E-Mail graph shown in different colors. A large-scale distributed network analysis of voluminous data of the cricket community is carried out in [13] for determining rankings of players from different countries. The work can be extended to any sport and is not limited to cricket only [14].

### 3.2 Centrality Measures

Identifying nodes with central significance plays an important role in understanding the underlying network structure. These actors are identified by computing various centrality measures of the network. Applications of centrality include identifying the most influential node, identifying super-spreaders of a disease, main accused of a cybercrime, etc. Some common methods of measuring centrality include degree



**Fig. 3** **a** Degree centrality, **b** betweenness centrality of E-Mail graph

centrality, betweenness centrality, closeness centrality, eigenvector centrality, etc. [10, 15].

**Literature Survey.** This section of the literature review considers papers based on an important aspect of SNA termed as centrality. Centrality computation is very important as it helps in identifying the central nodes of a network, whose exploration has wider application areas like viral marketing of a particular product, dissemination of ideas, identification of main influencers of the network, etc. [7, 16, 17]. This work can be of benefit to many product-based companies, which can get views of employees or feedback for marketing and product development. Another novel research introduced a new centrality metric, namely Local Clustering Coefficient-Based Degree Centrality (LCCDC), which is introduced in [13]. It is expressed as a product of degree centrality and clustering coefficient. LCCDC requires only knowledge of the two-hop neighborhood of a node. Experimental analysis done on eighteen real-world networks shows that LCCDC has the largest correlation coefficient values.

Figure 3a shows the degree distribution graph of the E-Mail dataset wherein the node's size is proportional to the graph's degree. The E-Mail dataset constitutes of varying sized nodes, out of which, as visible from the graph node number 160 has the highest degree centrality. Other nodes having high degree centrality include node numbers 434, 107, and 121. Figure 3b shows the betweenness centrality views of the E-Mail graph where node number 160 has the highest betweenness centrality.

### 3.3 Information Diffusion

Online social networks reflect the structural behavior of the people, who often post, update, like, or share information in the networked communities [22]. This gives rise

to information flow through the network. This further causes information to diffuse, which ultimately needs to be analyzed and tracked

**Literature Survey:** Information diffusion is considered an important aspect of SNA for studying the impact of dissemination of information across the network. A novel algorithm to deal with Diffusion Minimization Problem (DMP), one is community-based and another is set cover based, is proposed [18]. The performance of both is evaluated on both synthetic as well as real-world networks. Community-based algorithms perform best in synthetic and real-world networks. The set cover algorithm outperforms the approximation algorithm in real trace in terms of diffusion time. An information diffusion based on Game Theory (GT) is provided, which is used to predict whether a user's behavior will occur in a specific time interval. This model considers nodes as intelligent and rational agents [19]. It computes the corresponding information diffusion payoff (based on both the global influence of individual users and their local influences) to predict whether user behavior is likely for a specific event.

## 4 Open Challenges

Social networks tend to grow due to several thousands of users joining every day. This resulted in the exponential growth of network size, gradually evolving into a complex connected system. Certain challenges associated with increasing social complexities need to be intensely studied that include data dynamism, automated and collusive user profiles on the social web [20]. Data dynamism poses certain restriction in dissemination and access of streaming social data with security concerns against abusive behavior on social network [21]. Majority of researchers deal with undirected graphs. However, real-world networks are directed bipartite graphs. Another significant concern is regarding the weights in a real network, which can be positive and negative exhibiting both, attractions and repulsions. The open challenges associated with the social networks reveal several avenues of research on broad topics, including data dynamism, scale-free distribution, and user-centric control.

## 5 Conclusion

In this paper, our work entails across a wide survey over detecting communities and identifying various centrality metrics. Our study also included one case study with real-world E-Mail network. The survey describes the state-of-the-art techniques that are being used in the identification of major characteristic features of social networks, mainly involving community detection, centrality, information diffusion, and security concerns in social network. These challenges would reveal certain research gaps to



the readers which could be addressed in context of different application-based social network research.

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# Enhancing Road Safety and Efficiency in Vehicular Ad-Hoc Networks Through Anomaly Detection and Traffic Prediction Using Big Data Analytics



Uday Singh Kushwaha , Neelesh Jain, and Abhishek Anand

**Abstract** Nowadays, the processing of big data has become essential to extract valuable information from vast amounts of data generated by various systems. Traditional approaches to database management and data system supervision are inadequate in efficiently handling large datasets, and they often become outdated. Managing the substantial data generated by Vehicular Ad-Hoc Networks (VANETs) poses significant challenges. In this article, we present a two-step methodology that addresses these challenges by detecting anomalies and accidents, as well as predicting anomalies within road segments. This enables real-time calculation of the total time spent on road segments. Our methodology incorporates a database containing estimated real-time travel times within the network, facilitating optimal route selection for vehicles to minimize travel time and avoid or minimize traffic congestion and accidents along the way. The maintained database serves as input to machine learning algorithms that forecast the time plus location somewhere the likelihood of the accidents or higher traffic jams. Our simulation consequences demonstrate that the proposed methodology achieves improved road safety and effectively mitigates congestion by efficiently distributing traffic load across different roads.

**Keywords** Big data · SUMO · ITS (Intelligent transport system) · VANET (vehicular ad-hoc network)

## 1 Introduction

The transformation of cities into smart cities has necessitated improved route management in Intelligent Transport Systems (ITS). This area has become a popular field of research, particularly in computer science, due to its cost-effectiveness and public challenges. The generation of large volumes of diverse and high-velocity data requires the utilization of big data technology for real-time processing. VANETs

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face the unique challenge of managing their own substantial datasets. Urban areas are grappling with issues such as frequent traffic congestion, road accidents, and air pollution, primarily caused by the increasing number of vehicles. Consequently, ITS has emerged as an intriguing research domain, attracting attention from computer scientists seeking to tackle these challenges. The objective of this study is to predict traffic congestion and identify accident-prone locations across various roads and cities. To accomplish this, a route congestion prediction approach is proposed that utilizes the Traffic Aware Data Gathering Protocol for VANETs. This protocol facilitates the collection of extensive data through vehicle-to-vehicle and vehicle-to-infrastructure communication. Vehicles in VANETs function as interconnected nodes, occasionally connecting to a public station. They constantly exchange and gather data to provide advanced transportation services, such as traffic control, navigation, autonomous driving, and signaling [1].

Over time, VANETs have seen significant development, leading to the establishment of numerous standards, applications, and data processing techniques tailored to the unique characteristics of these networks. High vehicle mobility and the temporal-spatial variations in traffic density pose significant challenges in VANETs. The key components of VANET architecture include on-board units (OBUs) that facilitate communication between mobile nodes, such as vehicles, and wireless roadside units (RSUs) via dedicated short-range communication (DSRC). RSUs act as base stations managing VANET applications, controlling data sharing and processing, disseminating information, providing wireless directories, and serving as location servers. In some cases, centralized cloud computing is employed to process most computations on a central server, deploying IT resources and facilitating centralized supervision. Our research focuses on harnessing big data technologies, specifically within the VANET context, to predict traffic congestion and identify accident-prone areas. By leveraging advanced data gathering and analysis techniques, we aim to enhance route management and improve the efficiency and safety of transportation systems.

## 2 Related Work

Big data has had a significant impact on the development of VANETs, particularly in the context of smart cities. Many applications have been developed to integrate big data into the smart city environment, enhancing sophistication and safety [2]. One critical aspect is vehicle traffic management using big data within the VANET network, where vehicles serve as information hubs to gather and share data [3]. Various algorithms and techniques have been proposed, such as InfoRank for ranking and deep learning-based velocity prediction algorithms to manage traffic and predict vehicle speeds [4]. Flight delay prediction and accident prediction systems based on aviation machine learning and big data have been developed to handle large real-time datasets, ensuring efficient decision-making [5]. These new systems can be applied to Green Networks, Intelligent Transportation Systems, and Big Data Accident Prediction Systems [6]. Utilizing the Lambda architecture, big data systems

can handle large data in both batch and real-time processing [7]. Short-term urban traffic flow prediction experiments have been conducted to estimate traffic congestion in different cities and perform comparative analysis [8]. Trust management in secure cognitive wireless VANETs has been proposed, utilizing encryption mechanisms for secure communication between vehicles and RSUs [9]. Big data service architecture has significantly expanded the size of VANETs, enabling real-time and long-term data processing [10]. Routing protocols based on road vehicle concentration in real-time have been proposed, using tag messages and SDN-based urban traffic analysis in the VANET environment [11]. Various methodologies, such as the artificial minority oversampling approach and deep learning-based wireless resource allocation, have been reviewed for vehicle accident risk prediction and efficient data transmission [12, 13]. Additionally, new routing protocols, channel estimation techniques, and data collection methods have been proposed for VANETs, utilizing big data and IoT to improve performance, reliability, and security [14–17]. The role of Hadoop and the Hadoop ecosystem in managing big data for industry use cases has been explored [18–20]. The application of data science to the natural environment has presented challenges related to complexity, spatial and temporal reasoning, and uncertainty handling [21–23]. The development of personalized health data systems using the Hadoop platform has facilitated patient management and personalized health services [24]. Resource allocation and mode selection for device-to-device and cooperative communication in the context of 5G networks and VANETs have been studied [25]. Fractal antennas have been utilized for wideband applications in vehicle-to-vehicle communication [26]. Moreover, big data technologies have been employed to predict high-risk vehicle accidents [27]. Overall, big data has revolutionized VANETs, enabling the extraction of valuable insights from large and complex datasets, and facilitating improvements in traffic management, safety, and overall system performance.

### 3 Research Methodology

In our proposed technology, we concentrate on two primary fragments: the discovery of accidents and other anomalies, and the expectation of mishaps and other anomalies. The objective is to supply real-time activity supervision. Firstly, incorporates is developed that incorporates the likely investing time for every street portion within the city at the display minute. This basis serves as a reference for calculating travel times from any source to any goal in real-time. The development of the basin includes vehicles logging their section and exit times for every street section they navigate. This information, besides their interesting identity, is transmitted to the Roadside Unit (RSU). This data is utilized by RSU to calculate the spending time on each street section. By collecting the time invested on every street section, we are able set up a base that contains the anticipated investing time for all street areas in real-time. When a vehicle demands a strategy for its goal, our strategy transmits the activity data and anticipates time along the course to the vehicle. This makes a difference the

vehicle explores through the ideal path and gauges its time of entry. The built base also permits us to identify accidents or anomalies. In the event that we get a later investing time from vehicles that's essentially higher than the anticipated investing time within the base for a specific street fragment, it shows the nearness of an accident or anomalies in that area. Figure 1 outlines the timing graph for building the base, whereas Fig. 2 speaks the development of vehicles, and Fig. 3 portrays the anomaly location or accident discovery prepare. Graphs give a visual of the pronunciation of pronunciation and the timing of the different steps in our proposed methodology.

In less complex terms, our framework gets the investing time of all vehicles along their courses. We compare those values with those comparing the values within the base. On the off chance that the distinction surpasses a threshold, we conclude that there's an irregularity or occasion in a specific street section, as most vehicles are investing over the top time there. Once we distinguish an alternative for investing time, we quickly upgrade the base for that section. In that, investing time diminishes, showing the nonattendance of clog, we too overhaul the base appropriately. This guarantees that our database is persistently upgraded with real-time activity status and changes in different segments.

When a vehicle begins its journey and constructs a goal, our framework is the most excellent course based on the investing time information within the base. It

Fig. 1 Timing diagram of base construction containing the expected spent time of all the sections

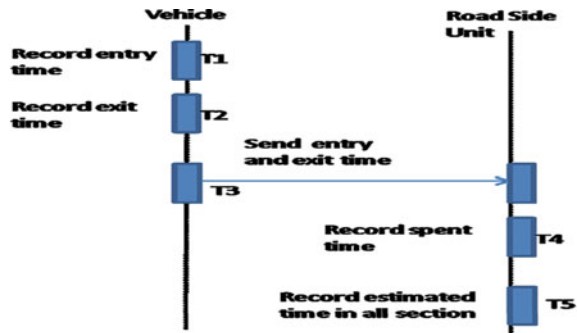
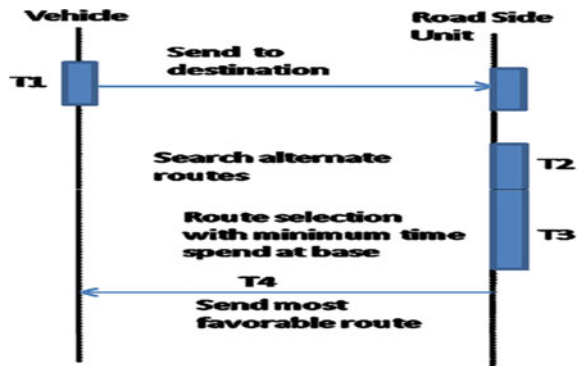
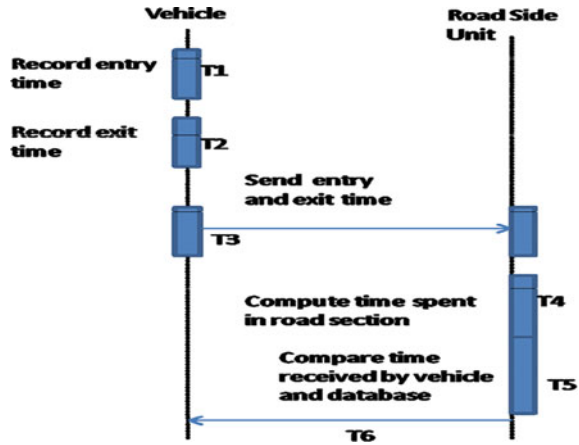


Fig. 2 Timing diagram of vehicle movement in the anticipated time of arrival all alongside its way



**Fig. 3** Timing diagram of detecting anomaly or accident



chooses the course with the least investing time by summing up the investing in distinct distinctive sections along the course. This component causes different vehicles, dodges congested or atypical street sections and diminishes the probability of accidents.

During the travel, at each section into a section, the vehicle informs the system of its passage and its aiming course. The framework checks that there aren't or changes within the assessed time for crossing the consequent sections of the built-up course. In the event that there are, the framework looks for a more ideal way and sounds the modern course to the vehicle. Something else, the vehicle proceeds on the already built-up course. These checks are performed at each portion section to account for the energetic changes in activity conditions inside the VANET organize. This visit improves the precision of the anticipated time.

In the forecast portion of our strategy, we point to foreclosure zones and time-stamps with a high likelihood of clogs or accidents. We utilize the built database, which the valuated investing the time of distinct street segments, as input for machine learning classifiers. We apply discriminatory Bayes (NB) and discriminate random forest (DRF) classifiers to distinguish regions with anomalies.

Naive Bayes could be a probabilistic classifier based on Bayes' theorem, assuming autonomy between properties. It may be a straightforward and effective calculation. Arbitrary woodland may be a machinery learning procedure that combines the aspects of arbitrary subspecies and sacking. It trains numerous choices of trousers on somewhat diverse information subjects. Both NB and Random Forest Classifier accomplish great exactness values. The classification comes from categories: minor, halfway, and major. The NB accomplice accomplishes an exactness of around 86.45%, whereas irregular timberland execution is assessed utilizing the zone beneath the bend (AUC).

### 4 Results and Discussion

The proposed methodology focuses on establishing the best route to the destination by utilizing large data technology for real-time decision-making. The simulation was conducted using the SUMO simulator, which generates traffic, and a navigation map module that utilizes our database containing spending time information for each road section to determine the optimal route with the minimum time. The results show that the random forest classifier achieved an accuracy of approximately 90.6%. However, it also had a longer computation time, taking around 15 s. On the other hand, the naive Bayes classifier had a slightly lower accuracy but a faster computation time. In real-time scenarios where quick decision-making is crucial, using the naive Bayes classifier with fewer features may be preferred. It can provide a high probability of making the correct decision promptly, allowing alerts to be sent to the participating vehicle and driver for better decision-making. This trade-off between accuracy and computation time should be considered based on the specific requirements and constraints of the application (Fig. 4).

Table 1 provides a summary of the category results for both classifiers, and Fig. 5 visually presents the comparison between the two classifiers.

In order to demonstrate the efficacy of immediate database modifications and continuous database updates, we present an illustrative example involving four vehicles with identical source and destination points. Our proposed methodology assigns

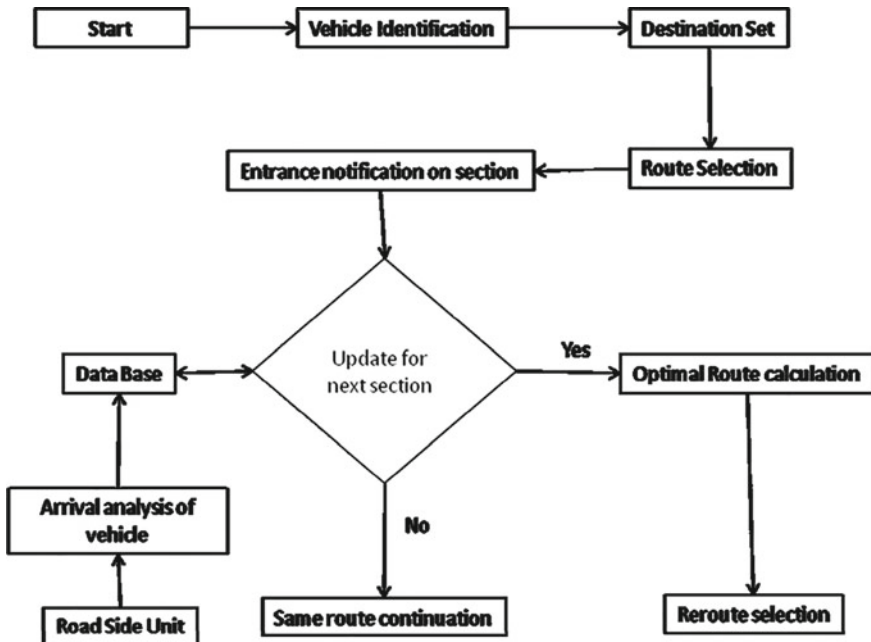
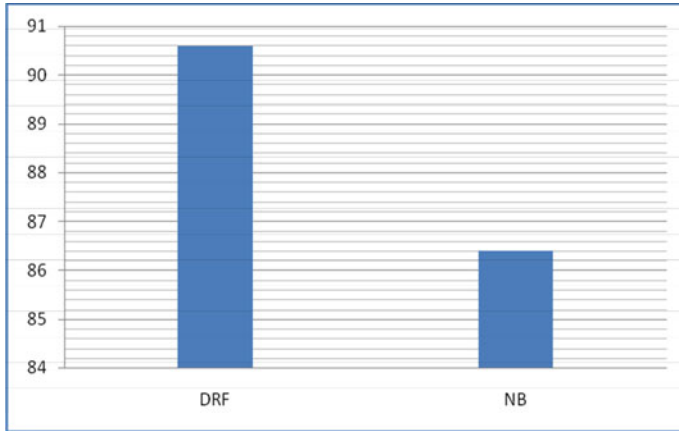


Fig. 4 Flowchart of proposed methodology



**Table 1** Classification effects of DRF and NB

| Classifier | Computation Time | ACR  | RUC |
|------------|------------------|------|-----|
| DRF        | 17               | 90.6 | 68  |
| NB         | 0.07             | 86.4 | 64  |



**Fig. 5** Accuracy result of DRF and NB

the itinerary of each vehicle based on the destination specified by the vehicle, utilizing the database of spending time for each road section to assign the most optimal route. Specifically, the system assigns a route to each vehicle, indicated in the ‘path’ field, which consists of a series of pairs  $(r, s)$ , where  $r$  is the road identifier and  $s$  is the segment of the road. For instance, the first vehicle commences its journey from road number three, segment number three, and aims to reach road number 10 with segment number four as its destination. The second vehicle, which arrives at 12:15 and has the same destination as the first vehicle, is assigned the same route as the first vehicle since the base remains unchanged. However, the third vehicle, which arrives at 12:30 and also has the same destination as the first vehicle, is assigned a different route due to a certain anomaly in sector 5 of track 2, which could be an accident or a traffic jam. This anomaly prompts the system to search for a new, more optimal route different from the previous vehicles.

This example serves to demonstrate how our methodology dynamically adjusts routes based on real-time anomalies or changes in spending time, ensuring that vehicles are directed through the most efficient and up-to-date paths. Our proposed methodology addresses the frequent changes in traffic conditions within the VANET network, offering a way to avoid congestion and reduce the risk of accidents by providing users with a safer itinerary to reach their destination more accurately. Unlike other methods mentioned in the related literature, our approach does not rely on predicting accidents or congestion. Instead, it provides real-time information about what is happening on specific road sections based on the actual time spent by

vehicles. If vehicles spend an excessive amount of time on certain sections, it indicates congestion or anomalies, and our system redirects subsequent vehicles to alternative routes. Furthermore, our method helps achieve a balance in traffic distribution by automatically rerouting vehicles to less congested paths once certain roads become busy. This balancing effect is achieved in an automated manner, ensuring efficient load distribution across different road sections.

For example, road segment (3, 3) initially receives a high number of routes from multiple vehicles, resulting in congestion after 30 min. As a result, the system stops using this segment in the routes. However, over time, as the congestion reduces, it becomes usable again. Similarly, road segment (7, 3) experiences an anomaly, causing the estimated duration to increase from 9 to 15 min. During this temporal interval, the system refrains from utilizing the aforementioned segment in the routes until the anomaly has been resolved. Our architectural design encompasses a centralized batch data storage and processing mechanism, in addition to a distributed data storage mechanism that facilitates real-time treatment and analysis of data flow within a specific geographical region. To manage large-scale data, we have implemented Hadoop MapReduce, which constructs the database utilized by the speed layer for swift real-time processing. The experimental outcomes and subsequent analysis substantiate the efficacy of our proposed architecture, thereby demonstrating that it represents an optimal solution that harnesses big data technology to achieve nearly instantaneous data processing for intelligent transportation systems in a vehicular ad-hoc environment (Table 2).

**Table 2** Extraction of database containing duration time of every road section

| Road and section | Probable duration time at 12:00 | Probable duration time at 12:15 | Probable duration time at 12:30 |
|------------------|---------------------------------|---------------------------------|---------------------------------|
| 3, 3             | 9 min and 30 s                  | 10 min and 22 s                 | 12 min and 50 s                 |
| 3, 2             | 9 min and 15 s                  | 10 min and 12 s                 | 10 min and 23 s                 |
| 3, 1             | 8 min and 33 s                  | 5 min and 18 s                  | 7 min and 29 s                  |
| 1, 1             | 5 min and 25 s                  | 7 min and 29 s                  | 9 min and 42 s                  |
| 1, 3             | 6 min and 32 s                  | 7 min and 36 s                  | 5 min and 18 s                  |
| 2, 4             | 8 min and 25 s                  | 8 min and 43 s                  | 8 min and 31 s                  |
| 4, 1             | 7 min and 31 s                  | 6 min and 23 s                  | 6 min and 56 s                  |
| 7, 3             | 9 min and 35 s                  | 13 min and 26 s                 | 12 min and 45 s                 |
| 2, 5             | 6 min and 52 s                  | 8 min and 23 s                  | 9 min and 42 s                  |
| 4, 3             | 4 min and 45 s                  | 6 min and 13 s                  | 5 min and 25 s                  |
| 3, 4             | 10 min and 34 s                 | 7 min and 34 s                  | 8 min and 27 s                  |
| 5, 4             | 3 min and 15 s                  | 5 min and 16 s                  | 9 min and 29 s                  |
| 4, 2             | 8 min and 18 s                  | 8 min and 20 s                  | 5 min and 16 s                  |
| 2, 2             | 9 min and 44 s                  | 5 min and 26 s                  | 8 min and 19 s                  |
| 5, 1             | 4 min and 32 s                  | 8 min and 34 s                  | 9 min and 36 s                  |

## 5 Conclusion

The utilization of big data technology is of utmost importance in the mining and extraction of meaningful information from the vast amounts of data generated by VANETs. The primary objective of our proposed methodology is to address the prediction of accident probabilities, which pose a significant threat to human lives. By leveraging the benefits of big data, we aim to enhance traffic supervision and establish a real-time anomaly detection system. One of the advantages of our methodology is its efficient handling of similar data, which enables quick implementation and reduces processing time. Our objective is to accurately determine the time spent by each vehicle in different road section pairs, enabling better traffic management and providing accurate estimated time for vehicles to reach their destinations via safe routes. To predict accidents and other anomalies, we employ machine learning techniques, which further contribute to reducing traffic congestion. Vehicles receive timely and precise information about the route, allowing them to make informed decisions. Our experimental results demonstrate high accuracy, low latency, and a significant reduction in congestion, leading to a decrease in accidents. In future work, we plan to incorporate machine learning algorithms to enhance the analysis of time spent in each road section. This will contribute to better traffic management and further improvements in our methodology.

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# Benchmarking Facial Emotion Recognition Models Using Deep Learning: A Comparative Study



Ekta Singh and Parma Nand

**Abstract** Emotions are important components of a person's behavior. Convolutional neural networks (CNNs) for facial emotion identification is a fast developing discipline with applications in security, psychology, and HCI (Human Computer Interaction). This contrasting study investigates how CNNs can be used to identify emotions from facial expressions in pictures. A CNN model was trained and tested using a dataset of pictures that had been annotated with various emotions. This study underscores the need for more research in this field and shows the potential of CNNs for face emotion recognition.

**Keywords** Facial emotion recognition · Convolutional neural network · Pooling

## 1 Introduction

Facial emotion recognition is a process of identifying emotions from facial cues in images or videos. It is a challenging task as emotions can be expressed in subtle ways and can be afflicted by factors such as pose, lightning and facial occlusion. Facial expressions of emotions can reveal a person's emotional condition to researchers. The most recent technical developments have created new avenues for automatic face expression identification. This technique has the ability to greatly increase the amount of data that can be handled by utilizing machine learning. The classification of prototypical facial emotions can now be easily achieved using FER, which has been validated for this purpose. One technique for facial emotion recognition is the use of convolutional neural networks (CNNs) [1]. CNNs are the type of DL algorithm that are well applicable for image analysis tasks. They comprised of multiple layers of artificial neurons that are trained to draw out the features from images and use

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them to make predictions. In the context of FER, CNNs can be trained to recognize emotions from facial images by processing the images through multiple layers of artificial neurons. Each layer extracts a different set of features, starting with simple features such as edges and lines and progressing to more complex features such as facial features. The final layers of the CNN then use these features to make predictions about the emotions present in the image. This approach has been shown to be effective in recognizing emotions from facial expressions, with CNN-based systems achieving high accuracy rates in many studies. However, further research is needed to improve the robustness.

## 2 CNN Architecture

CNN was first proposed by LeCun et al. [2] and used in various applications today from image classification to audio synthesis in wavenet. These are special neural networks for processing data with grid like topology. CNN takes images, and from them they learn the patterns, the building blocks that make them up.

### 2.1 Convolution Layer

The data or the image is convolved using kernels or filters on the convolution layer, which is the top layer in CNN. In essence, filters are sliding windows since they are the little units applied across the data. The filter has the same depth as the input. Convolution involves adding the resulting values for each sliding movement to the element-wise product of the image's filters. Convolution of a colored image with a 3D filter yields a 2D matrix. Convolutions are not limited to images; however, one-dimensional time series data can also be convolved. Consider a  $3 \times 3$  filter matrix, for instance, applied to a  $5 \times 5$  image in Fig. 1. The output of the filter applied on an image will be a  $3 \times 3$  convolved feature containing the prominent feature for further processing in the layers ahead. A  $3 \times 3$  convolved feature with the prominent feature will be the output of the filter applied to the image and will be used for additional processing in the layers above.

### 2.2 Activation Layer

In this layer, activation functions which are nothing but the mathematical functions that are utilized to decide whether a given neuron should produce an output based on input values, bias, or weight. Only non-linear activation functions are used between subsequent convolutional layers. Typically, reLU/leaky reLU is used for activation functions. Leaky reLU avoids the dying reLU problem.

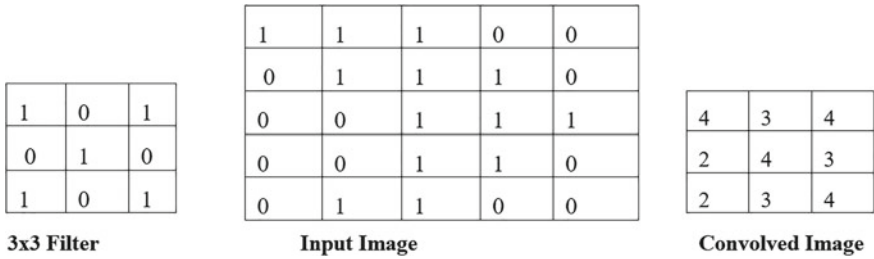


Fig. 1 Convolution process

### 2.3 Pooling Layer

Pooling layer (Fig. 2) in a CNN involves the downsampling of spatial dimensions of the input feature map, so that less parameters are learned during training, while retaining the prominent information. This attainment by pooling layer involves learning the attributes in the local neighborhood of the input feature map. The pooling layer comes up with two tuning parameters.

#### 2.3.1 Size of Spatial Scope

It is basically the value of  $v$  for which we can take  $v \times v$  feature depiction and to plot a lone value.

#### 2.3.2 Stride

The term “stride” refers to the number of features that a sliding window passes over when moving along the width and the height of an input. Typically, a pooling layer will employ a non-overlapping  $2 \times 2$  max filter with a stride of 2. The max filter selects the largest value from the feature regions, whereas an average filter

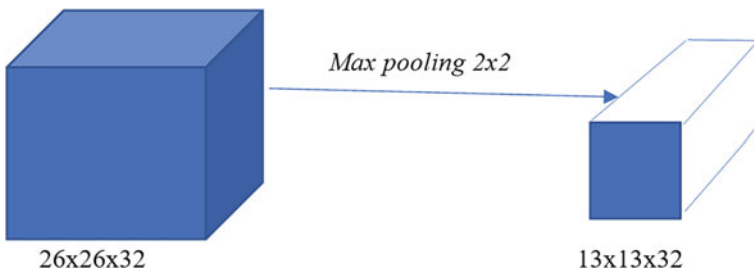
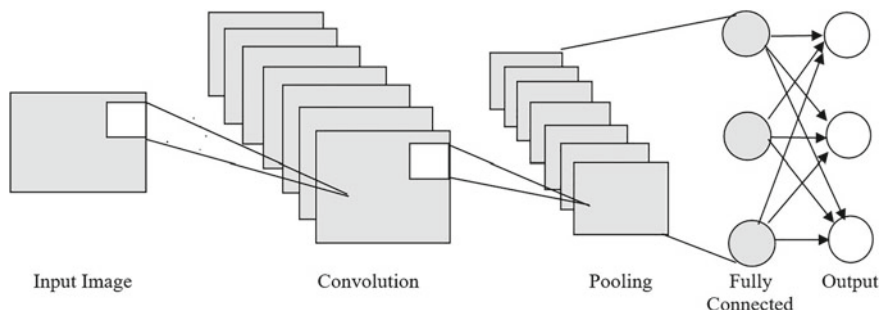


Fig. 2 Pooling process



**Fig. 3** General architecture of CNN

would compute the average of the features within the region. While both options are available, max pooling is generally preferred in practice.

Due to the fact that pooling is done through each layer in a 3D volume, and after pooling, the feature map's depth won't change. The chance of overfitting also reduces as there are less variables.

For instance: Consider one dataset after the output from the convolutional layer, and we have  $26 \times 26 \times 32$  volume; now using a max pooling layer  $2 \times 2$  and stride of 2, this volume is now reduced to  $13 \times 13 \times 32$  feature maps. Clearly, there is a significant decrease in the no. of parameters which is around 25% less from the original.

## 2.4 Fully Connected Layers

In fully connected layers, every unit (or neuron) in the presentation layer is connected to every other unit (or neuron) in the layer above it. The output of the convolutional layers is a representation of high-level features. The fully connected layer is a straightforward technique for learning nonlinear combinations of different features. It flattens the output of the previous layer and connects it to the output layer. More importantly, the convolutional layers provide fully connected layers in a low-dimensional, invariant feature space that can be used to train nonlinear functions. A 1-D feature vector is the output of the FC layer (Fig. 3).

## 3 Related Work

Some current FER methods use pattern recognition to separate different emotions based on face traits. These methods include approaches based on texture, geometric characteristics, appearance features, and hybrid approaches (which mix several types of information). The positioning of facial characteristics, such as the corners of the



eyes or the lips, or the style of facial features, such as the eyes, brows, or mouth, is used in geometric feature-based approaches. On the other hand, appearance-feature-based techniques rely on the texture of the facial picture, which is resistant to changes in lighting and misalignment [3, 4] used two techniques to carry out the demos. In the first, a two-level classifier (Gabor + NMF + Libsvm) is used to classify the filter image of each filter after decomposing it using principle component analysis.

We experimented with several CNN settings and designs in addition to Sabrina Begaj et al. [3] exploration of the difficulties of emotion recognition datasets. Ali Osman Topal et al. [3] have used ICV MEFED as the main dataset. The three main steps when using the deep learning approach are deep feature learning, deep feature categorization, and pre-processing. The first CNN network to go online consisted of two fully connected layers, one dropout, four convolutional layers, four max pooling layers, and four convolutional layers. Until yet, the algorithm has performed best at identifying emotions of joy and worst at identifying emotions of contempt. According to CNN, the FER2013 dataset’s accuracy is 91.62% (Fig. 4).

Two convolution layers with dropouts between each convolution layer are used in proposed model [5]. The first convolution layer is fed a resized input image. The output of the convolution layer, called the activation function, is transmitted through the feature map. Use of the Rectified Linear Unit (ReLU) activation function results in the reduction of the negative values to zero while maintaining the positive values. The pooling layer receives this feature map, which minimizes the size without sacrificing the data. The introduction of a dropout layer helps to lessen overfitting. The convolution layer is then added, and so on. Ultimately, a 2-D array with a small number of important feature values is produced. The 2-D objects are converted using a flatten layer.

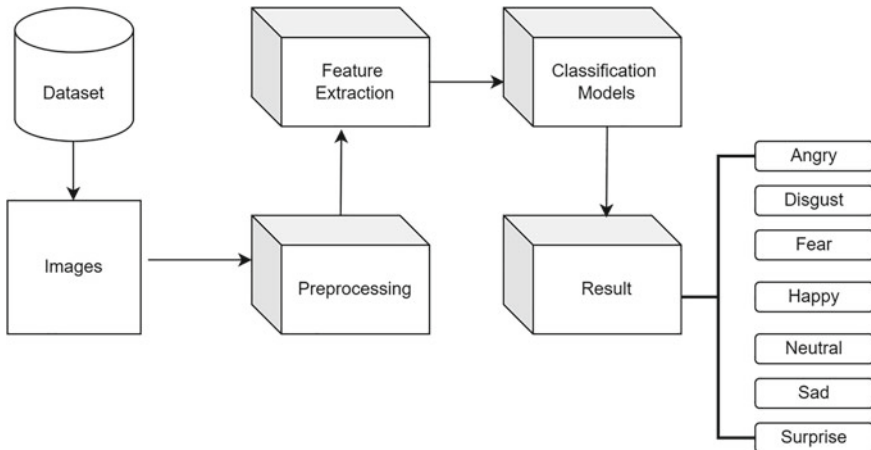


Fig. 4 Basic emotion detection process from images

## 4 Comparative Results

A comparative study of various facial emotion recognition models using CNN typically involves evaluating the performance of different CNN architectures on a standardized dataset for facial emotion recognition task. Some popular datasets used for this task include FER2013 [6], CK + [7] and JAFFE [8]. The evaluation metric used to compare the models can vary, but accuracy, F1-score, and AUC are some common ones. The field of facial expression recognition has seen encouraging results from deep learning-based methods, particularly CNNs. However, depending on the type of dataset and the hyperparameters utilized in each model, the performance of these models may differ. The datasets utilized in the FER method are described in Table 1.

Table 2 Comparative survey of accuracies of various models used for FER:

**Table 1** Datasets used for FER

| Datasets        | Descriptions  | Emotions   |
|-----------------|---|--|
| CK+ [7]         | 593 expressions in posed and unposed videos   | 6 basic emotions along with neutral and contempt         |
| FER2013 [6]     | 35,887 photos in grayscale were found online  | Neutral along with 6 elementary emotions                 |
| JAFFE [8]       | 213 grayscale images constituting expressions by 10 Japanese females                  | Neutral and 6 elementary emotions                        |
| KDEF [9]        | Contains a total of 4900 images of human facial expressions                           | Neutral and 6 elementary emotions                        |
| SFEW [10]       | 700 photos were used, each having a unique age, lighting, head posture, and occlusion | Neutral and 6 elementary emotions                        |
| MultiPie [11]   | More than 750,000 images recorded under 19 illumination conditions and 15 views       | Happy, Neutral, Disgust, Squint, Surprise, Scream, Anger |
| AffectNet [12]  | More than 440,000 images collected from the web                                       | Neutral and 6 elementary emotions                        |
| RAFD-DB [13]    | 30,000 images from real world   | Neutral and 6 elementary emotions                        |
| Oulu-CASIA [14] | 2880 videos recorded in 3 different lightning conditions                              | 6 elementary emotions                                    |
| MMI [15]        | 2900 videos, indicating neutral, apex, onset, and offset                              | Neutral and 6 elementary emotions                        |

**Table 2** Accuracies of various models

| Reference | Datasets  | Issues   | Accuracy (%) |
|-----------|---|--|--------------|
| [16]      | KDEF [7]  | Less amount of training data was used  | 88           |
| [17]      | FERC-2013   | Accuracy can further be improved   | 70.14        |
| [18]      | Manually collected static images  | Anger and fear emotions were not efficiently recognized                              | 75           |
| [19]      | CK + [9]  | Results in misclassification of few emotions   | 92.81        |
| [5]       | Using a 48 MP camera, five different facial expressions were carefully recorded | Limited number of emotions (only 5) are classified                                   | 78.04        |
| [4]       | JAFFE [8]   | Two face features—the lips and eyes—are all that are used to determine the outcome   | 78–95        |
| [20]      |   | Poor accuracy compared to higher light intensity in cases of inadequate illumination | 86.7         |

## 5 Conclusion and Future Work

Facial expression detection feature is being implemented in various industries these days, which was initially confined to the computer vision field. With the advancement in technology, robots are becoming more intelligent and are utilizing this feature to identify humans more correctly. Various techniques have been proposed to tackle this issue. Upon reviewing various research papers, it has been found that the facial emotion recognition techniques based on CNN have the highest accuracy rate ranging from 93 to 98%. This technique has demonstrated more benefits over existing FER techniques. FER is also limited to learning only the 6 basic emotions plus neutral which conflicts with what is more evident in everyday life, which constitutes even more complex emotion types. It is evident that researchers still need to push their research into unexplored area to build bigger databases and to create more impactful deep learning models that can identify all basic and secondary emotions. Computational cost and accuracy, both these factors, will continue to be the primary factors during the development of a better facial expression detection system. In the near future, a new emotion recognition technique could be proposed which could identify emotions in different scenarios and eliminate various types of noises.

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# A Novel Approach to Minimize the Energy Consumption Using Task Scheduling in Cloud Data Centers



J. Praveenchandar, V. JaganRaja, V. Prabhu, and G. Kumaran

**Abstract** Data centers play an important role in the modern computational virtual environment. The data center is made up of servers, storage devices, cooling equipment's, and power delivery equipment's to deliver general services such as platform-as-a-service (PaaS), software-as-a-service (SaaS), and infrastructure-as-a-service (IaaS). In this aspect, all the devices are generating more heat since all are electronics devices. It increases the power consumption and carbon emission in the environment also. As a result, it may lead to be a part of possibility of global warming. So, the carbon emission should be minimized in the entry level. In this paper, it is achieved this with the help of task scheduling. To minimize the same and improve the efficiency, we have tested three task scheduling algorithms: TPPC, RASA, and PALB. The experimentation results of all are these algorithms are compared, and then the differences in terms of efficiency and carbon minimization are also analyzed. The results are given in the comparative analysis.

**Keywords** Power consumption · Carbon emission · Resource allocation · Improving stability

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## 1 Introduction

Cloud computing is the most recent technology that allows applications and resources to be managed and shared in a safe and cost-effective manner. It is typically accessed over the Internet. Three key services that can be delivered in Public, Hybrid, and Private clouds are software-as-a-service (SaaS), platforms-as-a-service (PaaS), and infrastructure-as-a-service (IaaS). Cloud computing has been employed in a variety of industries, including physical computing equipment, to reduce power consumption and, as a result, IT expenses through virtualization, dynamic, and clustering setup. Cloud computing has made its way into the IT business in order to conserve energy and increase efficiency through the expansion of IT. It is a framework for facilitating easy and on-demand access to shared resources in large-scale distributed computing. This advantage has resulted in the unregulated global expansion of large-scale data centers, resulting in higher power consumption, higher operating costs, and more CO<sub>2</sub> emissions. CO<sub>2</sub> emissions in cloud data centers represent the amount of carbon dioxide (CO<sub>2</sub>) released into the atmosphere as a result of these data centers' energy consumption and operations. Cloud data centers are enormous buildings that house a large number of computers, networking equipment, and storage systems to support the storage, processing, and dissemination of digital data and services. The energy sources utilized to power and cool the infrastructure are the key contributors to CO<sub>2</sub> emissions in cloud data centers. Data centers require a substantial quantity of electricity to run its servers and keep the temperature and humidity levels at acceptable levels. The energy utilized in these facilities is frequently supplied by the electrical grid, which can be fueled by a variety of energy sources like coal, oil, and natural gas. CO<sub>2</sub> is produced as a byproduct when fossil fuels are burned to generate power.

CO<sub>2</sub> emissions from data centers can vary based on factors such as the facility's energy efficiency, the energy mix used in the region, and the cooling technologies used. In recent years, efforts have been undertaken to lessen the environmental impact of cloud data centers. Many data center operators are integrating energy-efficient technologies, optimizing cooling systems, and powering their buildings with renewable energy sources. Some cloud companies have also pledged to be carbon neutral or to use 100% renewable energy in their data centers. However, due to factors such as varying energy sources, operating practices, and data center locations, precise and up-to-date statistics on the exact CO<sub>2</sub> emissions of individual cloud data centers might be difficult to get. Furthermore, data centers have an impact on the overall energy usage and carbon footprint of cloud computing, as do the devices and networks used by end users to access cloud services. As a result, power management has emerged as a critical challenge in large-scale cloud computing systems.

This paper is primarily concerned with cloud computing, and we are assessing three task scheduling algorithms. These evaluations are carried out on the cloud simulator, in which three methods are assessed using simulation parameters based on three fundamental factors: power consumption, carbon emission, and efficiency. The purpose of this research is to investigate the task scheduling algorithms RASA, TPPC,

and PALB in order to identify the most effective task scheduling algorithm among the three and differentiate that algorithm in order to achieve three parameters: a reduction in carbon emissions, a reduction in power consumption, and an increase in energy efficiency. This entire procedure is known as simulation. Because this simulation was performed in a cloud environment, it is referred to as Cloud Simulation. We have three factors in this work: reduced power usage, reduced carbon emissions, and increased energy efficiency. The three job scheduling algorithms are used in the cloud simulator using these settings, and the results are calculated, noted, and distinctions between these three parameters are made. We shall get the simplest scheduling method based on the outcomes of the difference between scheduling algorithms. And the three algorithms are described in detail. RASA stands for resource awareness scheduling algorithm. It is a hybrid of the Min–Min and Max–Min algorithms.

This work scheduling technique was divided into three stages. The phases are initialization, second phase, and final phase. The expected response time for each VM will be determined in the first step. The efficient VM will be discovered in the second phase. Two-Phase Power Convergence Algorithm is the second algorithm. It is specifically designed to reduce system power usage. It is the Round-Robin optimization version. This job scheduling technique was divided into two phases: the scaling-down phase and the scaling-up phase. If the average workload is less than the scale-down threshold, the VM will be moved from the current server to another server, and the server will be shut down. In the scale-up phase, if the average workload exceeds the scale-up threshold, it signifies that the number of requests is more than the number of servers available. Then, VMs will be relocated from high-workload servers to recently booted servers. The third PALB algorithm is power-aware load.

## 2 Related Work

In this section, different methods and approaches to minimize the CO<sub>2</sub> emission in a real-time data center are analyzed. In Aldossary et al. [1] present a multi-level strategy based on a mixed-integer linear programming (MILP) model to reduce data center CO<sub>2</sub> emissions by optimizing resource consumption and VM placement in fog-cloud situations. This method calculates the CO<sub>2</sub> emissions of the British Telecom (BT) network using carbon intensity data from the National Grid ESO and multiple traffic demand scenarios at various times of the day and year. The findings demonstrate that the best site to host applications is heavily influenced by carbon intensity and traffic demands. The results also suggest a trade-off between reducing CO<sub>2</sub> emissions by shortening network journeys and increasing CO<sub>2</sub> emissions by hosting more apps in fog nodes. Benblidia et al. [2] discuss a microgrid-cloud architecture, and they simulate a two-stage optimization strategy. In the first stage, they imagine that cloud data centers are operated by several providers and attempt to obtain as much electricity as possible from the microgrid, store this energy, and execute as many user applications as possible.

To reduce the risk of blackouts and power outages, such power behavior necessitates optimal power allocation from the microgrid. As a result, the massive power requirement of the data center was modeled as a non-cooperative game. The microgrid controller determines the ideal power for each data center based on its power demand effectiveness (PUE), quantity of real-time applications, and network bandwidth demand. In the second step, microgrids attempt. Beloglazov et al. [3] present a resource management policy for virtualized cloud data centers that is efficient. The goal is to continuously condense VMs via live migration and turn off inactive nodes to save power consumption while maintaining the appropriate Quality of Service. They report evaluation findings demonstrating that dynamic reallocation of VMs saves significant energy, justifying continued development of the suggested policy. Prathiba et al. [4] propose a method to reduce the energy usage of computer resources in a cloud data center. Architecture has various entities, which are detailed in the relevant sections. The suggested architecture conserves energy by grouping comparable client requests and turning off ideal resources in the cloud data center. The suggested architecture is a resource management paradigm for cloud data centers that is efficient in terms of energy consumption. Dong et al. [5] the current VM placement strategies are primarily intended to reduce energy consumption by optimizing the utilization of physical server or network elements, but the issue of aggressive VM consolidation is overlooked, potentially resulting in network performance degradation. To address the issue, this paper proposes a VM placement scheme based on a new two-stage heuristic algorithm that optimizes network performance while reducing energy consumption of physical servers and network elements, allowing the trade-off between energy efficiency and network performance to be achieved.

Tian et al. [6] examine the power-aware scheduling of real-time VMs using defined processing intervals. Finding the ideal method of minimizing the total number of PMs is NP complete in the situation of all VMs sharing random sections of the overall capacity of a Physical Machine (PM), as proven in several open journals. As a result, they characterize the problem as a modified interval partitioning problem to provide approximate solutions and propose scheduling techniques to reduce power consumption. Depoorter et al. [7] have given the many of these measures' potential which is frequently strongly tied to climate conditions, and the location of data centers can have a significant impact on their energy demand. Furthermore, when accounting for the electrical qualities from the grid, regional variances become much more significant. To analyze these discrepancies, that work compares the behavior of a data center located at different sample locations in Europe using energy metrics. To that end, a dynamic energy model incorporating free cooling and photovoltaic energy is created. The article concludes by recommending that future data center developments examine site selection as a new technique for reducing the environmental effect of this industry.

Uddin et al. [8] discuss the servers and other equipment use a lot of power and produce a lot of CO<sub>2</sub>. In a typical server system, 30% of the servers are 'dead' and just use energy, although these servers are underutilized, with utilization ratios ranging from 5 to 10%. The authors provide a new algorithm for appropriately managing and categorizing the workload of various underutilized volume servers in

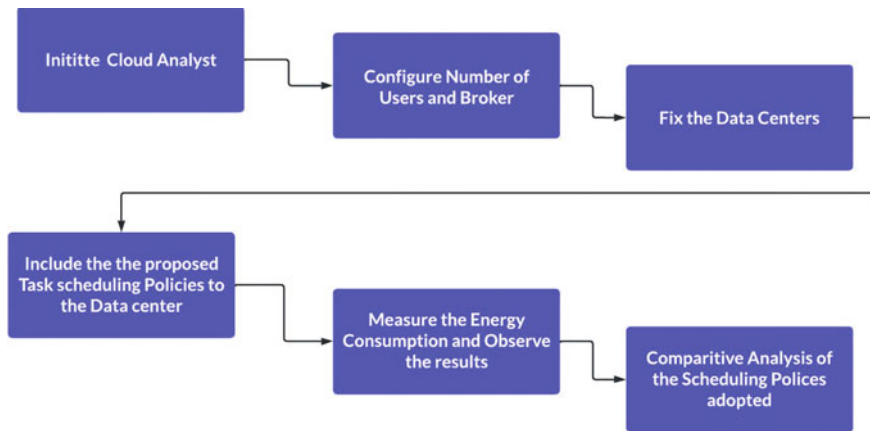


order to boost their utilization capacity. The suggested algorithm aids in the application of server consolidation methods and raises the utilization ratio of underutilized servers by up to 50%, resulting in significant power savings and an 88% reduction in greenhouse gas emissions. Maaouia et al. [9] summarize the most well-known findings in the literature on the reduction of energy consumption in both traditional cloud computing and volunteer cloud computing. Thilagavathi et al. [10] suggested a method which uses a nature-inspired Modified Bacterial Foraging Optimization Algorithm (MBFOA) to balance load and decrease eco-conscious energy costs. To determine the efficacy of the proposed MBFOA algorithm, simulations were run. The approach efficiently minimizes the system's eco-aware power cost compared to the baseline methods. Çavdar et al. [11] identified the primary facilitators of green data center research. First, they are analyzing the green indicators that are relevant to data centers. Following that, they summarize the most recent stage of study and provide a taxonomy of relevant work. They focus on computing and networking proposals for green data centers, while they briefly discuss additional green data center studies such as cloud computing and cooling. Katal et al. [12] clearly describe different strategies to minimize energy consumption at each level, which definitely adds value to the current environmental problem of pollution reduction. This article also discusses the challenges, issues, and requirements that cloud data centers and cloud businesses must understand, as well as some of the elements and case studies that affect green cloud adoption.

### 3 Methodology

The data center's growth has occurred as a result of advancements in information and communication, resulting in a huge increase in power consumption and a detrimental influence on the environment due to extremely high CO<sub>2</sub> emissions. Efforts had been made to reduce power consumption, implementation costs, and load imbalance. Previous scholars used various algorithms, methodologies, frameworks, and models to take various aspects of this issue into account with the goal of reducing power usage, cost, and CO<sub>2</sub> emissions. The amount of policy decisions made in terms of a virtual cluster is analyzed and contrasted in order to reduce operating costs. To examine cloud computing technology, a thorough analysis of cloud computing and its benefits is performed, and the results show that cloud technology allows knowledge communication regardless of time and place.

A greenness effect is proposed in a multi tier system to identify the causes on power wastage. Furthermore, an infrastructure is necessary for evaluating the set of metrics. VM migration methods and server consolidation frameworks are being explored in order to provide optimized VM migration techniques that reduce power usage and carbon emissions. And these algorithms are classified based on these parameters. Power efficiency, cost-effectiveness, and CO<sub>2</sub> emissions are all factors to consider. And by calculating the differences between different algorithms based on parameters, we can obtain an efficient algorithm. All of these processes are referred



**Fig. 1** Data flow processing

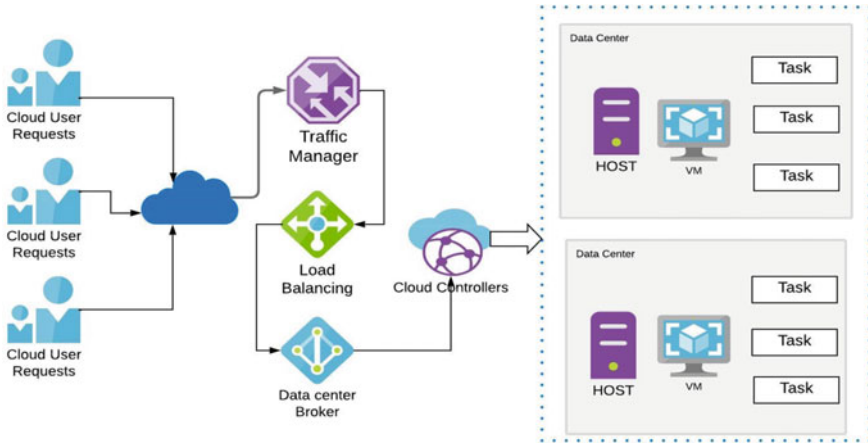
to as simulation. Because the process is carried out on the cloud, it is referred to as a cloud simulator.

We can cut power usage, carbon emissions, and boost energy efficiency by using these task scheduling methods. The feasibility of the project is immediately assessed, and a general plan for the extension and a few bids are advanced (Fig. 1).

The suggested framework's practicality must be investigated during framework analysis. This can be done to guarantee that the suggested framework will not be a burden to the organization. Understanding the various framework requirements is essential for feasibility analysis. This is built on job scheduling algorithms in cloud simulators and other low-cost tools, making it financially feasible to carry out. This paper is based on task scheduling algorithms and the application of these algorithms to improve the efficiency of cloud data centers that are feasible with present technology.

This research work implements a work scheduling algorithm to reduce carbon emissions, power consumption, and boost efficiency for the advancement of cloud data centers. In the basic setup, we introduced user bases based on region, such as UB0–UB5. Furthermore, user bases include the request per user per hour, data size per request, and average peak users. In addition, the major setup includes service broker policies and data centers. We must configure the data centers in the primary configuration under Data center configuration. The name, region, VMM, Arch, cost per VM, OS, and memory cost are all parts of the configuration. Finally, the advanced phase of configuring simulation includes the scheduling policy, where we must add the three algorithms TPPC, RASA, and PALB. After initialization, we must run the simulation to obtain cost and response time reports.

The TPPC algorithm's working model is depicted in Fig. 2. The job scheduling algorithm is divided into two phases: scale-down and scale-up. Getting to the first stage in the scale-down phase, if the average workload is less than a scale-down threshold (0.25), the VM will be transferred from the current server to another server, and the server will be shut down. The following step is the scale-up phase. If the



**Fig. 2** Proposed system architecture

average workload exceeds the scale-up threshold (0.70), VMs will be transferred from higher workload servers to recently booted servers. Task scheduling is an important aspect of cloud computing since it plays a significant role in it. Specifically, in scheduling, jobs should be ordered in such a way that balance increases the quality of services while retaining efficiency.

## 4 Task Scheduling Algorithms

As we mentioned in the paper, there are three task scheduling algorithms which are being used. Workload along with efficient PM utilization is the main determinants of power consumption in a cloud data center. Two Phases Power Convergence (TPPC) algorithm is adopted to reduce the power utilization of the system.

### (i) *Two Phases' Power Convergence*

This technique, which is an improved version of the Round-Robin technique, can be used to produce higher CPU utilization, a wider range of process times, and reduced power consumption, according to comparative analysis and results [14]. It was suggested that the servers' power consumption can be taken into account when balancing the virtual machines running on them. The power management algorithms include TPPC. This algorithm employs a two-phase strategy, scaling phase and balancing phase. This algorithm comprises three phases: the independent starting phase, the scaling phase, and the balancing phase. However, other components will be used in alternate fashion in order to effectively utilize booted PMs by limiting the amount of booted hosts. Based on utilization level, TPPC can be used to scale the power consumption of cloud data centers. By equitably allocating computer resources among PMs, TPPC seeks to increase resource utilization.

(ii) *Resource-Aware Scheduling Algorithm*

The Min–Min and Max–Min approaches are combined in the RASA algorithm [13]. With respect to the total number of VMs in the data center, these two procedures are to be applied. If the number of VMs is odd, Min–Min will be used; otherwise, Max–Min will be used to give the first job. This algorithm’s structure can be declared using an example. In the event that a data center has five VMs available, Min–Min will be utilized to allocate the first task and Max–Min for the subsequent round. The last job will be assigned after these two approaches have been used alternately. As a result, tasks that take a long time to complete would not be missed because of shorter-duration chores, and vice versa. By allocating the most effective resource, you can reduce the amount of time it takes for activities to be completed overall. This raises the degree of efficiency.

(iii) *Power-Aware Load Balancing Algorithm*

All computer nodes can have their states maintained by this approach. According to how much power the servers use, the PALB algorithm can be used to distribute the load among the VMs. This algorithm, which belongs to the category of power management algorithms, will take many factors into account while determining if the number of servers is below a given threshold [15]. Otherwise, VM would not start until the workload attained threshold for all servers has been reached. This approach, which is based on the VM load balancing technique, is strong and effective. Based on the VM’s request size, this technique would assign the VM to an active PM with the capacity to host it. A compute node that is powered off will be active to host the virtual machine if the active computing node is insufficiently resourced to do so. Nevertheless, this approach aims to reduce power consumption by turning off idle processing nodes. The three key portions of PALB are the upscaling, balancing, and downscaling sections. The lowest utilization value will be used to choose which new VM will be instantiated on PM in the balancing portion.

Using the TPPC algorithm, an efficient job scheduling strategy should aim for a shorter response time. The jar file can be used to open the Cloudsim. CloudSim is made up of the data center, data center Broker, VM, and host. The data center is made up of several hosts, and the hosts will manage the virtual machine. It functions similarly to an IaaS provider, taking VM requests from the data Center broker and creating the VMs in hosts. And the data center broker acts on behalf of the user and performs only two functions: submitting VM processing requests to data centers and submitting tasks to VMs. And hosts perform VM management tasks such as updating task processing on VMs. And hosts perform VM management tasks such as updating task processing on VMs. When it comes to VMs, they represent a software implementation of a computer that functions similarly to a physical machine. Each virtual machine splits the host’s resources among the tasks that are running out. Specifically, in scheduling, jobs should be ordered in such a way that balance increases the quality of services while maintaining efficiency. And resources include storage, RAM, data, costs, and so on.

## 5 Experimentation

In experimentation part, we analyze the efficiency metrics of this approach after it adopts to the cloud system. We must obtain the Cloudsim libraries from the Internet and import them into Eclipse.

And now, under `cloudsim.ext.data center`, add a new algorithm, and under `cloudsim.ext.data center`, create a string in `constant.java`. As a result, under `cloudsim.ext.gui.screen`, add a task scheduling policy to `ConfigureSimulationPanel.java`. Now, add the simulation to `Data centerController.java` in `cloudsim.ext.data center`. Now that the algorithm process has been completed, we can run the code in eclipse and access the cloud analyst panel to configure the most configuration and data center configuration. The input comes from configuration simulation and includes the main configuration, data center setup, and advances. The user bases and data centers must be added in the primary configuration. And we must configure the names, region, request per user, data size per request, and average peak users in data center configuration. All of these are handled by the cloud analyst.

When we integrate these data into the cloud analyst and run the simulation, we get the output as data centers sharing to the user bases in a network manner, and the simulation reports' dialogue box appears, displaying the overall response time, data center processing time, data center loading, and overall cost.

Figure 3 represents the cloud analyst simulation environment and Fig. 4 gives some of the configuration setup made during the implementation of the proposed algorithm in simulation. The test strategy in this proposed approach is to evaluate the three task scheduling algorithms on three different bases. The first is energy efficiency. The second is cost-effectiveness, and the third is the amount of CO<sub>2</sub> emitted. From the results, the following analysis is made.

Tables 1 and 2 give the output values of the simulation results and from which we could clearly understand the power consumption and cost analysis of the taken

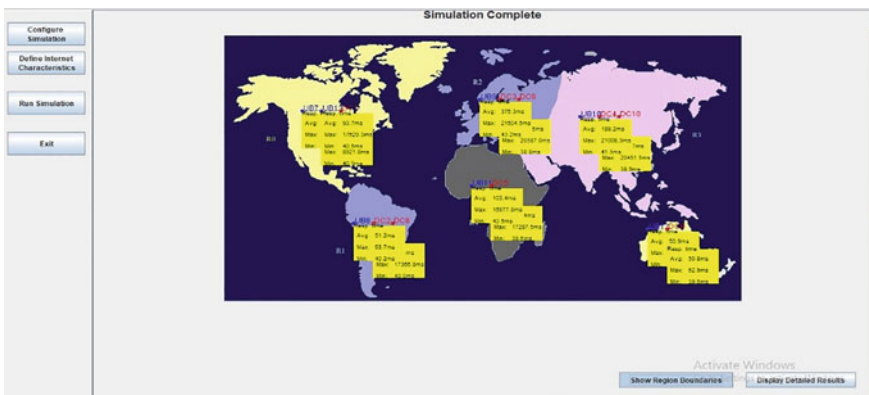


Fig. 3 Simulation environment

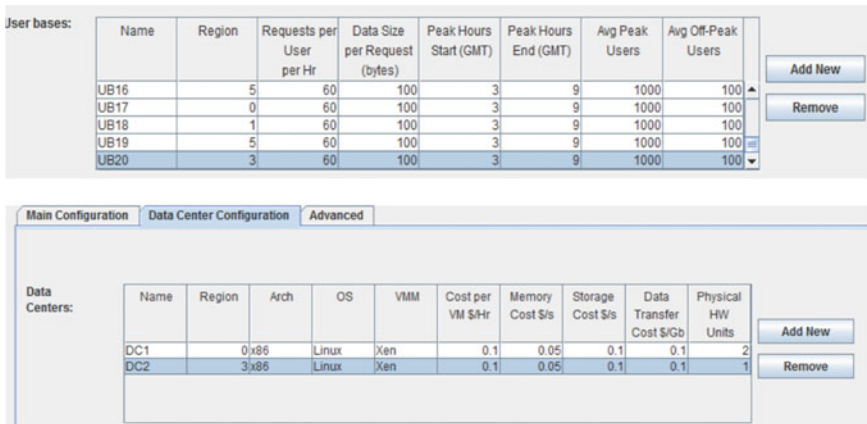


Fig. 4 Cloud analyst configuration

three algorithms. Figure 5 represents the overall comparative analysis of the three approaches in terms of power consumption, cost, and resource utilization. Considering the power consumption compared with other approaches, the TPPC got the optimum results, and in terms of utilization cost compared with other scheduling algorithms, PALB got the minimum results. After the simulation completes, the number of VM usage is also measured. In this aspect, all three algorithms are utilizing the same number of VM which is two each.

Finally, the power consumption of each scheduling algorithms compares each other since our ultimate aim is to minimize the power consumption by reducing the CO<sub>2</sub> in a cloud data center. In this aspect, comparing with other two algorithms, the TPPC scheduling algorithm gives the better results. But while adopting this algorithm to a real-time cloud data centers, some limitations and constraints need to be addressed. That will be analyzed and addressed in the future research works.

Table 1 Power consumption

| Algorithm | Power consumption (Kwh) |
|-----------|-------------------------|
| RASA      | NA                      |
| TPPC      | 2.85                    |
| PALB      | 205.24                  |

Table 2 Cost analysis

|                    | RASA | TPPC | PALB |
|--------------------|------|------|------|
| Cost (\$)          | 2534 | 456  | 282  |
| Total VM used      | 2    | 2    | 2    |
| Resource usage (%) | 98   | 21.7 | 13.2 |

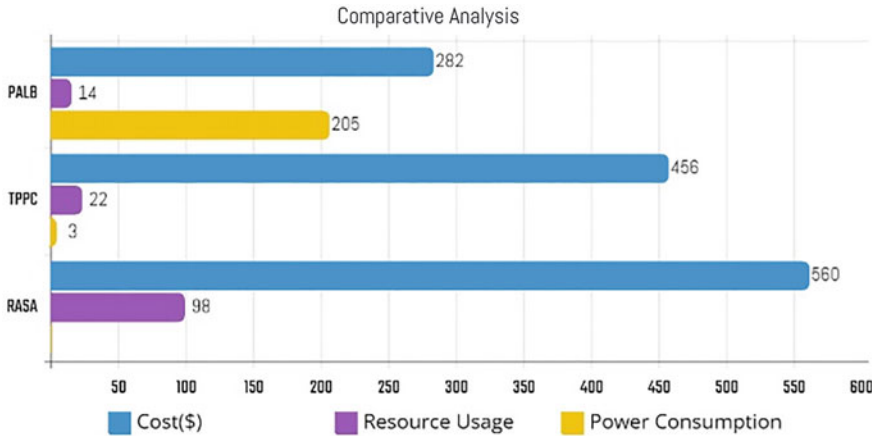


Fig. 5 Comparative analysis

## 6 Conclusion and Future Work

In this research work, the comparative analysis of three scheduling algorithms is done. Out of three algorithms in TPPC task scheduling algorithm, we achieve the best results in terms of power minimization, reduced carbon emissions, and increased efficiency. The methods investigated in the experimentation achieved the goal of performance improvement in data centers. The domain has a very broad scope and the experimentation can be upgraded concerning different task scheduling algorithms to enhance as per the future requirements. Also, we can gain further minimization into the data centers by adopting the advanced and more efficient cooling equipment available in the market, which can be achieved by altering code in Cloudsim-associated Eclipse IDE.

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# The Impact of Antidepressants in Tech Industry by Medical History and Interpersonal Factors: A Systematic Review and Meta-analysis



Diya Gandhi, Manishka Pareta, Samarth Varma, and Pratiksha Meshram

**Abstract** This research paper gives a systematic and comprehensive review and meta-analysis, investigating impact of antidepressants on tech industry employees with a specific focus on their medical history and inter-personal factors. Depression presents itself as a mental health disorder marked by persistent feelings of sadness, hopelessness, and a diminished interest or enjoyment in everyday activities. It is commonly accompanied by physical and cognitive symptoms. Developing predictive models for depression is essential for early intervention, reducing stigma, allocating resources efficiently, providing personalized treatment, and advancing research and understanding of the condition's underlying mechanisms, mental health conditions. Additionally, 71% of tech workers acknowledged that their productivity suffers due to mental health issues, while 57% of employees within the tech industry reported experiencing burnout. This is why the subject of mental health in the tech industry should not be ignored, and hence, it is important for us to analyze the effect of antidepressants in this industry. And hence by examining relevant studies and research papers, we aim to provide a systematic and detailed analysis of the relationship between use of antidepressants, medical history, and their outcomes on specific parameters in tech employees.

## 1 Introduction

### 1.1 A Subsection Sample

Please note that the first depression impacts an individual's cognition, emotions, and day-to-day functioning, frequently hindering their capacity to engage in regular activities and sustain relationships. Recognition of mental state (stress, anxiety, or depression) of a person is an important subject of research to avoid any unfortunate happening [5].

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Common symptoms of depression include: Persistent feelings of sadness, emptiness, or hopelessness, loss of interest or pleasure in activities once enjoyed, mental health can be influenced by one's physical health [12].

Depression can manifest in diverse ways, impacting appetite and weight and leading to significant changes in eating patterns. Sleep disturbances, such as insomnia or excessive sleeping, often accompany this condition. Feelings of worthlessness, guilt, or self-blame are frequent, along with difficulties in concentration, decision-making, or memory recall. Restlessness or irritability may also be present, and individuals might experience physical symptoms like headaches, digestive issues, or chronic pain that may not respond to standard treatments. Distressing thoughts of death or suicide can also be a part of depression.

It is crucial to recognize that the severity and duration of depression can vary from person to person. Some may experience isolated episodes, while others might encounter recurring bouts throughout their lifetime. Depression is a complex condition influenced by various factors, including genetic predisposition, imbalances in brain chemistry, hormonal fluctuations, traumatic life events, and other medical conditions. Treatment typically involves a combination of psychotherapy, medication, lifestyle adjustments, and support from loved ones.

If your acquaintance is showing symptoms of depression, seeking help from a mental health doctor is crucial. The depression in tech industry is a very important mental health concern as it is affecting substantial number of individuals worldwide. Depression can significantly impact the tech world, affecting individuals in multiple ways. It can lead to decreased productivity, difficulty concentrating, and a decline in overall performance. The social withdrawal and isolation associated with depression can strain workplace relationships, hindering effective communication and collaboration. The demanding and fast-paced nature of the tech industry can contribute to burnout, exacerbating the symptoms of depression and leading to exhaustion. Depression may also hinder career progression, making it challenging to take on new responsibilities or engage in professional development. Additionally, the stigma around mental health in some tech cultures can discourage individuals from seeking help and support. However, an increasing number of tech companies are recognizing the importance of mental health and implementing measures to create a supportive work environment. Individual initiatives, such as prioritizing self-care and seeking professional help, can also aid in managing depression in the tech world.

Almost 60% of the world population is in work [8]. Ensuring a safe and healthy work environment is a fundamental right for every worker. The World Health Organization (WHO) has identified depression as a universal mental disorder, impacting around 300 million individuals globally. This recognition has led to increased focus from health researchers on studying this area. However, distinguishing between anxiety, depression, and stress poses a significant challenge for machine learning algorithms, underscoring the need for a suitable learning algorithm to achieve precise diagnoses.

As per the World Health Organization (WHO), being healthy entails not only physical well-being but also having a healthy brain [15]. Shockingly, depression affects

over 264 million people worldwide, contributing to numerous suicides, particularly among young individuals.

Detecting mental disorders like depression poses a dilemma for physicians who often lack sufficient training in handling such cases. Community studies indicate that at least 50% of the general population experiences a mental disorder at some point in their lives, with approximately 20% acutely affected at any given time [24]. Surprisingly, despite psychological complications accounting for 70 care visits, over 80% patients with undiagnosed symptoms receive psychological treatment from physicians, while only 10% follow up with mental health professionals. This lack of proper care results in 70% people with depression remaining undiagnosed. Furthermore, among individuals attempting suicide, 90% had mental health problems, and 40% had consulted their physician within the last month.

In a JAMA publication, doctors compared patient results, monetary care costs, and other factors between those who received overt diagnosing and treatment for mental health during regular appointments versus those patients with no or irregular appointments. The results revealed that patients who received mental health intervention experienced reduced costs, better utilization of healthcare services, improved results of patients, decreased initial care doctor consultations, earlier initiation of treatment interventions, and reduced consultations and emergencies.

Antidepressant medications such as SSRIs, SNRIs, tricyclic antidepressants, MAOIs, Agomelatine, Mirtazapine, and other non-SSRIs antidepressants are commonly prescribed to manage the symptoms of depression on the patients [1]. However, the impact of antidepressants on tech employees based on their medical history is unclear and parameters such as sleep cycle, BMI change, sexual desire, suicidal behavior, and educational outcomes can be used to determine the effects of antidepressants. When evaluating depression in tech employees, several parameters can be utilized to gauge its presence and impact. While a formal diagnosis requires the expertise of a mental health professional, certain indicators can shed light on the situation. Performance and productivity should be considered, including a decline in work output, missed deadlines, and difficulties with concentration. Attendance and punctuality may also be affected, with increased absences or tardiness. Changes in interpersonal relationships, such as withdrawal, irritability, or conflicts, could suggest depression's influence on workplace dynamics. Self-isolation and a diminished desire to engage in social activities might also be observed. Evaluating emotional well-being involves observing for consistent emotions such as sadness, hopelessness, or irritability. Physical indicators like fatigue, alterations in appetite or weight, sleep disturbances, and headaches might also be evident. Furthermore, a decrease in motivation, creativity, problem-solving skills, or negative feedback from supervisors and colleagues could suggest the influence of depression. Although these measures are not diagnostic in themselves, they can trigger further assessment and the necessary support for tech employees dealing with depression. Encouraging professional assistance and offering mental health resources within the organization can contribute significantly to their overall well-being.

More than half the global workforce works in the informal economy [17], where there is no regulatory protection for health and safety. These workers often find themselves in hazardous working conditions, enduring long hours and lacking adequate financial protections, leading to discrimination, all of which can significantly impact their mental health.

Men have faced societal pressure to hide emotional pain, resulting in delayed help seeking behaviors. When men seek assistance, they may present physical symptoms like chest pain or engage in behaviors such as intentional self-harm or drug and alcohol abuse, which can mask their underlying emotional distress. However, symptoms of depression may go unnoticed when men expect physicians to discern the signs and symptoms without openly expressing their emotional struggles.

Suppression of emotional pain can also lead to an escalation of negative affect toward anger, triggered by negative external events [19].

In [20], it was revealed that similar work conditions were associated with a comparable increase in depressive symptoms among both men and women. Despite no gender differentiation in the heightened risk related to adverse work conditions, research indicates that women actually experience higher levels of job stress than men, potentially contributing to their higher prevalence of depressive symptoms. Additionally, work conditions may impact men and women differently, influencing the development of various major depressive disorders (MDD). Research has found a positive correlation between depression and white-collar occupations, leading to a decrease in work activities. While white-collar workers, in general, were less prone to reducing their work activities compared to blue-collar workers (as indicated in Table 2), those who had recently gone through a depressive episode were found to have nearly three times higher odds of reducing their work activities (specific data not presented). This distinction suggests that depression may have a more significant impact on activities that are more prevalent in white-collar jobs compared to other occupations [23].

In [13], the authors found moderate evidence linking the psychological demands of a job to the development of depression, with relative risks of approximately 2.0. However, this evidence may be weakened by the presence of publication bias. On the other hand, having social support in the workplace was linked to a decreased risk of future depression, with all four studies examining this connection showing relation with risks of approximately 0.6. Although this review has examined psychosocial factors (work-related) that reputable epidemiologic studies link to depression, additional research is necessary to explore the duration and intensity of exposure needed for the development of depression in greater depth.

With the rise of tools like artificial intelligence, the use of physiological data to explore potential new indicators of mental disorders and create new applications for mental disorder diagnosis has become a burgeoning research topic [4]. This systematic review and meta-analysis aim to gather existing evidence to gain an understanding of the effects of antidepressant use on the mental health of adolescents (Fig. 1).

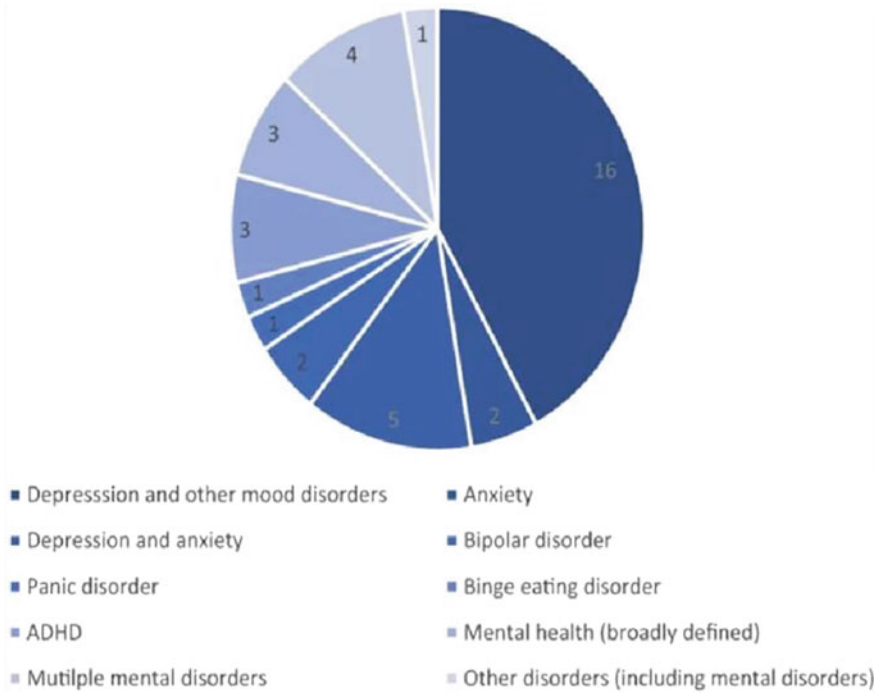


Fig. 1 Types of disorder

## 2 Literature Review

A literature review is essential for the study titled “The Impact of Antidepressants in the Tech Industry by Medical History and Interpersonal Factors: A Systematic Review and Meta-Analysis” for several reasons. As it allowed us to gain an understanding of the present state of knowledge on the topic. By reviewing prevalent literature, we identified what has already been studied, what gaps exist in the literature, and what research questions needed to be addressed.

### 2.1 Analysis of Different Algorithms

We have computed the Accuracy, F1 score, Recall, and Precision of various algorithms such as SVM, Decision Tree, Logistic Regression, Linear Regression, Random Forest, and KNN. The results are shown in the below figure (Table 1).

**Table 1** Comparison of algorithms

| Model               | Precision | Recall | F1 score | Accuracy |
|---------------------|-----------|--------|----------|----------|
| Logistic regression | 0.93      | 0.99   | 0.96     | 0.92     |
| Decision tree       | 0.93      | 0.92   | 0.93     | 0.86     |
| SVM                 | 0.91      | 1.0    | 0.95     | 0.91     |
| Random forest       | 0.92      | 1.00   | 0.96     | 0.92     |

## 2.2 Research Goal

Implementing integrated mental health services, as discussed in previous studies, can pose challenges for many clinics and doctors. Establishing benchmark services that involve consistent mental health disorder screening and seamless treatment coordination among a group of physicians and psychological professionals can be costly and require extensive training and coordination among different healthcare providers, potentially leading to overwhelming situations. Additionally, logistical factors in some areas may make it impractical to follow such an approach.

The research goal of the study titled “The Impact of Antidepressants in the Tech Industry by Medical History and Interpersonal Factors: A Systematic Review and Meta-Analysis” is to examine how antidepressant medication affects individuals working in the technology industry, considering their medical history and interpersonal factors. The study aims to provide a comprehensive understanding of how antidepressants influence the well-being, productivity, and overall mental health of tech professionals, taking into account their specific medical backgrounds and social interactions. This literature review utilizes machine learning models to identify and summarize existing evidence concerning depression among tech industry employees. Similar works in the research domain focus on predicting mental illness using antidepressant and personal factors.

Although the works mentioned earlier bear some resemblance to our research, none of them have taken social interactions into account. While one of the reviewed works did touch upon social interactions, it was not entirely focused on detecting depression. In this regard, the primary distinctions between our literature review and similar works are as follows:

- (1) We extensively examine the most contemporary and relevant works.
- (2) We identify the social media sites that have been most frequently studied and the characteristics of the datasets used.
- (3) We determine the semantic feature extraction methods employed.
- (4) We analyze the machine learning models utilized.
- (5) We assess the computing tools applied.
- (6) We investigate the quantitative analysis methods most commonly considered for depression sign detection from digital platforms.

**Table 2** Comparison of dataset with machine learning algorithms

| Objective  | Sample size   | Method/M L classifier  | Method limitation   | Depression screening scale                                     | Result  |
|--|---|--|---|--|---|
| Instantaneous mood measurement using voice samples, mobile and social media data                                   | 202 (training), 315 (testing) participant’s data              | Moodable application with SVM, KNN, and RF   | Not feasible for larger datasets  | PHQ-9  | 76.6% Acc   |
| Diagnosis of depression using various psychosocial and socio-demographic factors                                   | 604 Bangladeshi citizen                                       | KNN, AdaBoost, GB, XGBoost, Bagging. Weighted voting with SelectKBest, mRMR, Boruta feature selection, and SMOTE     | No use of any biological marker and only BDC was considered as ground truth for diagnosis | Burns depression checklist (B DC)                              | 92.56% Acc (AdaBoost with SelectKBest)  |
| An ML-based predictive model for early depression detection  | 6588 Korean Citizens (6067 non-depression and 521 depression) | RF with SMOTE, 10 fold cross-validation, AUROC   | Biomarkers were not included in the dataset   | CES D-II   | 86.20% Acc  |
| Use of linguistic and sentiment analysis with ML to distinguish depressive and non-depressive social media content | 4026 social media posts                                       | RF with REUEFF feature extractor, LIWC text-analysis tool, and hierarchical hidden markov model (IMM) and ANEW scale | All depression categories are taken as a single class for classification                  | Hamilton depression rating Scale                               | Acc% 90% depressive posts classification 92% depression degree classification 95% depressive communities classification |
| Logistics is less expensive computationally than neural network and easy to implement                              | 11,081  | LR   | –   | Need to use more datasets that are accepted by other countries | 90%   |

(continued)

**Table 2** (continued)

| Objective                                | Sample size | Method/M L classifier    | Method limitation   | Depression screening scale | Result                                   |
|--|-------------|--------------------------|---------------------|----------------------------|--|
| Predicting clinical depression           | 1148        | Logistic regression, SVM | –                   |                            | 81% for SVM, 92% for Logistic Regression |
| Student depression prediction using text | 3000        | KNN, logistic regression | More data is needed | –                          | 88% for KNN, 97% for logistic regression |

### 3 Methodology

#### 3.1 Analysis of Machine Algorithms for Depression Diagnosis

This section highlights the comparison table of supervised learning models used in other studies for diagnosing depression. In [22], Moodable is a mobile application that utilizes machine learning classifiers such as SVM, KNN, and RF to analyze voice samples, smartphone data, social media handles, and the Patient Health Questionnaire (PHQ-9) data. The aim of this framework is to assess an individual’s mood, mental health, and infer symptoms of depression. Impressively, the framework achieved a precision rate of 76.6% for depression assessment. This indicates the potential effectiveness of Moodable in providing valuable insights into a person’s well-being. By combining various data sources and applying machine learning algorithms, the application offers a comprehensive approach to mood assessment (Table 2).

However, it’s important to consider other evaluation metrics and seek professional evaluation to ensure accurate diagnosis and appropriate treatment recommendations. Moodable shows promise in supporting mental health assessment, but it should be seen as a tool rather than a substitute for professional care.

The researchers employed six machine learning classifiers in [9], namely KNN, Weighted Voting classifier, AdaBoost, Bagging, GB, and XG Boost, to make predictions regarding depression. To extract relevant features, they utilized feature selection techniques such as Select K Best, m RMR, and Boruta. In order to address imbalanced classes, they implemented the SMOTE technique. The dataset used for this study consisted of 604 individuals, encompassing sociodemographic and psychosocial data along with the Burns Depression Checklist (BDC) data. From their analysis, they observed a depression prevalence of 65.73%. The results indicated that the AdaBoost classifier, in combination with the Select K Best algorithm, achieved the highest classification accuracy, reaching an impressive 92.56%.

A machine learning model utilizing the Random Forest (RF) algorithm was developed in [14], to prognose depression among Korean adults. In order to address class



imbalance between the depression and non-depression classes, the SMOTE technique was applied. The CES-D-11 screening scale was employed for assessing depression, and hyperparameter tuning was conducted using tenfold cross-validation. The study incorporated data from a total of 6588 Korean citizens. The model achieved an Area Under the Receiver Operating Characteristic (AUROC) value of 0.870, indicating good predictive performance, and an accuracy of 86.20%. It's worth noting that this study did not include biomarkers in the dataset.

In the study [18], the author employed sentiment and linguistic analysis, along with machine learning techniques, to differentiate between depressive and non-depressive social content. They utilized Random Forest (RF) as the classification algorithm, combined with the RELIEFF feature extractor, the LIWC text-analysis tool, and the Hierarchical Hidden Markov Model (HMM) along with the ANEW scale. The analysis focused on examining 4026 social media posts. The results were promising, with an accuracy of 90% achieved in classifying depressive posts, 92% in classifying the degree of depression, and 95% in classifying depressive communities.

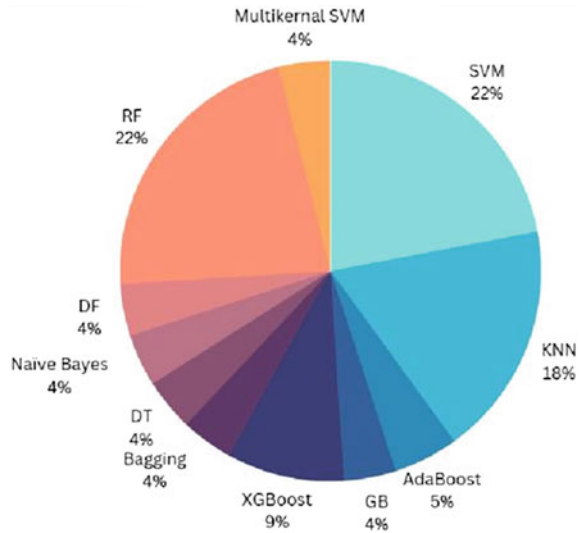
It is important to note that this study treated all depression categories as a single class. This means that the classification did not differentiate between various subtypes or severities of depression. While achieving high accuracy rates in the classifications mentioned, it would be beneficial for future studies to consider distinguishing between different depression categories to provide more comprehensive insights.

The combination of sentiment and linguistic analysis with machine learning techniques offers a valuable approach for identifying depressive content in social media posts. The use of RF, RELIEFF, LIWC, HMM, and the ANEW scale showcases the application of various tools and methods to extract meaningful information from textual data. These findings contribute to our understanding of depressive content in social media, highlighting the potential for early detection, intervention, and support for individuals experiencing depression.

The primary objective of the study was to evaluate the computational cost and ease of implementation between logistic regression and neural networks. Logistic regression, a statistical method, was chosen as the approach and applied to an extensive dataset comprising 11,081 individuals. By analyzing the results, the study revealed an important insight: there is a need to incorporate additional datasets that are accepted and acknowledged by other countries. This suggests that expanding the dataset to include a broader range of individuals from various countries would enhance the model's generalizability and applicability on a global scale. Furthermore, the logistic regression model showcased impressive performance, achieving an accuracy rate of 90%. This high accuracy level implies that the model's predictions aligned closely with the actual outcomes, bolstering its credibility and effectiveness.

The objective of the study was to develop a predictive model for clinical depression. To accomplish this, two machine learning algorithms, Logistic Regression and Support Vector Machine (SVM), were employed on a dataset containing information from 1148 individuals. The study's findings revealed that both models achieved substantial accuracy in their predictions. The SVM model attained an accuracy rate of 81%, while the Logistic Regression model outperformed it with an accuracy of 92%.

**Fig. 2** Comparison of classification models for depression diagnosis



These results indicate that Logistic Regression was more effective in accurately identifying and predicting clinical depression based on the given dataset. By employing Logistic Regression, researchers were able to successfully leverage its capabilities to improve the identification and prediction of this mental health condition, thereby contributing to the field of clinical depression research.

The main objective of the study was to utilize K-Nearest Neighbors (KNN) and Logistic Regression algorithms to predict Student Depression based on textual data. The researchers applied these models to a dataset comprising 3000 entities. The outcomes of the study indicated that the models required additional data to improve their performance further. The achieved accuracy for the KNN algorithm was 88%, while the Logistic Regression model demonstrated higher accuracy, reaching 97%. These findings highlight the superior predictive power of the Logistic Regression model in identifying Student Depression based on the provided text data. The study underscores the potential of utilizing Logistic Regression as an effective tool in predicting and understanding mental health conditions among students. However, the researchers also emphasized the need for a larger and more diverse dataset to enhance the model's generalizability and ensure accurate predictions across different populations (Fig. 2).

### ***3.2 Workflow of Depression Detection Model***

The depression data will be utilized for feature selection in the proposed model, as depicted in Fig. 3. Once the initial data processing is completed, the model will be trained using various machine learning approaches, including Naive Bayes,

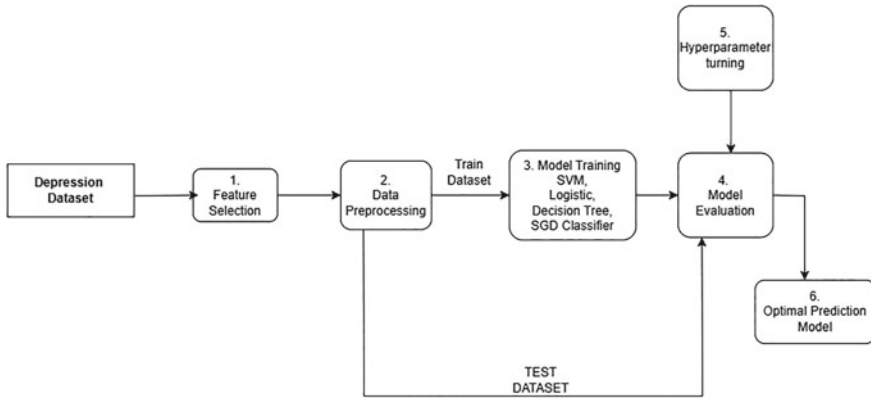


Fig. 3 Machine learning workflow

SVM, KNN, and Decision Tree. The questionnaire for the preprocessed data will be related to the Hamilton tool and will encompass non-negative attributes such as pet ownership and the presence of nearby parks. Additionally, the preprocessed data will include individual’s weekly comments.

### 3.3 Proposed Methodology

Ensemble methods are often considered effective for depression prediction (and many other tasks) because they leverage the collective wisdom of multiple models to make more accurate and robust predictions. Here are some reasons why ensemble methods are favored for depression prediction:

Ensemble methods combine several base models, reducing the risk of overfitting on the training data. Overfitting occurs when a model becomes too specialized in the training data and fails to generalize well to unseen data. By averaging or combining multiple models, ensemble methods can smooth out individual model biases and result in better generalization to new data. Different models might capture different patterns or relationships within the data. By combining their predictions, ensemble methods can exploit the diverse strengths of individual models and yield more accurate predictions overall. Depression prediction can be a complex task with various factors contributing to an individual’s mental state. Ensemble methods can effectively deal with model uncertainty by aggregating predictions from multiple models, providing a more comprehensive understanding of the problem. To be effective, ensemble methods require diverse base models that make different types of errors. This diversity helps to cover a broader range of possible patterns and reduces the chance of all models making the same mistakes.

Ensemble methods tend to be more stable and robust against fluctuations in the data and model choices. Even if one model performs poorly in certain situations,

the overall ensemble can still maintain its accuracy. In depression prediction, imbalanced data might be an issue, with a small number of people experiencing depression compared to those who don't. Ensemble methods can balance predictions from individual models and provide a more accurate representation of the entire dataset. In some cases, depression prediction might involve using multiple sources of information, such as text, images, social media activity, and physiological data. Ensemble methods can efficiently combine predictions from models specialized in different modalities, leading to a more comprehensive assessment.

It's important to note that while ensemble methods can enhance prediction performance, the success of the ensemble relies heavily on the diversity and quality of the individual base models. Additionally, the choice of ensemble technique, such as bagging, boosting, or stacking, can also impact the overall effectiveness of the ensemble. As with any predictive modeling approach, the quality and availability of data play crucial roles in achieving accurate depression predictions.

## 4 Methods

Data preprocessing in this project involved feature engineering, handling missing values, and scaling to improve model accuracy. For each model type, a base model was trained and fitted with actual parameters. Then, important parameters were selected for tuning using sklearn's GridSearchCV, and the perfect parameters were applied to execute the model. The tuned parameters were utilized to encompass the similar model using resampled data to assess correlations. Performance was compared between the base model and the tuned model for each type and across various model types. The F-beta score was used as the scoring metric, and evaluation was done with help of a classification report, confusion matrix, and ROCAUC plot.

Data for the project was sourced from the Centers for Disease Control and Prevention National Health and Nutrition Examination Survey, a comprehensive health data collection from a sample of the American population every two years. Data from the years between 2005 and 2018, consisting of 36,259 entries of US adults, were utilized. Only consistent data across these years was used, focusing on information commonly found in a patient's medical file. The aim was to achieve accurate predictions using minimal data to accommodate individuals with limited medical history and reduce the burden on healthcare providers.

The target variable was derived from the PHQ-9 depression screening tool, administered to all NHANES participants. A score of 10 or more on this screening tool indicated major depression, with a specificity and sensitivity of 88%. Participants were categorized as "depressed" or "not depressed" based on their screening tool scores.

The project employed various model types to identify the best performing ones and distinguish between different models. Following the OSEMiN process, the project began with simpler models and gradually progressed to more complex ones.

However, other parameters and values were also amalgamated in the dataset via following methods:

### **Data Resources:**

This section encompasses data resources gathered from employees who were observed for a week. During this phase, participants were requested to fully cooperate with the study and sign a detailed consent form indicating their willingness to participate. Following this, sufficient descriptive data was collected from those who willingly took part in the research. The researchers assessed the participant's depression scale, sociodemographic information, physiological data, and social contact through interviews. The study focused on poor mental health and medical history [25] primarily measured in terms of depression and/or anxiety, and its correlation with lost productivity, including absenteeism and presenteeism. However, one and only, the most significant mental disorders were thoroughly studied. The studies utilized questionnaires/surveys, administrative data, and regression analysis [7].

## ***4.1 Effects of Antidepressants***

### **1. BMI**

Initial empirical evidence indicates a possible connection between the utilization of particular serotonin reuptake inhibitors (SSRIs) and weight gain in overweight adolescents. This discovery emphasizes the importance of conducting further investigations into the impact of antidepressant use on weight increment in various pediatric populations.

Additionally, it is essential to conduct prospective studies to obtain more robust and conclusive evidence regarding this association. By conducting comprehensive research across diverse populations, we can gain deeper insights into the relationship between antidepressant medications and weight gain among young individuals. This knowledge will aid in making informed decisions regarding the use of SSRIs and help develop appropriate strategies to mitigate any potential adverse effects related to weight gain in pediatric patients [21].

### **2. Sexual Desire and Behavior**

The use of antidepressants during childhood has been linked to potential disturbances in the normal development of sexual desire, particularly in women, which can significantly affect solitary sexual desire. This underscores the critical need for well-controlled research to comprehensively investigate the impact of antidepressant use during childhood and adolescence on sexual functioning in adulthood. Such research is vital to empower patients and their loved ones to make informed decisions, carefully considering the known negative consequences of untreated mental health issues in comparison to the potential side effects of antidepressant use on future sexual desires.

By conducting comprehensive studies, we can gain a better understanding of the long-term effects of antidepressants on sexual functioning and ensure that patients receive appropriate guidance and support in managing their mental health while considering potential impacts on their sexual well-being in the future [11].

### 3. Suicide Attempt

In a comprehensive study encompassing a large cohort of adolescents from across the United States, the use of antidepressant medication was found to have no statistically significant impact on the probability of a suicide attempt. This finding emerged after adjusting for treatment allocation based on propensity and controlling for various other factors. The relationship between suicidal behavior and the use of antidepressants is a complex and multifaceted one, necessitating additional investigation. Further research is crucial to gain a deeper understanding of the dynamics involved and to explore potential contributing factors that might influence the association between antidepressant medication use and suicidal behavior in adolescents. By conducting thorough investigations, we can better inform clinical decision-making processes and develop appropriate interventions to address mental health concerns in this vulnerable population. It is imperative to continue studying this topic to ensure the safety and well-being of adolescents who may require antidepressant treatment, while simultaneously minimizing any potential risks associated with their use [16].

### 4. Educational and Health Outcomes

Children experiencing severe mental health conditions that necessitate the use of antidepressants exhibit unfavorable outcomes in various areas, including education and health. Specifically, in boys, although antidepressant use is less prevalent, it is associated with poorer outcomes. It is crucial to identify and support these affected children at an early stage to mitigate the risk of school absences or exclusion. By providing the necessary support, the aim is to minimize the potential long-term impacts on their employment prospects and overall health. Early identification and appropriate interventions are essential in ensuring that these children receive the assistance they need to thrive academically and maintain their well-being. Furthermore, targeted support can help alleviate the potential negative consequences associated with severe mental health conditions and antidepressant use, enabling these children to lead fulfilling lives and achieve better educational and health outcomes in the long run [11].

### 5. Quality of Life

The use of antidepressants in adolescents diagnosed with Major Depressive Disorder has shown positive effects on overall functioning. However, when examining the impact on quality of life (QOL), no significant positive outcomes were observed. Further analysis of specific subgroups revealed that Second Generation Antidepressants (SGAs), such as fluoxetine and nefazodone, were particularly effective in improving overall functioning. Conversely, First-Generation Antidepressants (FGAs) did not yield the same level of improvement.

These findings suggest that SGAs, specifically fluoxetine, escitalopram, and nefazodone, may be valuable options for enhancing the functioning of children and adolescents with MDD. However, it is important to note that further research is required to gain a deeper understanding of the impact of different antidepressants on both functioning and quality of life in this population. By conducting additional investigations, we can refine treatment approaches and optimize the therapeutic benefits for children and adolescents with MDD, ultimately improving their overall functioning and well-being [2].

## 5 Results and Recommendations

The depression class was particularly tricky to classify accurately. The classification of the depression class can pose significant challenges due to several intricate factors. Firstly, depression is a complex mental health condition that lacks objective measurements, making it challenging to define clear boundaries for classification. Diagnosis primarily relies on subjective symptoms and clinical assessments, which introduce subjectivity and variability into the classification process. Different individuals may experience and express depression in unique ways, leading to a wide spectrum of symptoms and manifestations that must be considered. Secondly, depression exhibits significant heterogeneity. This heterogeneity adds complexity to the classification task, as the algorithm needs to accurately account for the diverse presentations of depression. In addition, contextual factors play a significant role in depression classification. Environmental, social, and cultural influences can impact the expression and manifestation of depressive symptoms. These external factors can make it challenging to separate depression from situational distress or other factors influencing an individual's mental well-being. The algorithm needs to account for these contextual factors to improve classification accuracy. Another challenge is the lack of objective biomarkers for depression diagnosis. Currently, there are no definitive biological markers or laboratory tests that can conclusively diagnose depression. While research has identified potential biomarkers associated with depression, their use in clinical practice is limited. As a result, the classification of depression relies heavily on subjective assessments and symptom reporting, further adding to the complexity of achieving accurate classification. To address these challenges, machine learning algorithms can be employed to assist in the classification of depression. However, to improve accuracy, these algorithms must be trained on diverse and representative datasets that encompass the various dimensions of depression. Incorporating a comprehensive range of symptoms, severity levels, comorbidities, and contextual factors can help enhance the algorithm's ability to accurately classify depression.

Pretty much every model was able to accurately recognize over 80% of the true negatives. Mostly the almost perfect models were at determining the depressed class, the faulty they were at determining the non-depressed class.

### The Recommendations Are as Follows:

Healthcare professionals in white-collar positions should focus on developing themselves to better support patients with depression, especially by understanding and utilizing important features identified by the model. Presently, physicians largely provide initial care for patients with depression, but they should strive to enhance their skills to offer more effective care for these individuals. Some key characteristics that the model found to be crucial and showed a significant difference in those who are depressed are:

- Patients experiencing memory problems
- Individuals with lower income, limited education, and inability to work
- Those facing difficulties with sleep, such as insomnia or excessive sleeping

By recognizing and monitoring these features, healthcare providers can be more vigilant in identifying depression in their patients and providing appropriate support and treatment. **Machine learning algorithms are powerful generalizers and predictors [3]**, One of the key strengths of machine learning algorithms is their ability to generalize from a training dataset to make predictions on new, unseen data. By gaining knowledge from a diverse set of examples during the training phase, the algorithm captures underlying patterns and relationships in the sample. This allows it to make accurate predictions on new data that it has not encountered before. The algorithm essentially learns the general rules and trends that govern the data, enabling it to make informed predictions on similar instances. The predictive power of machine learning algorithms stems from their ability to extract relevant features from the data. Features are specific attributes or characteristics of the data that are informative for the task at hand. For example, in an image recognition task, features might include pixel values, color gradients, or texture patterns. By analyzing the data and identifying important features, the algorithm can make predictions based on these learned representations.

With the use of Python's scientific programming principles and machine learning methods like Decision Tree, K-Nearest Neighbor, and Naive Bayes, study results were analyzed. Additionally, a comparison of these techniques is done. Survey concludes that KNN has given accurate outcome than other techniques on the basis of accuracy and Decision Tree has given better outcomes with the respect to latency to determine the depression of a person. At the conclusion, a machine learningbased model is suggested to replace the conventional method of detecting sadness by asking people encouraging questions and getting regular feedback from them [6].

**Tree-based models are not the best for this task and linear models performed the best [15]**. One possible reason is that the relationship between the input features and the classification of depression may be better captured by a linear model. Linear models assume a linear relationship between the features and the target variable, making them suitable when the decision boundary separating depression from non-depression cases can be approximated well by a hyperplane. Additionally, linear models offer simplicity and interpretability, allowing for insights into the importance and direction of the influence of each feature. This interpretability can be valuable for



understanding the underlying factors contributing to depression. Furthermore, tree-based models, such as decision trees or random forests, may be more susceptible to noise and overfitting, particularly in high-dimensional datasets. Linear models, especially when combined with appropriate regularization techniques, can be more robust to noise and less prone to overfitting.

Linear models offer the advantage of explicit feature selection, allowing for the identification of the most relevant features for the classification task. This feature selection capability may have contributed to the superior performance of linear models when classifying depression, compared to tree-based models. However, it is essential to consider that the choice of the best model depends on the specific context, dataset, and requirements, and various factors can influence the relative performance of different algorithms.

The XGBoost classifier initially performed on par with nontree models as the base model. However, after tuning, its performance deteriorated significantly. Further tuning and investigation may lead to improved results for the XGBoost model. On the other hand, the more trees classifier yielded results most accurate to the linear models. Overall, the linear models proved to be the most effective for classifying the given data.

**In the context of depression detection, logistic regression is often considered suitable for several reasons:** [11] Interpretability: Logistic regression provides interpretable results. The coefficients related with each input variable determine the direction and strength of their relationship with the presence or absence of depression. This interpretability can bolster clinicians and researchers understand the factors that contribute to depression and make informed decisions based on the model's outputs.

Probability estimation: Logistic regression estimates the probability of an individual having depression based on the input variables. By providing a probability estimate, logistic regression can offer insights into the likelihood of depression, which can be valuable for further analysis, such as identifying individuals at higher risk or setting appropriate thresholds for intervention.

Handling of continuous and categorical variables: Logistic regression can handle a mix of continuous and categorical input variables, making it flexible for depression detection models that may include various types of data. This flexibility allows for the inclusion of diverse information such as demographic factors, symptom severity ratings, or questionnaire responses.

Model simplicity: Logistic regression is relatively straightforward to implement and interpret compared to more complex models like neural networks. It does not require extensive tuning or a large amount of training data, which can be advantageous in scenarios with limited data availability, common in medical and psychological research.

Feature selection: Logistic regression allows for feature selection, identifying the most relevant variables for predicting depression. This capability is valuable in understanding which factors are most influential in determining the presence or absence of depression, potentially leading to insights for clinical practice or further research.

While logistic regression has these advantages, it's essential to consider the specific characteristics of the data, study goals, and other factors when choosing a model for depression detection. Alternative machine learning algorithms, such as support vector machines, random forests, or gradient boosting, may also be appropriate based on the context and requirements of the problem.

**In the context of predicting depression in machine learning, lazy learning algorithms, such as K-Nearest Neighbors (KNN), have certain characteristics that could be considered advantageous.** These algorithms offer flexibility in capturing complex relationships present in the data, which is particularly relevant for understanding the multifaceted nature of depression influenced by various factors. Lazy learners do not impose strong assumptions about the underlying data distribution, allowing them to adapt and learn from diverse and complex datasets commonly associated with depression prediction. Furthermore, they can handle imbalanced data more effectively by considering the local distribution of instances and adjusting predictions accordingly. Another benefit of lazy learners is their incremental learning approach, enabling them to quickly adapt to new instances or changes in the dataset without requiring a full model retraining. However, it's important to reiterate that the effectiveness of any algorithm for depression prediction should be thoroughly evaluated and compared against other methods using appropriate evaluation metrics, taking into account factors such as accuracy, precision, recall, and generalizability. Ultimately, the choice of algorithm should be based on empirical evaluation and considerations specific to the dataset and problem at hand.

Carefully select the amount of data for modeling purposes. Initially, a dataset with fewer features was utilized, but it resulted in worse performance for all models. To improve the model's accuracy in classification, more characteristics were added to the dataset, leading to a notable enhancement in performance. Subsequently, the prescription information was included in the final version of the project to provide users with comprehensive analysis and insights in the companion dashboard project. However, it is essential to acknowledge that striking a balance between model simplicity and improvement can be challenging. Additionally, at this stage, it might be more appropriate to focus on adding more patient entries rather than features to the dataset.

Avoid using SMOTENC or combining undersampling with SMOTENC to address class distribution imbalance. While SMOTENC is a popular technique for oversampling imbalanced datasets that include both nominal and continuous features, it may not be the most suitable approach for the given task. SMOTENC generates synthetic samples by interpolating feature values of minority class instances, aiming to address class imbalance. However, its effectiveness may vary depending on the specific scenario, and alternative strategies should be considered when dealing with class imbalance.

In some cases, oversampling techniques like SMOTENC can introduce synthetic samples that might not accurately represent the minority class. This can lead to the generation of unrealistic data points that may negatively impact the performance of the classification model. Furthermore, when combined with undersampling,

SMOTENC can further distort the representation of the original data, potentially resulting in the loss of important information from the minority class.

In the specific context of classifying depression, it is essential to consider the sensitive nature of mental health data. Generating synthetic samples that do not accurately reflect the characteristics and complexities of depression may hinder the model's ability to generalize and make accurate predictions. It is crucial to handle imbalanced class distributions with caution and carefully evaluate the potential impact of oversampling techniques on the performance and reliability of the model.

Alternative approaches, such as using different sampling techniques or applying appropriate class weighting strategies, should be considered to address class imbalance while ensuring the integrity and validity of the minority class representation. Each dataset and problem may have unique characteristics that require a tailored approach to class imbalance, and it is important to carefully assess and experiment with different methods to determine the most suitable approach for achieving reliable and accurate classification results.

Exploring other techniques or combinations of undersampling and oversampling might be beneficial for modeling purposes. Initially, only SMOTENC was attempted, followed by a combination of undersampling and SMOTENC, but both approaches performed worse than using the initial imbalanced dataset with the class weight parameter. While these aspects were briefly detached from the notebook narrative, it's essential to mention that they were explored to facilitate others who may consider building upon this work.

Everyone should be prepared to address mental health problems and encourage those they know to seek proper help. It is crucial to destigmatize mental health issues and support individuals in seeking assistance from experienced professionals. Additionally, seeking guidance for oneself is vital if one finds themselves in need of it. It is highly likely that at some point, everyone may require professional help for their mental well-being.

## 6 Future Scope

Experimenting with various algorithms is essential when attempting to predict depression, as it is a complex and multidimensional problem that presents challenges in modeling. Exploring different model categories could potentially uncover an approach that is well-suited for this task. For instance, considering a neural network might offer a wide range of possibilities that have not been explored in this project. However, one drawback of neural networks is the lack of transparency in understanding the specific features and categories the model utilizes to make predictions.

The future holds promising opportunities for exploring different models to predict depression, paving the way for further research and improvements. One potential avenue is the application of deep learning models, such as convolutional neural networks (CNNs) or recurrent neural networks (RNNs), which can record complex

patterns and relationships within depression data, including textual, visual, or physiological information. Ensemble methods, like random forests or gradient boosting, offer another direction by combining multiple models to leverage their individual strengths and enhance overall predictive performance and robustness in classifying depression.

Incorporating multiple modalities, such as textual data, audio signals, physiological measures, and social media data, into depression prediction models is another promising avenue. Multimodal fusion techniques or multiview learning can be employed to integrate information from various modalities, improving prediction accuracy and comprehensiveness. Furthermore, exploring longitudinal analysis using models that capture temporal dynamics, like recurrent neural networks or hidden Markov models, can enhance prediction accuracy by considering changes and patterns over time.

Real-time monitoring of depression using wearable devices or mobile applications is also a potential area of focus. Developing models that can continuously monitor and predict depression in real-time offers opportunities for early detection and intervention. These models can provide timely support and personalized interventions for individuals at risk of developing or experiencing worsening symptoms.

The future of predicting depression lies in the exploration of diverse models, including deep learning, ensemble methods, and explainable AI. Emphasizing multimodal data, longitudinal analysis, and real-time monitoring can lead to more accurate and context-aware prediction models. Ongoing research and collaboration between data scientists, clinicians, and mental health experts are vital for advancing the field, improving our understanding, and enhancing the prediction of depression.

To achieve a well-performing model, it is desirable to use as little patient information as possible. Initially, the modeling was attempted with fewer features, but the outcomes were unsatisfactory. Adding more features in one round improved the results, but further increasing the number of features in another round did not provide significant benefits and only increased complexity.

Continuing this work presents an opportunity to evaluate and identify valuable features, separating those that are not helpful and potentially exploring the inclusion of other features that could prove beneficial. Striking the right balance between an acceptable level of error and the amount of data required for an accurate model is indeed a challenging task.

Furthermore, a valuable approach for this project could involve increasing the number of patient entries. Given the variations in medical histories, having more entries could potentially reveal complex patterns that would enhance the model's predictive capabilities while requiring fewer features.

Identifying and evaluating valuable features is crucial for enhancing the prediction of depression. While traditional features such as demographics, self-reported symptoms, and medical history have been widely used, exploring novel and relevant features can provide additional insights. For instance, incorporating data from wearable devices, social media posts, or electronic health records can offer a rich source of information that captures real-time behavior, physiological signals, and social interactions.

To evaluate the value of features, advanced feature selection techniques can be employed. These methods can help identify the most informative and influential features for depression prediction, thereby improving the efficiency and interpretability of the models. Additionally, the integration of domain knowledge and expert input can guide the selection process, ensuring the inclusion of relevant and meaningful features.

Incorporating longitudinal data is another important aspect of future research. Longitudinal studies that follow individuals over time can provide valuable insights into the temporal dynamics of depression and its predictors. Analyzing how features change and interact with each other across different time points can lead to more accurate and personalized prediction models.

The incorporation of domain-specific knowledge and psychological constructs into the modeling process can enhance the prediction of depression. For example, including measures of cognitive functioning, personality traits, or social support can offer a more comprehensive understanding of the individual factors associated with depression.

Overall, the future of predicting depression lies in expanding the dataset with diverse entries, evaluating valuable features from multiple sources, and incorporating longitudinal and domain-specific information. By embracing these approaches, we can improve the accuracy, reliability, and applicability of depression prediction models, leading to better early detection, intervention, and personalized care for individuals at risk of or experiencing depression.

Testing numerous parameters becomes essential when dealing with the challenging task of classifying the depressed class. In such cases, considering different scoring metrics, like maximizing recall or giving it extra weight in an F-statistic scoring object, could be worth attempting. It might be beneficial to prioritize maximizing the identification of depressed features and then implementing strategies to improve the not depressed category as necessary.

Moreover, there are many combinations of parameters that remain unexplored, especially in the stacking and voting classifiers, and the XGBoost algorithm holds potential for further exploration to enhance outcomes

Fine-tuning the parameters of prediction models can significantly impact their performance and effectiveness. Researchers can explore various parameters such as learning rate, regularization strength, batch size, network architecture, and optimization algorithms in the context of depression prediction. Systematic and rigorous testing of these parameters can lead to optimized models that provide more accurate predictions.

Testing parameters related to data preprocessing and feature engineering. Different techniques for handling missing data, outlier detection, feature scaling, and dimensionality reduction can be investigated. Evaluating the impact of these preprocessing parameters on the performance of depression prediction models can provide insights into the most effective data preparation strategies.

Exploring the impact of data imbalance and testing different strategies to address it is an essential area of future research. Imbalanced data, where the number of instances in different classes is uneven, is common in depression prediction. Testing

various techniques, such as oversampling, undersampling, or hybrid approaches, can help balance the dataset and mitigate the bias toward the majority class, leading to more accurate predictions for both the minority and majority classes.

Incorporating cross-validation techniques is another important aspect of future research. Testing different cross-validation strategies, such as k-fold cross-validation or stratified cross-validation, can provide a more robust assessment of model performance and reduce the risk of overfitting. It can also help validate the generalizability of the models across different subsets of data.

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# Artificial Neural Networks for Enhancing E-commerce: A Study on Improving Personalization, Recommendation, and Customer Experience



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Vishal Khatri, and Vijay Gautam

**Abstract** With e-commerce companies, artificial intelligence (AI) has emerged as a crucial innovation that allows companies to streamline processes, improve customer interactions, and increase operational capabilities. To provide tailored suggestions, address client care requests, and improve inventory control, AI systems may evaluate consumer data. Moreover, AI can improve pricing methods and identify fraudulent activity. Companies can actually compete and provide better consumer interactions with the growing usage of machine learning in e-commerce. This essay examines how AI is reshaping the e-commerce sector and creating fresh chances for companies to enhance their processes and spur expansion. AI technology which enables companies to enhance their procedures and offer a more individualized customer experiences has grown into a crucial component of the e-commerce sector. Purpose of providing product suggestions and improve pricing tactics, intelligent machines may examine consumer behavior, interests, and purchase history. Customer service employees will

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have less work to do as a result of chatbots powered by artificial intelligence handling client queries and grievances. AI may also aid online retailers in streamlining their inventory control by anticipating demands and avoiding overstocking. The use of AI technologies can also identify suspicious transactions and stop economic losses. AI is positioned to assume a greater part in the expansion and accomplishment of the e-commerce sector as it grows in popularity.

**Keywords** Artificial intelligence · Machine learning · E-commerce · Artificial neural network (ANN) · Feature selection · AI-powered chatbots

## 1 Introduction

The e-commerce sector is changing as a result of machine intelligence (AI), which is giving companies new possibilities to improve their businesses and provide enhanced customer experiences. Massive amounts of data may be analyzed by AI systems, yielding insightful information about prior transactions, interests, and consumer behavior. Using this information helps enhance pricing tactics, customize product suggestions, and stock control. Giving clients a much more individualized buying experience represents one of the most important advantages of AI in e-commerce [1, 2]. Organizations may better target product suggestions and incentives to specific consumers by evaluating customer information, increasing the likelihood of a sale, and raising the satisfaction of customers. Another illustration of how AI is enhancing the e-commerce environment is a chatbot. Chatbots may manage client requests and grievances around the clock, relieving human customer care personnel of some of their labor while delivering prompt and precise replies [3]. AI may help e-commerce companies raise earnings as well as improve customer experiences while also lowering expenses. Designed to detect fraudulent activity utilizing conventional manual methods seems to be time-consuming as well as incorrect, rendering such manual techniques more unrealistic to have the emergence of big data [4]. Artificial intelligence (AI) algorithms may identify suspicious transactions and improve large businesses, assisting companies in staying competitive and making their businesses profitable [5]. AI applications may assist in minimizing overstock and minimizing the requirement for an amount of inventory by policy to increase and offering recommendations regarding when to refill items, eventually increasing the bottom line. The e-commerce sector has seen significant change because of machine learning (AI), which has given companies new tools to improve customer experiences and operate more efficiently. Among the ways, AI is affecting e-commerce are the following [6–8]:

1. Customized suggestions may be made using AI algorithms that examine consumer behavior, interests, and previous purchases. This boosts customer satisfaction and raises the possibility that a transaction will be made.

2. Virtual assistants for customer support: AI-powered virtual assistants can respond to questions and feedback from consumers around the clock, lightening the strain on conventional support representatives. Virtual assistants may respond quickly and precisely, enhancing the general customer experience.
3. Stock management: By policy to increase and recommend when to refill items, AI may assist e-commerce enterprises in optimizing their inventory control. This lessens the requirement for additional inventory and assists in avoiding stockouts.
4. Fraud prevention: AI applications can analyze enormous quantities of information to identify nefarious transactions and avert financial difficulties. This is crucial for e-commerce companies that handle electronic purchases and operations.
5. Price performance metrics: To improve pricing models, AI systems may examine pricing data and competitive data. This aids in the profitability and competitiveness of e-commerce companies.

Visual layouts also have a major influence on customers' decisions as investigated using eye-gaze tracking [9]. Overall, AI has transformed the e-commerce sector, giving companies new opportunities to enhance consumer satisfaction, boost revenues, and improve productivity. We should anticipate seeing much more cutting-edge e-commerce uses for AI as this technology progresses. In this environment, the objective of this article is to examine the ways that artificial intelligence (AI) is changing the e-commerce sector and how companies may use this innovation to improve both internal processes and customer interactions.

## 2 Literature Review of Related Work

A powerful invention that has transformed several sectors, including e-commerce, is machine learning (AI). Customers can benefit from an intuitive and tailored buying experience thanks to AI, which also enables e-commerce companies to grow their profits and revenue. In this literature research, we will look at how AI has affected e-commerce and analyze its many uses and advantages. Abbasi et al. [10] have suggested that work on AI is being employed in several e-commerce applications, including advertising, fraud prevention, tailored suggestions, product searching, and customer support. According to Abdel et al. [11], a key component of e-commerce websites is personalized suggestions tailored to previous purchases, internet history, and web searches. Technologies with AI-powered recommending capabilities have excelled in boosting conversion rates and patronage. The recommendation engines evaluate user data and present pertinent buying guides using algorithms based on machine learning. According to Adomavicius et al. [12], AI might be applied to e-commerce search engines to improve the accuracy and relevancy of search engine results. Natural language processing (NLP) and deep learning methods are used by AI-powered search engine results to comprehend customer inquiries and deliver the most pertinent results. According to Aguwa et al. [13], virtual assistants and chatbots

powered by AI are utilized in e-commerce to give clients prompt, individualized help. NLP and deep learning techniques are employed by these chatbots to comprehend consumer inquiries and deliver pertinent replies. The use of artificial intelligence (AI) in e-commerce to identify and stop fraudulent actions such as credit card fraud, identity theft, and impersonation attack has been suggested by Akter et al. [14]. Algorithms based on machine learning are used by AI-powered systems for identifying fraud examining trends and uncovering abnormalities in user behavior. According to Barzegar et al. [15], AI might be applied to e-commerce and provide clients with tailored marketing strategies. Algorithms based on machine learning are used by AI-powered marketing techniques to evaluate client data and present individualized offers and suggestions. Research by Zhang et al. [16] examined the application of AI to tailored product suggestions. In recent times, it has become more and more popular to employ AI to make customized product suggestions. Purpose of providing individualized suggestions to specific customers, AI systems may examine vast volumes of data, including client preferences and purchase history. This may boost consumer satisfaction, boost revenue, and foster client loyalty as well as advertising, management of supply chains, and inventory control. Fosso Wamba et al. [17] research on automation marketing techniques has been put out that can provide clients with individualized suggestions and offers, whereas AI-powered supply chain management platforms assist companies in streamlining their supply chains. AI-powered inventory control solutions assist companies in more successfully managing levels of inventory and lowering the expenses of excess inventory or shortage of inventory. Computer algorithms are frequently applied in e-commerce and can provide unique customers with individualized product suggestions. For instance, Geng et al. [18] created individualized suggestions for clients in an online clothing store using a deep learning-based methodology. They discovered revealed their method was more successful in terms of correctness and appropriateness than conventional recommendation algorithms. Digital commerce businesses utilize chatbots and automation tools that are AI-powered to offer improved client care and assistance. For instance, Chen et al. [19] created a chatbot with AI for an e-commerce grocery shop that could respond to user questions and make tailored product suggestions. Anomaly detection and prevention in e-commerce are made possible by machine learning. As an illustration, Deng et al. [20]'s AI-based fraud identification system for an e-commerce marketplace was able to accurately identify suspicious transactions. The e-commerce market is using AI applications to improve product identification and searching. For instance, Zhao et al. [21] created an AI-based merchandise search and recommendation engine for an e-commerce furniture company that could offer clients suggestions and search engine results that have been extremely relevant to them. AI is now being utilized in e-commerce for real-time price-optimized products depending on aspects like customer preferences, supply, and competitiveness. For instance, Singh et al. [22] developed an interactive pricing scheme powered by artificial intelligence for an online platform that has been able to boost sales via actual price optimization. Research by Tran et al. [23] presents a thorough analysis of the adaptive personalization methods utilized in e-commerce. The researchers examine the different AI-based personalization strategies and their related influence on consumer

happiness and sales. According to the study’s findings, AI-based customization can significantly increase consumer happiness and sales. Zhang et al. [24] show how Alibaba’s Smart Warehouse has improved e-commerce fulfillment by using AI for resource orchestration. The report emphasizes how AI can optimize warehouse operations while cutting labor expenses and raising overall productivity. The effect of AI on consumer demand in e-commerce is examined by Khrais [25]. The report makes the case that AI has the power to fundamentally alter how companies perceive and respond to customer requirements. Artificial intelligence (AI) can assist businesses in foreseeing consumer demand and customizing shopping experiences by evaluating vast amounts of data and forecasting future trends. Areiqat et al. [26] investigated how AI may affect the general growth of e-commerce. The study highlights how AI has the power to disrupt industries by improving customer experiences, cutting costs, and boosting profits for companies. The authors contend that in order for politicians and corporate executives to remain competitive in the quickly changing world of e-commerce, they must embrace AI and make investments in its development. von Zahn et al. [27] show how putting in place fairness standards in AI might drive up operating expenses for e-commerce. The authors contend that in order to accomplish fairness without having a negative effect on corporate efficiency and profitability, a balanced strategy is required. Blockchain, big data analytics, and machine learning are some of technological advancements that Shen et al. [28] examine in the context of e-commerce operations and supply chain management. The paper emphasizes how these technologies could help with supply chain transparency, reductions in expenses, and improved customer service. The term “intelligent” or “smart” e-commerce was first used by Turban et al. [29] to describe the application of AI and other cutting-edge technologies to improve consumer experience and streamline e-commerce activities. The authors give instances of how intelligent e-commerce can be used in areas including pricing, logistics, and suggestions for products [30].

| Study                   | Reference | AI technique          | Work done                            | Result obtained  |
|-------------------------|-----------|-----------------------|--------------------------------------|--|
| Chen et al. (2018)      | [19]      | Text analytics        | Second-hand seller reputation        | Improved prediction of seller reputation                       |
| Deng et al. (2019)      | [20]      | Machine learning      | Personalized advertising copy        | Smart generation system developed for personalized advertising |
| Zhao et al. (2019)      | [21]      | Machine learning      | Privacy-preserving fair data trading | Improved data trading with privacy protection                  |
| Singh and Tucker (2017) | [22]      | Machine learning      | Product review disambiguation        | Improved product review classification                         |
| Tran et al. (2019)      | [23]      | Bibliometric analysis | AI in health and medicine research   | Global evolution of AI research in health and medicine         |
| Arora et al. (2023)     | [1]       | Machine learning      | On-demand ordering food              | Developed OCD system for online food ordering                  |

(continued)

(continued)

| Study                | Reference | AI technique              | Work done                                    | Result obtained  |
|----------------------|-----------|---------------------------|--|--|
| Arora et al. (2023)  | [2]       | Social network analysis   | Behavioral patterns analysis                 | Comprehensive study of SNA for digital platforms       |
| Sharma et al. (2023) | [3]       | Deep learning             | Operational management of strategic planning | Framework developed for strategic planning using DL    |
| Upreti et al. (2023) | [5]       | Machine learning          | Job recommendation strategies                | Developed framework for online job portals             |
| Upreti et al. (2023) | [6]       | AI techniques             | Delivery time prediction                     | Developed OFDA system for predicting delivery time     |
| Gupta et al. (2023)  | [7]       | Virtualization techniques | Green computing in cloud computing           | Sustainable green approach for virtualized environment |

### 3 Proposed Work on AI in E-commerce

An increasingly used approach for using machine learning and artificial intelligence in e-commerce is the use of artificial neural networks (ANNs). The accompanying methodology may be used to construct artificial neural networks (ANN) in e-commerce:

1. **Data preprocessing:** The first stage in the procedure is to clean and prepare the data for the ANN's training. This comprises actions like addressing insufficient information, characteristic augmentation, and data normalization.
2. **Feature selection:** Choose the characteristics that the ANN will utilize as inputs that have the greatest amount of pertinent. This stage entails determining the critical characteristics that influence the predictions of the intended outcome.
3. **Creating the ANN:** Create the ANN by defining the quantity of incoming, concealed, and hidden and output, together with the quantity of neurons within each layer. To optimize the network, choose an appropriate nonlinear activation for every level and provide the gradient descent.
4. **ANN training:** To use the preprocessed data, train the ANN. To do this, the required information must be continually fed into the network, which must then compute an outcome, compare it to the intended result, and modify its parameters to reduce error.
5. **Validation:** To evaluate the trained ANN's effectiveness, evaluate it using a confirmation dataset. This aids in identifying overfitting and fine-tuning the ANN's hyperparameters.
6. **Testing:** In order to assess the ANN's effectiveness when it comes to precision and generalization, test it by employing a test dataset. The ANN can be implemented in the e-commerce software if the efficiency is sufficient.

```

- Data Preprocessing:
- Load and preprocess the data
- Normalize and scale the features
- Handle missing data
. Feature Selection:
- Select the most relevant features
- Identify the important features that contribute to the prediction of the desired output
. Build the ANN:
- Specify the number of input, hidden, and output layers
- Define the number of neurons in each layer
- Use suitable activation functions for each layer
- Define the loss function to optimize the network
. Train the ANN:
- Initialize the weights randomly
- Repeatedly present the input data to the network
- Compute the output
- Compare it to the desired output
- Adjust the weights to minimize the error
- Repeat until the error is minimized or a maximum number of iterations is reached
. Validation:
- Validate the trained ANN using a validation dataset
- Assess its performance
- Detect overfitting
- Fine-tune the hyperparameters of the ANN
. Test the ANN:
- Test the ANN using a test dataset
    
```

**Fig. 1** To show the pseudocode algorithm used for implementing AI in e-commerce

The following pseudocode algorithm is used for implementing AI in e-commerce using artificial neural networks (ANN) (Fig. 1):

If the performance is satisfactory, deploy the ANN in the e-commerce application. Following code, we have used to implement the ANN in the e-commerce application using the .Net Framework in C Sharp as shown in Fig. 2.

This code loads a dataset from a CSV file, initializes an artificial neural network with 1 hidden layer, trains the network using backpropagation learning, and then tests the network by making a prediction on a new input. The CSV file should contain the input values in the first column and the output values in the last column.

```

namespace EcommerceAI
{
    class Program
    {
        static void Main(string[] args)
        {
            // Load dataset
            double[][] inputs = LoadDataset("ecommerce.csv", out double[][] outputs);
            // Initialize neural network
            ActivationNetwork network = new ActivationNetwork(new SigmoidFunction(2), inputs[0].Length, 10, 1);
            BackPropagationLearning teacher = new BackPropagationLearning(network);
            // Train neural network
            double error = double.PositiveInfinity;
            int iteration = 0;
            while (error > 0.01 && iteration < 1000)
            {
                error = teacher.RunEpoch(inputs, outputs);
                Console.WriteLine("Iteration {0}, Error = {1}", iteration, error);
                iteration++;
            }
            // Test neural network
            double[] input = { 0.3, 0.5, 0.7, 0.2 };
            double[] output = network.Compute(input);
            Console.WriteLine("Prediction: {0}", output[0]);
        }
        static double[][] LoadDataset(string filename, out double[][] outputs)
        {
            List<double[]> inputList = new List<double[]>();
            List<double> outputList = new List<double>();
            using (StreamReader reader = new StreamReader(filename))
            {
                while (!reader.EndOfStream)
                {
                    {
                        string line = reader.ReadLine();
                        string[] values = line.Split(',');
                        double[] inputs = new double[values.Length - 1];
                        for (int i = 0; i < inputs.Length; i++)
                        {
                            inputs[i] = double.Parse(values[i]);
                        }
                        inputList.Add(inputs);
                        outputList.Add(double.Parse(values[values.Length - 1]));
                    }
                }
                double[][] inputs = inputList.ToArray();
                outputs = Accord.Math.Matrix.ToJagged(Accord.Math.Matrix.Transpose(outputList.ToArray()));
                return inputs;
            }
        }
    }
}

```

**Fig. 2** To implement the ANN in the e-commerce application using the .Net framework in C sharp

## 4 Experimental Results and Validation

The results of an experimental study in AI in e-commerce using artificial neural networks (ANN) would depend on the specific research question being addressed, the experimental design, and the data used. However, generally, the use of ANN in e-commerce has shown promising results in improving the accuracy of predicting consumer behavior, personalizing product recommendations, and optimizing pricing strategies. ANN models have been used to predict customer churn rates, identify key customer segments, and optimize product recommendations in online marketplaces.

**Table 1** To show the descriptive statistics for AI in e-commerce using artificial neural networks

| Sr No. | Statistics             | Value |
|--------|------------------------|-------|
| 1      | Mean                   | 0.74  |
| 2      | Median                 | 0.8   |
| 3      | Standard deviation     | 0.12  |
| 4      | Min                    | 0.5   |
| 5      | Max                    | 0.95  |
| 6      | Skewness               | -0.15 |
| 7      | Kurtosis               | -0.05 |
| 8      | Correlation with sales | 0.85  |
| 9      | R-squared with sales   | 0.72  |

**Table 2** Confusion matrix of an AI model

| Types             | Predicted fraudulent | Non-fraudulent |
|-------------------|----------------------|----------------|
| Actual fraudulent | 90                   | 10             |
| Non-fraudulent    | 20                   | 880            |

ANN models have also been used to optimize pricing strategies by predicting demand and price expensive to train and require large amounts of data to perform well. The table of descriptive statistics as shown in Table 1 includes summary statistics such as mean, median, standard deviation, and range for the variables used in the study using descriptive statistics for AI in e-commerce using artificial neural networks. Fig. 1 shows the descriptive statistics for AI in e-commerce using artificial neural networks elasticity. In terms of performance, ANN models have been shown to outperform traditional statistical models in many e-commerce applications, particularly when dealing with large and complex datasets. However, ANN models can be computationally.

A confusion matrix of an AI model in e-commerce using artificial neural networks (ANNs), by using a dataset of 1000 transactions as shown in Table 2.

1. True Positive (TP): The model correctly identified 90 fraudulent transactions.
2. False Positive (FP): The model incorrectly identified 20 non-fraudulent transactions as fraudulent.
3. True Negative (TN): The model correctly identified 880 non-fraudulent transactions.
4. False Negative (FN): The model incorrectly identified ten fraudulent transactions as non-fraudulent.



Using this confusion matrix, the model’s performance can be evaluated using various metrics such as:

1. Accuracy:  $(TP + TN)/(TP + TN + FP + FN) = (90 + 880)/1000 = 0.97$  or 97%
2. Precision:  $TP/(TP + FP) = 90/(90 + 20) = 0.82$  or 82%
3. Recall:  $TP/(TP + FN) = 90/(90 + 10) = 0.90$  or 90%
4. F1 Score:  $2 * Precision * Recall/(Precision + Recall) = 2 * 0.82 * 0.90/(0.82 + 0.90) = 0.86$  or 86%

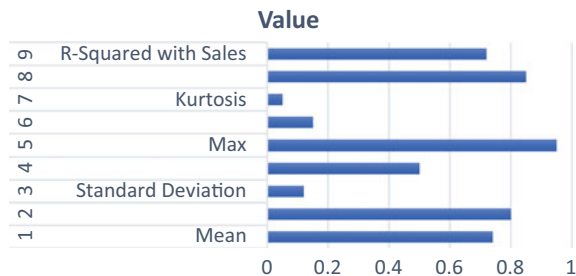
These metrics can help in determining the effectiveness of the AI model and identifying areas for improvement.

Table 3 for ROC curve for AI in e-commerce utilizing neural networks with artificial intelligence illustrates the trade-off among particularity and sensitivity for varied thresholds. This table illustrates the TPR and FPR for a variety of parameters employed by an artificially generated neural network to categorize consumers as being either affirmative (made a transaction) or negative (failed to complete a transaction). The percentage of immediate valid instances that the models properly recognized as affirmative is represented by the TPR, whereas the percentage of actual negative instances that perhaps the model wrongly categorized as positive is represented by the FPR. The ROC curve is built that use these parameters. Figure 3 depicts the final graph (Figs. 4, 5).

**Table 3** Sensitivity and specificity for different threshold values of a binary classifier ROC curve

| Threshold | True positive rate (TPR) | False positive rate (FPR) |
|-----------|--------------------------|---------------------------|
| 0.1       | 0.2                      | 0.05                      |
| 0.2       | 0.35                     | 0.08                      |
| 0.3       | 0.55                     | 0.12                      |
| 0.4       | 0.7                      | 0.18                      |
| 0.5       | 0.8                      | 0.24                      |
| 0.6       | 0.9                      | 0.35                      |
| 0.7       | 0.95                     | 0.45                      |
| 0.8       | 0.97                     | 0.58                      |
| 0.9       | 0.99                     | 0.7                       |

**Fig. 3** To show the descriptive statistics for AI in e-commerce using artificial neural networks



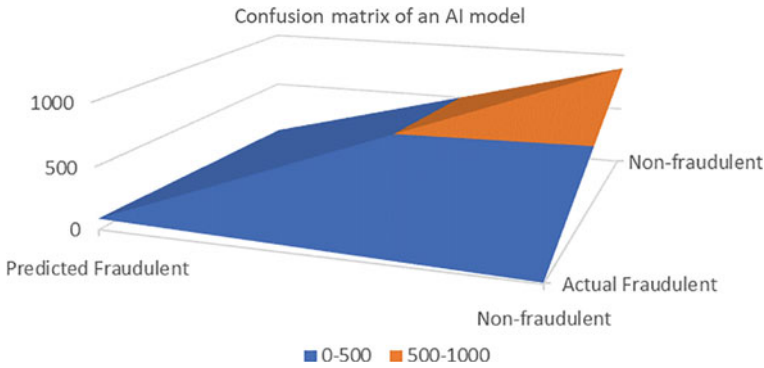


Fig. 4 Graph to depict the confusion matrix of an AI model for improving e-commerce

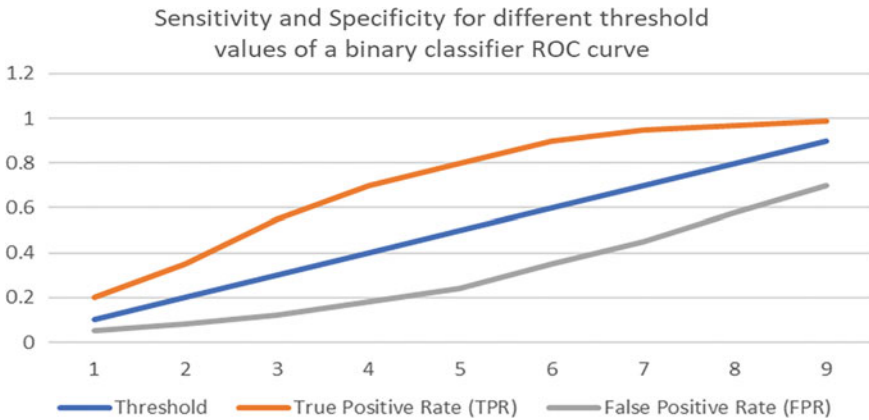


Fig. 5 Sensitivity and specificity for different threshold values of a binary classifier ROC curve

## 5 Conclusion

In summation, AI technology is significantly changing the e-commerce sector. E-commerce companies may streamline excellent customer service, provide tailored suggestions, enhance pricing policies, and truly comprehend their clients with the use of artificial intelligence (AI). Consumers now find it simpler to purchase online and get support whenever required thanks to virtual assistants and chatbots that are driven by AI. Moreover, AI also made it possible for e-commerce companies to estimate consumption, enhance inventory systems, and save costs by utilizing data analytics and predictive analysis. To improve operational effectiveness, increase business expansion, and improve customer engagement, AI is becoming increasingly important in the e-commerce sector. In reality, AI is revolutionizing the e-commerce sector by enabling companies to improve their operational processes, tailor the buying

experience of their clients, and streamline numerous activities. Customer satisfaction and commitment are rising because of the ease with which consumers can now find what it is they are searching for thanks to AI-powered chatbots, recommendation systems, and virtual agents. Moreover, AI is assisting e-commerce companies with controlling their supply chains, inventory control, and pricing strategy improvement.

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# New Paradigm of Marketing-Financial Integration Modelling for Business Performance: An IMC Model



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**Abstract** When it comes to the provision of financial services, the integrated marketing communication (IMC) process is crucial in the creation and maintenance of client-provider bonds. This research presents a literature assessment on the theoretical basis for using marketing communication tools in the provision of financial services. This research is an attempt to bolster the little theoretical literature on the effectiveness of marketing communication techniques in the provision of financial services. Financial service providers use marketing communication as a channel for two-way exchanges with their clientele, with the ultimate goal of maximising the benefits their customers bring to the company. When it comes to providing financial services, an organisation's success hinges on its ability to effectively manage its relationships with both current and potential consumers. As a result, it is important for practical reasons to be guided by well-defined marketing communications goals to identify the extent of usage and within the constraints of available resources. In this regard, businesses are free to establish specific communications objectives in accordance with their unique situations to direct the implementation of their IMC plan. This study aims to find out an impact of financial integration with IMC on

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business performance. This study is descriptive in nature. Primary data is collected with the help of questionnaire. The study finds that the financial integration in the IMC model has a statistically significant impact on business success.

**Keywords** Finance market integration · Business performance · Competitive advantage · Integrated marketing communication (IMC)

## 1 Introduction

Convergence of risk-adjusted returns on assets of similar maturity across markets is made possible through the process of financial market integration. Unrestricted access of participants to different market niches aids in the integration process. Deregulation, globalisation, and improvements in information technology have all contributed to a deeper level of interconnectedness among financial markets throughout the world. Following the lessons learned from a series of financial crises in the 1990s, central banks around the world made significant attempts to foster the growth of financial markets [1]. It stands to reason that more sophisticated economies will have more integrated financial markets. Furthermore, one of the prerequisites for market integration is the removal of constraints on the price of various financial assets, which has been achieved through deregulation in emerging market economies (EMEs). Increased ease of transnational capital flows has led to greater reliance on foreign deposits to supplement domestic reserves in many countries [2].

Today's businesses need marketing strategies and the insights of marketing experts just to stay afloat in the marketplace. Researchers have found that poor marketing skills are a leading cause of business failure. Companies like these failed to adapt to shifting markets and consumer preferences by prioritising sales and profits over satisfying existing customers. At the same time, marketing is a fight, but not a bloody one; as Albert Emery puts it, "marketing is a civilised conflict". Corporations and non-profits are able to improve their bottom lines by employing the art of the word and the science of ideas. Most of these fights favour those who keep their marketing strategies fresh and consistent. Marketing mix is the collection of strategies, tactics, and techniques used by businesses to reach their objectives, as defined by McCarthy (1960). McCarthy has developed a categorisation of this instrument into four factors, which he calls "4P" and consists of the following: price, product, promotion, and place [3].

The marketing mix strategy emphasises the importance of a company's ability to transform inputs into outputs; therefore, it stands to reason that marketing capabilities should be considered in the context of a company's overall success. According to Song et al., an organisation's capacity to sell itself helps shape its organisational makeup and fosters loyalty among its clientele and distribution network. When a company has great marketing capabilities, it can build a positive reputation for its brand and reach its full potential. Leadership, which in turn is dependent on structural elements, is also crucial to the company's success [4].

There is a significant correlation between a company's marketing prowess and its financial performance, according to empirical research. Yet investors, and stockholders, in particular, want metrics that provide reliable evaluations of business performance. Typically based on financial accounts and using value-based measures, the appraisal of performance at the oldest and most significant organisations is centred on financial and economic performance. Profitability, earnings per share, company strengths and weaknesses, and overall financial health are just few of the important areas that can be illuminated by doing a thorough financial analysis [5]. Financial performance and profitability discussions have garnered a lot of academic interest. Accordingly, the majority of these studies are grounded in Bain's classic performance guidance-structure paradigm, which places a premium on factors unique to each industry, such as the degree of concentration, the size of the market, and the prevalence of input/output issues [6].

There are several reasons why unified financial markets are so crucial. To start, policymakers can use integrated markets to send out crucial price signals to the public. Second, well-functioning financial markets are a key engine for stimulating household saving, business investment, and GDP expansion at home. Sixth, there is greater market discipline and informational efficiency when financial markets are interconnected. Seventh, integrated markets encourage the use of current payment and settlement systems, which is crucial to delivering efficient financial mediation at low cost [7].

Market integration at home has been pushed via increasing competition, broadening the financial sector with novel instruments, reducing barriers to entry and exit, reducing transaction costs, and boosting liquidity.

## **2 Relationship Between Marketing and Financial Dimension**

The "balanced scorecard" concept was created by Kaplan and Norton and first appeared in the Harvard Business Review in 1992. Their later works spent much time expanding on this idea. By taking into account multiple points of view, the revised list strikes a healthy middle ground between broad indicators (such as the financial results of past decisions). Parameters utilised in modern business management must include indications that represent not just the past but also information about future development if the company is to be managed in accordance with its long-term goals and ambitions [8]. The Balanced Scorecard tool developed by Kaplan and Norton considers both financial and non-financial metrics. In addition, they classified criteria according to four distinct viewpoints (dimensions): financial, customer, internal process, and learning and growth. The financial perspective parameter is significant since it is the basis for the other three perspectives that help businesses succeed. Indicators (such as customer satisfaction) that contribute to effective market and customer processing might be formulated from the customer's point of view.

When formulating a plan for running a business, it is important to think about the marketing and financial aspects together [9].

The dynamic nature of modern company, the interdependence of market actors, and the daily struggle for existence all necessitate a plethora of strategic choices. Complete, accurate, comparable, and easily accessible information is essential for a high-quality system of informing using financial indicators. Processing such data is fundamental to the development of both the enterprise's marketing strategy and its capacity to expand into new markets. Even the most well-defined, cutting-edge marketing plan could backfire without a suitable financial strategy to back it up [10]. However, the completion (realisation) of the high-profit-rate-targeting financial strategy requires the concurrent implementation of the necessary marketing strategy to bring in the anticipated level of sales. In order to achieve the specified objectives, a suitable budgetary plan is implemented. There is a direct correlation between the marketing plan and the budget. All aspects of the financial plan, including revenue, expenses, and capital expenditures, reveal this connection. We can get several profit models by merging financial goals and plans analytically. The financial effects of various firm marketing tactics are analysed using the provided models. Financial viability analysis is an integral part of strategic management [11].

These models are crucial because they bring together three essential facets of business management:

- Managing for a profit, or
- administration of company property;
- Managing resources and assets (sources of capital and debt ratio).

Interdependence between these fields is substantial. Moreover, these three domains are frequently boiled down to only two crucial domains. The first is concerned with the administration of resources and capital (a financial strategy) and the second with the administration of earnings (a promotional strategy). Profitability enhancement programmes can be designed with the help of customer profitability management (CPM), which uses pricing and cost data to set prices and set prices that maximise profits. The ability of a business to adapt to new circumstances and lead the way in the development of novel market trends depends on its ability to keep close tabs on the profitability of its many divisions [12]. The introduction of financial calculations in marketing to evaluate consumer profitability and brand value has led to fundamental shifts in the marketing idea (equity). CLV suggests a need for a unified approach to marketing and finance. CLV is also the bridge between these two time-honoured business processes. The growth of the Customer Lifetime Value (CLV) concept has made it possible to assess the effect of marketing strategies on company value with greater accuracy. An appropriate enterprise management plan that fosters growth and development must obviously take financial and non-financial drivers into account [13].

### **A. Measures of Financial Integration**

It is possible to quantify the development of national, international, and regional financial integration in a number of ways. The most common classifications for



these metrics are institutional/regulatory metrics, quantitative metrics, and monetary metrics. However, there are a number of problems with using such measures, as limits may not be legally binding or are ignored because of the existence of capital movements. Potential barriers to financial integration may not be addressed fully [14].

Both price and quantity measures are commonly used as de facto markers of financial integration. From the standpoint of policy, price convergence and the efficacy of policy can be measured by comparing the interest rate. Interest rate parity, both covered and uncovered, and asset price correlations across countries are further examples of price-related metrics [15]. The reason for this is that price movements may be correlated for reasons other than market integration, such as a shared external factor or shared macroeconomic fundamentals. Even if there is a high level of financial integration, there may still be noticeable price discrepancies due to disparities in currency, credit, and liquidity issues.

Changes in a country's capital flows over time provide insight into whether or not it is becoming more economically linked on a global scale. Since net capital flows may understate the degree of integration between nations with comparable substantial inflows and outflows, measuring the former is preferable in this situation. As a measure of the rate at which financial integration is progressing, capital flows have their limitations due to the fact that they are sensitive to fluctuations in short-term market conditions [16].

## **B. Benefits and Risks of Financial Integration**

While there are many upsides to a unified financial system, there are also many downsides. How much local financial market integration, international financial integration, and financial development there is, determines the magnitude of the benefits and costs of financial market integration [17]. Especially in a capital account-open economy, weighing the merits and demerits of a unified financial market is a challenging problem.

However, many analysts believe that opening up the capital account is crucial for developing nations hoping to join the middle-income club. Countries hoping to attract foreign investment should prioritise maintaining financial system stability and fostering long-term economic growth by enacting and enforcing effective regulatory frameworks [18].

One must have an opinion as to when and whether a country has crossed the threshold. The best way to integrate a system differs greatly depending on the specifics of each country and historical period. The process of financial integration must be handled with care, ideally within the framework of a credible road map that is developed taking into account the unique context and institutional elements of each country. In reality, market order is the consequence of public policy and cannot exist in a void (i.e. without some externally imposed norms). Fostering competition among institutions is important, but so is creating a system that allows for the maximum amount of information to be disseminated transparently and symmetrically to the markets [19].

### 3 Literature Review

Fachrurazi et al. describe that evidence that 2002 field investigations of firm marketing techniques will continue is the goal of this research. Without a thorough analysis, these numbers are useless for this study. In order to solve the research issues at hand, a comprehensive analysis requires a data coding system for analysing and digesting data. With one of the most rapid accelerations in technical and informational changes relating to how firms responded to these innovations for promotional purposes, we zeroed in on publications between 2010 and 2022 for our literature search. Based on the study's findings and the ensuing discussion, we can infer that in 2022, businesses will continue to employ marketing strategies that make use of cutting-edge technologies like AI-powered social media and other cutting-edge applications for which it has been demonstrated that their data is highly relevant to the promotion of all kinds of products and services [20].

Rehman et al. describe that because of how important it is for establishing and maintaining a company's identity, reputation, and performance in today's cutthroat marketing environment, brands have been compelled to include social media as a part of their marketing communication channels as its use has skyrocketed. The research also emphasises the significance of social media, showing how it can significantly affect customer behaviour. The study's results can be used as a jumping-off point for additional studies and practical applications of marketing mix theory and practice, with the end goal of solidifying the brand's position in consumers' minds and in the real world [21].

Sabita Rani et al. describe that when the financial markets of different countries, regions, or even the entire world are interconnected, this is known as financial integration. As a result of internationalisation and globalisation, several Indian companies have decided to list on overseas stock exchanges. Although it is crucial to economies and governments throughout the world, integrating the stock market in the Indian region has gotten little attention. The paper looks into whether or not the changes made to the Indian stock market have led to closer ties to other major stock exchanges across the globe. While the research acknowledges that the Indian stock market has improved, thanks to the implementation of a number of positive reforms [22].

Perwito et al. describe that the purpose of this paper is to analyse integrated marketing communications and their impact on customer perceptions of brand value. Quantitative methods, including an explanatory survey design and descriptive verification, were used in this study. Several statistical methods, including tests for data normality, correlation, regression, and hypothesis testing, are employed during analysis. A positive and statistically significant impact on Brand Equity was found for integrated marketing communications (IMC). Companies who are committed to optimising their performance as measured by sales, profitability, and wealth created for shareholder value by engaging in ongoing strategic initiatives connected to integrated marketing communication (IMC) deserve special attention [23].

Padhan examines the historical traces left on the measurement of financial integration (FI), along with its important difficulties and obstacles, using a literature review. We record the development of measures from 1980 to 2018, and we add new criteria to the measurement classification. The study also highlights the need for and criteria for selecting an appropriate measure, as well as identifying the benefits and drawbacks of current measurements [24].

Abdul Lasi describes that the purpose of this study is to inquire into SME business practices and operations (SMEs). The study focused on SMEs because of their economic relevance and the large number of SMEs in Malaysia. Specifically, this research looked into how several types of integrated communication affect the success of small and medium-sized enterprises (SMEs). Important pledges were made by professionals in this study to develop methods for achieving success in business among Malaysia's SMEs [25].

Akbari et al. suggest a novel method for separating the effects of emerging and mature economies on the drivers of economic and financial integration. Our sophisticated machine learning method accommodates nonlinear interactions, prevents overfitting, and is less susceptible to noise. Moreover, it accounts for multicollinearity and can handle a large number of strongly linked explanatory factors. The results show that developing nations have become economically integrated to the same degree as developed countries as a result of general economic development, rising international commerce, and controlled population growth. The pace of financial integration between developed and developing nations has been slowed, however, by emerging countries' delayed financial growth and the high investment riskiness that they face [26].

Akbari et al. describe that for those interested in international economics, market integration is a fundamental concept. One of the main literatures in this topic is driven by the question of whether or not markets are integrated with the global economy and to what extent. Recent empirical findings on the time series and cross-sectional dynamics of integration between developed and emerging economies are discussed in this overview. It also explores the benefits and drawbacks of the three commonly used measures of market integration and provides an empirical evaluation of each. Finally, the study recommends a few potential directions for this field of research [27].

Ali Asgher describes that the purpose of the current research is to identify the connection between marketing budgets and the acquisition of new customers in the future. Because of its significance, this research helps advance the marketing discipline in the classroom, laboratory, and office. This research aimed to fill in some of the blanks in our understanding of the factors we were studying so that we could draw some firm findings and provide some useful suggestions moving forward [17].

Opute and Madichie describe that this research took a two-pronged approach to its methodology. Before moving on, it is necessary to do a literature study in order to isolate the most important precursors in the existing literature. As a result, we employed four exploratory case studies to look at what came before the merger of accounting and marketing from a "frontier market" vantage point. As a conclusion,

this research proves that combining accounting and marketing may boost productivity inside an organisation. The study has two significant limitations that might restrict its usefulness and the conclusions that can be drawn from it. A qualitative literature analysis and evidence from four separate case studies form the basis of this investigation. Second, the backdrop of developing nations was not considered [28].

Shirley Malope et al. describe that a developed financial market is one that has increased in size, activity, efficiency, and stability. The impact of debt, equity, money, and international markets on investment was analysed. According to VECM, the rate of adjustment is around 13%, indicating that the variables will converge on a stable state of equilibrium in a short amount of time. Investments in government bonds were found to have a stronger impact on the prediction of future investments, as shown by variance decomposition [29, 30]. Given the magnitude of the influence of government bonds on investment relative to other proxies for financial development, these findings have policy implications for the government. Improve the financial sector's autonomy from political meddling and provide more risk diversification as policy priorities [31, 32].

## **4 Research Methodology**

### **A. The Pilot Study**

The purpose of the pilot study is to determine the number of accruing variables, the format in which the questioners' phrases are written, and the internal coherence of such variables. 15% of the population, or 146 customers and 20 organisations, participated in this study's sample of responders.

### **B. The Sampling Technique**

For the purposes of this study, we employ a purposive proportional sample to obtain information about our clientele. The response rate reaches 97.5%, or 463 out of the total sample size of 500 clients because 37 questionnaires are incomplete and missing information. The questioners are assigned in a face-to-face format.

### **C. Measurement**

Both "brand improvement" and "brand purchase" are measured on a five-point Likert scale.

### **D. Data Analysis**

The results of the study are analysed by computing descriptive statistics, such as the mean, standard deviation, and frequency distribution.

## 5 Result and Discussion

### A. The Independent Variable (Financial Integration)

The IMC model's success lies on its workers' capacity to coordinate the financial assessment process and the capability to make more effective allocations of funds to various marketing communications. There is an interdependent relationship between all of the many elements and units of the organisation, and this is what integration and coordination are all about. The levels of responses to the independent variable are shown in Table 1. Standard deviation is 0.93, while the mean is 3.41. There are six assertions that comprise the financial integration variable. There are two statements: Plan your budgets while coordinating your communication operations to identify what each other needs and the company's efforts to achieve its goals are unified by financial planning for MC activities with a lot of responses that are very high. The significance of correlations with other activities is demonstrated during the planning process statement got response with a moderate amount that is high one with a low amount, and one with no responses at all.

### B. The Dependent Variable (The Competitive Advantage)

The arithmetic mean for this variable is 3.45, indicating a sizable number of responses; it is a four-dimensional variable, with the following dimensions:

- **The Quality:** The arithmetic mean for this subvariable is 3.55, and its standard deviation is 0.8, which indicates that it has a high degree of response.
- **The Flexibility:** The arithmetic mean for this subvariable is 3.51, and its standard deviation is 0.99, which indicates that it has a high degree of response.
- **The Delivery:** The arithmetic mean for this subvariable is 3.52, and its standard deviation is 1.09, which indicates that it has a high degree of response as shown in Table 2.

According to Table 2, the quality dimension has 3.55 mean, 0.94 SD, and degree is high. The flexible dimension has 3.51 mean, 0.99 SD, and degree is high. The delivery dimension has 3.52 mean, 1.09 SD, and degree is high. So the competitive advantage has 3.49 mean, 1.02 SD and degree is high.

## 6 Testing the Hypotheses

HO1: "There is a Significant Impact of Financial Integration in The IMC Model on the Business Performance".

From the above table, it is clear that it has a positive impact on the business because dependent variable has a variation of 83%, and it is 91% correlated so they can be attributed to financial integration (business performance). Organisation's competitive advantage increases 0.98 units if there is an increment of one unit in

**Table 1** Frequencies, means, and SD of financial integration

| N | The statement  | Response degree |    |    |    |    | Mean | SD   | Degree    | Arrange |
|---|--|-----------------|----|----|----|----|------|------|-----------|---------|
|   |  | SDA             | DA | M  | A  | SA |      |      |           |         |
| 1 | Plan your budgets while coordinating your communication operations to identify what each other needs                                       | 1               | 1  | 4  | 35 | 92 | 4.62 | 0.8  | Very high | 1       |
| 2 | Sometimes, a communication activity's financial requirements are combined with those of another to be covered by a single programme        | 52              | 21 | 20 | 25 | 17 | 2.51 | 0.99 | Weak      | 5       |
| 3 | Some communication activities may be reduced and directed to support another   | 42              | 36 | 22 | 22 | 11 | 2.43 | 0.98 | Weak      | 6       |
| 4 | The significance of correlations with other activities is demonstrated during the planning process   | 9               | 12 | 22 | 29 | 61 | 3.91 | 0.9  | High      | 3       |
| 5 | The company's efforts to achieve its goals are unified by financial planning for MC activities   | 2               | 5  | 7  | 25 | 94 | 4.53 | 0.93 | Very high | 2       |
| 6 | The (Budget Committee) requires people in charge of communication activities to work together in a coordinated manner to create the budget | 43              | 28 | 21 | 28 | 13 | 2.55 | 1.12 | Low       | 4       |
|   | Overall of financial integration   | 25              | 17 | 16 | 27 | 48 | 3.41 | 0.93 | High      |         |

**Table 2** Frequencies, means, and SD of dimensions of competitive advantage

| N | The statement  | Response degree |     |     |     |     | Mean | SD   | Degree   | Arrange |
|---|--|-----------------|-----|-----|-----|-----|------|------|----------|---------|
|   |  | SDA             | DA  | M   | A   | SA  |      |      |          |         |
| 1 | Your expectations are exceeded by the way the business you work with offers you services                         | 37              | 189 | 414 | 566 | 257 | 3.56 | 1    | High     | 6       |
| 2 | Your satisfaction with the services is regularly monitored by the business you are working with                  | 32              | 231 | 336 | 625 | 238 | 3.54 | 1.02 | High     | 7       |
| 3 | The firm you work with constantly strives to improve the calibre of the services it offers                       | 20              | 154 | 462 | 626 | 200 | 3.57 | 0.9  | High     | 4       |
| 4 | The business you work with offers its services through knowledgeable staff that can live up to your expectations | 23              | 171 | 411 | 572 | 285 | 3.63 | 0.98 | High     | 2       |
| 5 | Compared to its rivals, the company you are dealing with produces products that are free from flaws or faults    | 54              | 336 | 462 | 408 | 203 | 3.25 | 1.07 | Moderate | 8       |
| 6 | The company you do business with provides its services to your satisfaction                                      | 23              | 183 | 440 | 560 | 255 | 3.57 | 0.97 | High     | 5       |

(continued)

**Table 2** (continued)

| N | The statement   | Response degree |     |     |     |     | Mean | SD   | Degree | Arrange |
|---|---|-----------------|-----|-----|-----|-----|------|------|--------|---------|
|   |   | SDA             | DA  | M   | A   | SA  |      |      |        |         |
| 7 | Your faith in the company you work with services is increased by the high quality of those services             | 26              | 195 | 377 | 549 | 315 | 3.64 | 1.02 | High   | 1       |
| 8 | The business you work with offers services in a way that satisfies your needs and preferences                   | 15              | 192 | 386 | 616 | 255 | 3.62 | 0.95 | High   | 3       |
|   | The quality dimension   | 29              | 206 | 411 | 565 | 251 | 3.55 | 0.94 | High   |         |
| N | The statement   | Response degree |     |     |     |     | Mean | SD   | Degree | Arrange |
|   |   | SDA             | DA  | M   | A   | SA  |      |      |        |         |
| 1 | Your business partner offers services that adapt to your changing demands                                       | 26              | 149 | 429 | 629 | 228 | 3.6  | 0.93 | High   | 1       |
| 2 | The company you do business with provides services that respond to market changes                               | 15              | 174 | 380 | 692 | 200 | 3.61 | 0.9  | High   | 3       |
| 3 | The business you interact with anticipates your requirements and preferences so that it can modify its services | 29              | 180 | 435 | 578 | 240 | 3.56 | 0.97 | High   | 2       |

(continued)



**Table 2** (continued)

| N | The statement   | Response degree |     |     |     |     | Mean | SD   | Degree   | Arrange |
|---|---|-----------------|-----|-----|-----|-----|------|------|----------|---------|
|   |   | SDA             | DA  | M   | A   | SA  |      |      |          |         |
| 4 | Due to customer feedback, the business you are dealing with modifies its services                               | 29              | 200 | 543 | 489 | 200 | 3.43 | 0.69 | High     | 4       |
| 5 | The company you do business with shapes its products within a short period                                      | 63              | 282 | 435 | 455 | 228 | 3.34 | 1.09 | Moderate | 5       |
| 6 | The flexible dimension  | 32              | 197 | 444 | 568 | 219 | 3.51 | 0.99 | High     |         |
| N | The statement   | Response degree |     |     |     |     | Mean | SD   | Degree   | Arrange |
|   |   | SDA             | DA  | M   | A   | SA  |      |      |          |         |
| 1 | The company you are dealing with provides the service at a time   | 20              | 149 | 300 | 663 | 329 | 3.77 | 0.96 | High     | 2       |
| 2 | Waiting for a service request versus receiving it is better than the competition                                | 23              | 219 | 480 | 528 | 212 | 3.47 | 0.97 | High     | 3       |
| 3 | The business you work with is able to respond to your questions and complaints more effectively than its rivals | 29              | 252 | 492 | 432 | 257 | 3.43 | 1.03 | High     | 5       |
| 4 | The business you work with is dedicated to giving your prompt after-sales support                               | 48              | 209 | 506 | 465 | 234 | 3.43 | 1.02 | High     | 4       |

(continued)

**Table 2** (continued)

| N | The statement  | Response degree |     |     |     |     | Mean | SD   | Degree   | Arrange |
|---|--|-----------------|-----|-----|-----|-----|------|------|----------|---------|
|   |  | SDA             | DA  | M   | A   | SA  |      |      |          |         |
| 5 | The business you work with provides self-service options for its products and services so you can quickly access what you need | 154             | 323 | 348 | 395 | 243 | 3.17 | 1.24 | Moderate | 6       |
| 6 | The business with which you do business is firmly committed to the times and locations where its services will be delivered    | 23              | 123 | 315 | 654 | 348 | 3.81 | 0.95 | High     | 1       |
| 7 | The delivery dimension   | 49              | 212 | 406 | 522 | 270 | 3.52 | 1.09 | High     |         |
| N | The statement  | Response degree |     |     |     |     | Mean | SD   | Degree   | Arrange |
|   |  | SDA             | DA  | M   | A   | SA  |      |      |          |         |
| 1 | The company that you deal with is the lowest in the price of its services  | 45              | 325 | 402 | 554 | 237 | 3.49 | 1.03 | High     | 2       |
| 2 | The business with whom you are working is constantly running promotions  | 18              | 260 | 348 | 632 | 203 | 3.51 | 0.98 | High     | 1       |
| 3 | Your company provides innovative services  | 40              | 266 | 497 | 483 | 177 | 3.34 | 1    | Moderate | 3       |

(continued)

**Table 2** (continued)

| N | The statement  | Response degree |     |     |     |      | Mean | SD   | Degree   | Arrange |
|---|--|-----------------|-----|-----|-----|------|------|------|----------|---------|
|   |  | SDA             | DA  | M   | A   | SA   |      |      |          |         |
| 4 | The company provides the possibility to reduce services to reduce the price  | 37              | 240 | 585 | 440 | 162  | 3.31 | 0.96 | Moderate | 4       |
| 5 | The business provides numerous purchase possibilities at competitive pricing | 83              | 291 | 380 | 515 | 192  | 3.3  | 1.1  | Moderate | 5       |
| 6 | Cost dimension   | 44              | 256 | 442 | 524 | 194  | 3.39 | 1.04 | Moderate |         |
| 7 | Competitive advantage  | 38              | 217 | 425 | 544 | 233, | 3.49 | 1.02 | High     |         |

financial integration according to estimated B. The F test for financial integration in the IMC model (0.00) yielded a significance level of less than 5%, as assessed statistically as shown in Table 3.

In addition, we use the Pearson correlation coefficient and the correlation matrix to determine whether or not there is a relationship between the independent and sub-dependent variables. Contrarily, the IMC model’s financial integration does not correlate with improved quality, lower costs, or greater adaptability. Since Saudi service providers compete on the basis of speed with which they can bring new items to market, this delivery dimension is a key area of differentiation.

**Table 3** Findings of the first hypothesis

| The financial integration | R                  | R 2     | F     | Sig      | B     | t        | Sig.  | The statistical Decision ( $\alpha = 0.05$ ) |
|---------------------------|--------------------|---------|-------|----------|-------|----------|-------|--|
|                           | 0.91               | 0.83    | 6.147 | 0        | 0.98  | 9.042    | 0     | 0.000 < 0.05                                 |
|                           | There is an effect |         |       |          |       |          |       |  |
| The correlation matrix    |                    |         |       |          |       |          |       |  |
| Cost                      |                    | Quality |       | Flexible |       | Delivery |       |  |
| R                         | Sig.               | R       | Sig.  | R        | Si.g  | R        | Sig.  |  |
| 0.352                     | 0.081              | 0.16    | 0.065 | 0.429    | 0.069 | 0.766    | 0.026 |  |

## 7 Conclusion

Financial service companies are expected to maximise customer value by meeting or exceeding customer satisfaction. Additionally, the financial service provider considers increasing customer satisfaction to be a practical strategy for luring in new clients. Delivering high-quality financial services that satisfy consumers' expectations is necessary for the financial organisation to be able to reach these aims. According to Manisha and Fill & Jamieson, developing strong and mutually beneficial customer-organisation relationships is the best way to deliver high-quality financial services that satisfy consumer requests. With integrated marketing communication, a financial service provider has a framework of chances to offer top-notch services to current clients, advertise those services to draw in new clients, and solicit feedback and requests from both current and prospective clients. Therefore, it is important to note that MC is essential to the financial organisation's goal of maximising client value. Financial companies must be able to put MC into practise and legitimately employ its tools in order to create and maximise client value. Financial service providers must conduct advertising, personal selling, sales promotion, and public relations in the light of suitable communication, relationship management, and service delivery models in order to employ IMC tools in a credible manner. Due to the tight alignment between relationship marketing, service delivery, and marketing communication, this is important.

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# Eagle Eye: Enhancing Online Exam Proctoring Through AI-Powered Eye Gaze Detection



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**Abstract** With the significant rise in online examinations, the demand for proctors has grown exponentially, leading to resource constraints. Unlike offline exams with a few invigilators overseeing large groups of students, online exams require individual monitoring to uphold the code of conduct. However, the prevalence of unfair practices among examinees in online exams remains notably higher than in offline settings, resulting in an extensive, tiresome, and inefficient process. To address these challenges, we present “Eagle Eye”, a coherent and efficient system that employs eye gaze detection with machine learning and artificial intelligence. During the exam setup, examinees undergo a calibration test to establish a designated border-box area for eye movement testing. Data gathered from this detection enables classification of examinee behaviour as fraudulent or fair based on their gaze within or outside the box. When fraud is detected, alerts are sent to both the examiner and examinee, allowing timely actions as needed. To ensure accurate predictions, we have curated a bespoke dataset with the help of volunteers, providing unfiltered and authentic samples for training. The implementation of Eagle Eye seeks to enhance online exam integrity and streamline the proctoring process.

**Keywords** Classification algorithms · Deep neural networks · Image classification · Image pre-processing · Face identification · Feature extraction

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# 1 Introduction

In the current era, where technology plays a crucial part in the successful operation of various sectors like employment, education, and the retail sector, it becomes essential to develop solutions that facilitate smoother processes and enhance effectiveness. With this vision in mind, our team introduces “Eagle Eye”. Eagle Eye, as its name indicates, acts as an additional eye and a monitoring tool that may be utilised in a variety of economic areas [1]. However, for the scope of this paper, we concentrate on its application in the education sector. We believe that the successful completion of this endeavour can potentially lead to its implementation in diverse fields such as crime, marketing, automobile, and many others. This innovation aims to make these challenging times more manageable and elevate the efficiency of both work and education [2].

The underlying goal of this paper was straightforward yet impactful: to improve the mechanism for online testing and education. We determined that the lack of an impenetrable proctoring technique was the main issue. This deficiency creates a significant gap, allowing students to engage in unfair practices without encountering any obstacles. Unlike the conventional offline examination method, when one invigilator is in charge of a whole class of pupils, the online method gives each student its own proctor, which requires significant cost outlays from organisations [3]. Even with a proctor present, it might be difficult to spot unfair tactics such as utilising notepads, phones to look up answers, or other quiet techniques because the video does not alter or make noise, which makes effective monitoring difficult.

The subpar outcomes of the current process put a heavy burden on organisations conducting these examinations. Not only does it lead to unfair and inequitable results, but it also requires a significant allocation of human resources and capital for employing proctors. These elements lead to a considerable gap between the online examination system and the current proctoring procedure [4]. To address these challenges and introduce a more robust approach to examinations, we propose the implementation of “Eagle Eye”. This solution aims to provide a more stringent and reliable method, ensuring fairness, and efficiency in the examination process [5].

We firmly believe that Eagle Eye presents an effective solution to address this problem and can effectively fill the void in the current system. Implementing Eagle Eye would relieve the burden on proctors and examiners during examinations [6]. Furthermore, it enables organisations conducting the examinations to ensure a fair and equitable process while optimizing their human capital usage. This system proves to be less wasteful than the current industry practices, making it a promising and efficient alternative.

In order to provide a straightforward explanation of how the system would work, we can say that it aids the examiner by quickly identifying when an examinee tends to glance away from the assigned display area of their device, regardless if it is a laptop, desktop computer, or smartphone screen [7]. The system will determine whether the examinee indulged in any fake behaviour after seeing this behaviour by



drawing their focus away from the required screen area, which is established at the start of the testing process through a calibration process.

The specified area will serve as the tracking and evaluation zone for monitoring the examinee's eye movements, providing the necessary data for assessment. The accountable examiner or supervisor will receive a prompt alert if any code of conduct violation is found, allowing them to respond appropriately [8, 9]. Their displays will be fixed prior the exam starts to prevent candidates from utilising the Internet to hunt for answers by swapping tabs while they're gazing inside the specified region. Any effort by a test taker to switch tabs while taking the test might result in disqualification.

Eagle Eye's proctoring procedure might be digitalised to greatly reduce the demand for actual proctors. With this technology, several exams may be efficiently managed by a single proctor or examiner at once, greatly simplifying and speeding up the procedure.

## 2 Related Work

For a long time, researchers and scientists in the field have been doing considerable study in the areas of gaze detection and tracking of eyes. Du Bois-Reymond first noticed a connection between eye movements and the potential of electrodes on the outermost layer of the skin in 1849, which led to the investigation of these issues. The use of placed electrodes on the temples coupled to a galvanometer to efficiently measure potential variations associated with eye movements was then proposed in research papers published in 1935. These historical milestones highlight the longstanding interest and investigations in these domains [10].

Since 1935, technology has improved significantly, especially with the recent development of computer vision technology, which has prompted the creation of more sophisticated and safe tracking of eyes and gaze detection techniques. These contemporary methods frequently rely on photos taken with digital cameras that show faces or eyes. In many cases, the gadget's built-in webcams may act as the camera, as demonstrated by this 2010 study and Webgazer, a Brown University eye tracking library [11]. These contemporary techniques may be divided into two categories of gadgets. Head-mounted trackers, which are commonly affixed to eyeglass frames, fall under the first group. The second category includes remote devices positioned a specific distance away from the user, such as the webcams mentioned earlier. These developments represent significant progress in the field, enhancing the accuracy and practicality of eye tracking and gaze detection methodologies.

Modern techniques that rely on computer vision may be divided into two categories. The first kind uses a camera together with certain sensors and gadgets to analyse geometry data and picture information for gaze recognition, such as eye corners, depth, and contours. These methods vary slightly depending on whether the dataset is two-dimensional or three-dimensional. Processing 2D data into geometric data is technically simpler than handling 3D data. Therefore, for 3D data, adjustments

are often made to account for depth, shadows, and other factors [12]. Hyperparameters that are very specific, such as the user's viewing angle and the cornea's radius, are used to improve the processing of geometrical features in 3D datasets. This enables more accurate and effective gaze detection in various scenarios [13].

The second method uses appearance-based techniques that interpret the image by using mapping functions. They do not need specialised sensors and equipment, unlike geometric techniques, to identify different geometric aspects. Instead, to identify the user's gaze, these systems primarily depend on pre-processed information retrieved from the picture, like complex characteristics or image pixels. Appearance-based approaches will be the main subject of our investigation because they require fewer equipment overall [14]. These methodologies can produce information for eye gaze recognition with machine learning as well as deep learning successfully. Their ability to work efficiently with minimal hardware requirements makes them highly suitable for our research objectives.

Numerous attempts to apply machine learning (ML) along with deep learning (DL) methods for gaze detection have been made since the mid-1990s. Pomerleau and Baluja headed from the common gaze tracking method of Writing Specular Reflection in a significant study conducted in 1994. Instead, they used ANNs, or artificial neural networks, to accomplish this [15]. They created a training dataset with 1000 horizontal and 1000 vertical images to accomplish this. The pixels of the image served as a source of information for the artificial neural network. They used a single hidden layer in their network architecture, which further broke down based on the information along the x- and y-axes, to determine the precise user gaze direction. This ground-breaking research showed how ML and DL could advance gaze detection methods.

This ground-breaking study launched the use of neural systems for gaze identification and provided a template and source of inspiration for many additional studies in this area. But as the field of study grew, a typical problem—head mobility while gaze identification from videos—rose. A 2006 research study suggested Bayesian differential posture tracking as a solution to this problem. This ground-breaking technique used previous keyframes to calculate the present frame by examining the gaps between nearby pictures, finally estimating the location of the head [16]. This work served as a source of inspiration for a number of additional research articles, including one from 2008 that made use of the Bayesian differential posture tracking movement detection methods. This study created an incremental learning strategy for detecting gaze, further advancing gaze detection techniques.

Regarding the dataset, as previously mentioned, it can be categorised into two types. First, there are the pictures that a head-mounted camera takes, which sometimes just take pictures of the eyes and sometimes pictures of the whole face. The second type of datasets are those produced from remote-shot photos or videos. In a dataset from research done at Columbia University, for instance, participants were told to rest their heads on something and concentrate on a specific location on a wall in front of them. Then, while this was happening, pictures were taken to document their gaze [17].

While the dataset provides high-quality images suitable for processing, it lacks diversity due to the minimal head movement exhibited by the subjects. The participants were instructed to focus on multiple targets that appeared on a screen or mobile phone in recent noteworthy advancements in this area. Webcams and front cameras were used to capture their eye movements. As an example, in a study, footage of the people being studied was taken during a session while twenty different target aims were displayed on a laptop screen [7]. This method provides a significant amount of our research's inspiration. Students will take a practice exam that we will administer, and we will film them taking it. This data collection method will facilitate a more diverse and comprehensive dataset, enabling us to explore gaze detection from various angles and scenarios.

In a ground-breaking study, Zhang, Sugano, Fritz, and Bulling introduced an initial convolutional neural network (CNN)-based method for gaze detection. Surprisingly, despite its higher economic cost, this straightforward gaze estimate method outperformed many traditional appearance-based techniques. The effectiveness of this CNN approach overshadows the financial considerations. In conclusion, despite the long history of gaze detection research, there is still much room for improvement, especially given the increase in popularity and use of deep learning, computer vision, and artificial intelligence in recent years. The ongoing advancements in these areas suggest there is still a lot of ground to cover and work to be done in the area of gaze detection.

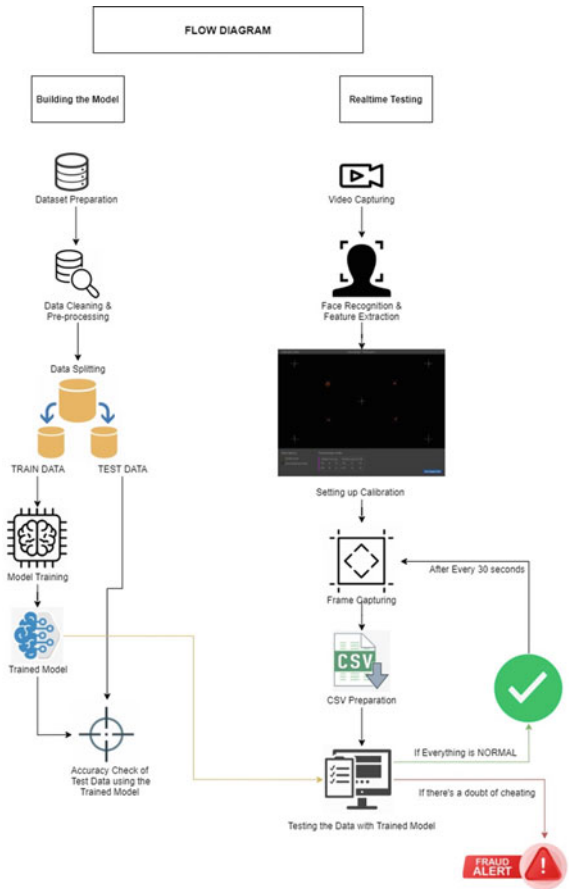
### 3 Methodology

The development of the “eye gaze detection” study is shown in Fig. 1. There are two major sections to it: the focus of the first section is on training models, while the second section includes real-time testing. The central part of the process, called model training, involves creating and deploying the model for use in real-time applications. On the other hand, real-time testing involves the user's interaction and utilisation of the fully optimised deployed model. To build the model, the first requirement is a dataset to work with.

It is crucial to have a well-featured dataset that will be processed using various machine learning pre-processing techniques. To guarantee a valid and trustworthy dataset, we plan to create one from scratch. For this purpose, we will seek volunteers who will participate in a mock examination, aiming to recreate an environment similar to an actual examination. In order to gather the information required for the model's training and optimisation, we will take videos of the volunteers.

We will take image frames and use them to perform data processing from the obtained videos. The processed data will then be used for training and testing the model. To achieve this, the processed data will undergo further cleaning and organisation, which may require significant effort since the data is self-created. Obtaining frames from the provided video in order to use them for extracting features in a later

**Fig. 1** Diagram illustrates the detailed flow of the implemented method



stage is the first step in creating the model. We take into account the video's FPS, which is (frames per second) as we gather frames from a live feed.

For instance, if the video has a 30 fps rate, we only need one frame per second. We employ cv2 and a timer to extract the required frames. In the phase of feature extraction, we want to find the individual's eyeballs and then figure out where they are with regard to the face and screen. For the model to be initialised and the process to be calibrated, these coordinates are essential. Recognising and identifying the user's gaze depends on precise eyeball location detection.

The precision with which we localise the user's pupil's centre directly affects the precision of an image-based eye gaze identification system.

To achieve this, the localisation process can be divided into three distinct parts:

1. Locating the face in the image.
2. Locating the eye's position and gathering information about the surroundings.
3. Detecting the pupil within the eye and calculating its centre.

This approach minimises computational space and speeds up the process. By bypassing the need for classifiers to process and classify the entire image, it becomes less error-prone and more streamlined. The eye's gaze detection system's overall effectiveness and accuracy are improved by this optimised method.

In our study, Haar cascade classifiers are used to identify the face and eyes in an image. The Haar-based classification model is an image analysing as well as machine learning approach for identifying objects in images or videos, and it was first presented by Michael Jones and Paul Viola in 2001. It employs a variety of unfavourable and favourable images to categorise the collection of images according to their significance or value according to categorisation. Utilising the idea of integral images, the classifier separates out lesser a rectangle images from the larger ones that are essential for object recognition and classification.

By minimising the quantity of data that needs to be processed, this method for producing integral images improves the model's effectiveness and speed. For more quick object detection and processing, Haar cascade classifiers use xml files, which contain enormous amounts of data. "haarcascade\_frontalface\_default.xml" and "haarcascade\_eye.xml" are the two Haar cascade XML files we use for our work.

The initial image is transformed into a grayscale image as part of the face detection process. The location of the face is then determined by a Haar cascade classifier, and the location of the eyes is determined by an additional Haar cascade classifier. Our programme initially crops a smaller a rectangle image that only includes the eye to determine the eyeball's centre. The eye is then turned into a picture with grayscale, and to reduce image noise, Gaussian blur is used. The programme dynamically and in real-time analyses via the range of the values between 0 and 255 to determine the proper threshold value to use for Gaussian models blur.

It determines the threshold value that produces precise coordinates for the eye and instantly corrects any errors brought on by varying lighting conditions. The blob identification artificial intelligence method from OpenCV is subsequently applied to the picture after the eyebrow has been eliminated from it and Gaussian blur has been added. Calculated with reference to the initial image, the blob's coordinates are determined to match the pupil's centre. We can precisely determine the eyeball's centre using this process to conduct additional gaze detection analysis.

We require pre-processed, cleaned, and organised data to start the model, which will be split into two sections: TRAINING DATA and TESTING DATA. An 80:20 split will be used to ensure that 80 per cent of the data will be utilised for learning and 20% over testing. The model will be trained using the CNN technique, which was developed as a result of the 2015 study from Fritz, Sugano, Zhang, and Bulling.

Despite being more expensive, this CNN-based method for gaze detection outperformed more traditional appearance-based approaches in terms of performance. In order to test the precision of the model and choose the best method for optimisation, we will use the CNN approach as well as other techniques. Next, we will test the trained model against our test data to determine how accurate it is. We will move on to the next section of the paper, real-time testing, if the accuracy reaches the desired level.

Before moving on to the next step, we will try various techniques to improve the model's accuracy if it is not accurate enough. The main application of our paper, real-time testing, is the subject of the second section. This entails having access to live footage of users or test-takers performing actions like taking a test. In these videos, we will apply face recognition and image processing techniques. Following face recognition, we will gather features to enable precise localisation of features like the eyes and, more specifically, the eyes themselves, whose movement the model must follow. The model will then examine the video footage and image frames to determine the users' eye movements. The core of our research and its primary application is represented by this real-time testing phase.

A calibration process will also be used to establish a fixed limit range for limiting user's eyeball movement. The boundaries range will be used as a guide to find any possible fraud during the examination. As mentioned before, frames will be taken at intervals of 5–10 s from the recorded videos. For testing purposes, these images will be turned into data and kept in a CSV file. The data will be scrubbed and pre-processed in order to organise it systematically before moving on to the testing phase.

Once the data is refined, testing will be performed using the trained model created in Part 1, employing the CNN technique as explained earlier. The paper adopts the classification metric, with the model providing results as 0 or 1. If the user's gaze remains within the calibrated boundary range, it signifies compliance, and the model will continue monitoring every 30 s until the exam concludes or the presence of fraud is discovered.

Yet if the individual's gaze leaves the checked boundaries for any of the frames that were captured, it suggests that they may not have been paying attention or participating in the test honestly. In such circumstances, the model will flag the particular candidate as having "FRAUD DETECTED" on it. A notification will be sent to the designated proctor or examiner, alerting them to the specific user and directing them to take the appropriate actions in accordance with the specified obligation or code of conduct.

## 4 Result

Tracking the eyeball's motion and location coordinates is the most important part of our gaze detection task, which we have successfully done. The observed eye of Medha Singh, who is one of the group's members, is shown in Fig. 2.

**Fig. 2** Diagram illustrating the process of capturing a face picture



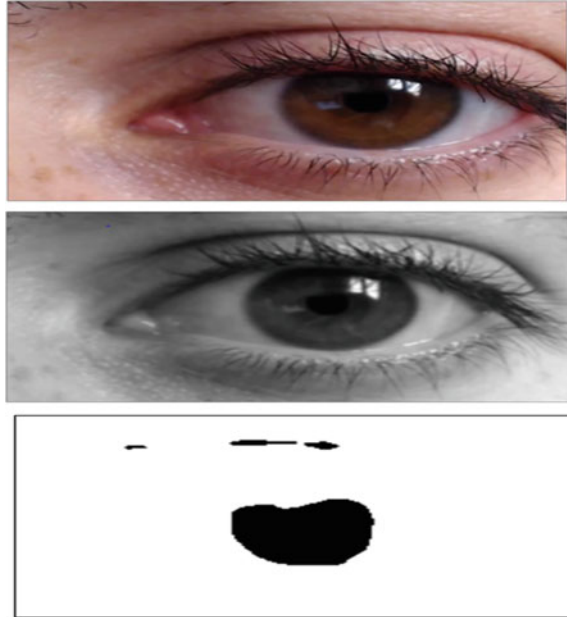
As shown in Fig. 3, we first turned the obtained eye image to a picture in grayscale to increase accuracy. We then converted it into an inverted, Gaussian-blurred image, alongside the threshold value being determined instantly from the live video. The illustration below helps to clarify the statement by giving an illustration of this procedure.

By assuming that the origin is the bottom-left area of the screen, we were able to determine the based distance ( $d_2$ ) for the eye coordinates employing the distance calculation formula from the origin. To determine the actual distance ( $d_1$ ), we manually determined the real coordinates of the eye.

The absolute variation between the scales of the based and actual distances was then used to calculate the error ( $E$ ). We determined the precision proportion for our paper based on three distinct frames that are employing a method shown in Fig. 4. The accuracy rates that were attained seemed 98.51, 97.67, and 98.75%.

Figure 5 shows how the built model is categorised when Reet Aggarwal, a member of our team, is looking inside the frame, denoting a normal state. On the other hand, a fraud warning is visible if a team participant looks outside the frame.

**Fig. 3** Image after applying Gaussian blur and inversion to the eye region



**Fig. 4** Accuracy calculation method

For,

Actual Distance ( $d_1$ )

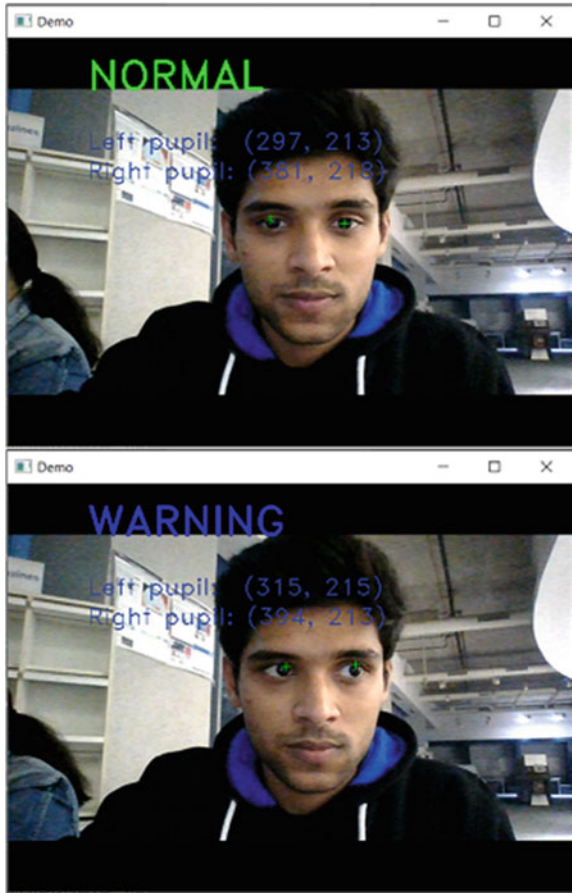
Derived Distance ( $d_2$ )

Error ( $E$ ) =  $|d_2 - d_1|$

Accuracy % ( $A$ ) =  $(d_1 - E) / d_1 * 100$



**Fig. 5** Our proposed built model classification



## 5 Conclusion

We aimed to develop an extensive eye gaze recognition system capable of precisely determining examinees' tasks during exams by fusing the face detection, eyeball detection, and eyeballs tracking techniques. The system's utility extends to proctors, providing them with valuable insights into candidates' behaviour, and to examination organisations, aiding in ensuring the integrity and fairness of the assessment process. In this paper, we meticulously crafted the eye gaze detection model by leveraging cutting-edge technologies and machine learning algorithms. The model enables us to classify an examinee's gaze behaviour into either fraudulent (indicative of malpractice) or fair (demonstrating legitimate engagement). The classification process results in a straightforward 0 and 1 format, simplifying the interpretation of the outcomes. The significance of this research lies in its potential impact on academic and professional examinations, enhancing the overall integrity of the evaluation process.

Administrators can utilise the model's results to trigger timely warnings whenever fraudulent activity is detected, thereby curbing unethical practices and ensuring the credibility and reliability of the assessment outcomes. Moreover, this system opens the door for further advancements in real-time monitoring during examinations, contributing to the continuous evolution and improvement of educational and professional assessment practices.

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# Fusing Management and Deep Learning to Develop Cutting-Edge Conversational Agents



S. M. P. Gangadharan, Subhash Chandra Gupta, Blessy Thankachan, Ritu Agarwal, Rajnish Kumar Chaturvedi, and Jagendra Singh

**Abstract** The use of conversational agents is recognized as a significant technological achievement that makes use of recent advances in machine learning and processing of natural languages. These “agents” which are considered to be computer programs enable effortless communication with users in natural language. Conversational bots have a lot of potential thanks to the recent integration of the processing of natural languages and artificial intelligence. In order to create an intelligent conversational bot, this research paper delves deeply into the incorporation of deep learning techniques. The implementation of a sequence-to-sequence simulation strengthened by a structure consisting of encoders and decoders is the main focus. A long-short cell memory recurrent neural network occupies the focal point of this architecture. The encoder facet is in charge of understanding user inquiries, and the decoder facet produces appropriate responses, resulting in an expert conversational system.

**Keywords** Recurrent neural networks · Deep learning · Long-short-term memory · Conversational agents · Sequence to sequence

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## 1 Introduction

One of the most effective uses of recent advancements in artificial intelligence (AI) and the processing of natural languages (NLP) which have been used often in recent years is conversational agents. Agents such as these are programs on computers that can interact with humans and speak with them in everyday language. They are frequently employed to automate shopping, hotel, and travel reservations, among other tasks. They might also be included in websites, mobile apps, messaging services, and other communication channels [1, 2].

It is an intriguing possibility for NLP to develop conversational bots utilizing AI methods. To create conversational bots, several research and development efforts employ NLP, deep learning, and machine learning methods. Additionally, programmers may create similar apps on a variety of platforms and frameworks, including IBM's Watson, Amazon's Lex, Google's Dialog flow, and Microsoft's Bolt Framework [3]. But they also have disadvantages, including NLP service lock-in and a hefty price. In the past, retrieval methods and manually constructed rule-based architecture have been used to build conversational bots. Neural networks have taken the place of these conventional models with the introduction of deep learning. Particularly, neural machine translation and the development of agents both require recurrent encoder-decoder models [4]. Using deep learning methods, we created a conversational AI in this study. The encoder-decoder architecture of the sequence-to-sequence (Seq2Seq) model was utilized [5]. This encoder-decoder employs LSTM cells in a recurrent neural network.

Following is how the remaining parts are organized: The pertinent pieces are displayed in Sect. 2. Section 3 provides a synopsis of our approach. The experiment was conducted and the results of our plan are displayed in Sect. 4. In Sect. 5, our paper concludes.

## 2 Related Work

A conversational agent, also referred to as a chatbot, embodies a computer program proficient in engaging in natural language conversations with humans. These interactions can span from uncomplicated rule-based mechanisms to more sophisticated AI-driven applications using natural language's strength understanding (NLU). The agent capitalizes on the amalgamation of machine learning (ML) and natural language processing (NLP) algorithms techniques to decode and comprehend user inputs, subsequently formulating responses in a coherent natural language manner. These dynamic applications often serve to automate diverse tasks encompassing customer service, e-commerce transactions, and travel bookings, among others. Seamless integration of these agents into mobile apps, websites, and social platforms bolsters user experiences by furnishing prompt and tailored responses [6].

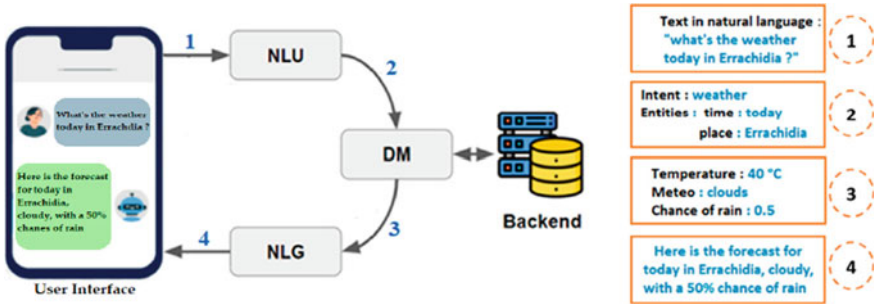


Fig. 1 Illustration of a conversational agent’s usual architecture

The first component is the natural language understanding (NLU) element, tasked with extracting intentions and entities from NL text obtained through the user interface (label no 1 in Fig. 1). This version of the dialogue is next handled using the dialogue manager (DM), and this analyzes the context of the conversation and carries out a variety of activities in line with the goal, such as calling on outside providers for data fetching (label no 3). The final piece is a natural language generation, or NLG, component, producing an answer that frequently takes the form of an NL phrase (label no 4).

Typically, we build these kinds of applications from scratch or by using services offered by certain platforms and frameworks [7] utilizing modern methodologies like deep learning, NLP, and machine learning techniques technologies.

Artificial neural networks called recurrent neural networks (RNNs) that created especially for the processing of sequential input (such as text and sound) utilized by agents. RNNs may receive variable-length sequences as inputs, such as  $v = (v_1, \dots, v_m)$ , and then use a recurrent loop to generate a series of hidden states,  $x = (x_{s1}, \dots, x_{sv})$ . This is in contrast to feed-forward neural networks (FFNN), which handle inputs of a set duration. As shown in Fig. 2, this is sometimes referred to as unrolling the network.  $Q_j$  and  $Q_k$  are the network weights, whereas  $X$  is used as the input sequence,  $x_{sm-2}$  is used as the sequence of the output,  $x_j$  is the occult state progression, and so on.

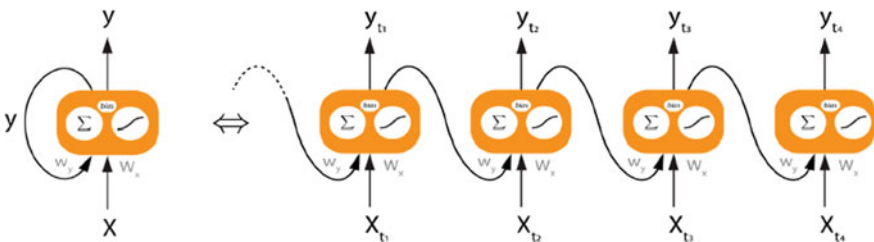


Fig. 2 Four-step unfolding of an RNN

Because RNN implementations cannot recall long-term dependencies (vanishing or exploding gradients), they are rarely employed for extended sequences and are difficult to train. As an illustration, consider the statement that follows: “Errachidia is one of the southeast of the country; it is one of Morocco’s popular tourist destinations. It is possible that the RNNs will overlook the relationship between the terms “Errachidia” and “it.” As a result, the problem of long-term dependency that RNNs face was addressed by the development of LSTM and gated recurrent units (GRU), allowing models learning how to remember both short and long-term data. With the use of LSTMs and GRU, conversational representatives for NLU and NLG have successfully been built. After that, the architecture for Seq2Seq is presented as a paradigm for a machine translation and conversation system [8, 9]. A decoder and an encoder, both RNNs, make up this system. One symbol is processed by an encoder at each time step after being entered as a sequence. Its objective is to convert a collection of characters to a vector of context that accurately expresses the meaning of the string. The context aids the decoder in producing a different output sequence.

Transformer design, which was developed more recently, makes use of attention strategies to let models take the entire context into account when writing text. Transformer models have significantly improved performance in a variety of NLP tasks, including developing conversational agents, including representations of bidirectional encoders from transformers, or BERT, and generative pre-trained transformers (GPT) [10]. For instance, GPT3 was used to create ChatGPT [11]. In the following section, a useful method for creating conversational bots is illustrated using the sequence to sequence. The model employs LSTM cells through the encoder–decoder process. Here, the encoder is used to read the request, and the decoder is used to provide the response [12, 13].

### 3 Methodology

Five steps make up our strategy for this study. To begin, we import the desired data (label 1 in Fig. 3). The following phase involves data preprocessing (label 2). The third phase involves splitting the data into two sets: a training set and a testing set (label 3). A Seq2Seq model that includes an encoder–decoder design and LSTM cells of both parts is created in the fourth phase (label 4). After being comprehended by an encoder, and this also generates the answer, the client’s input is decoded. The trained model is used to interact with users after being saved (label 7, label 8, and label 9).

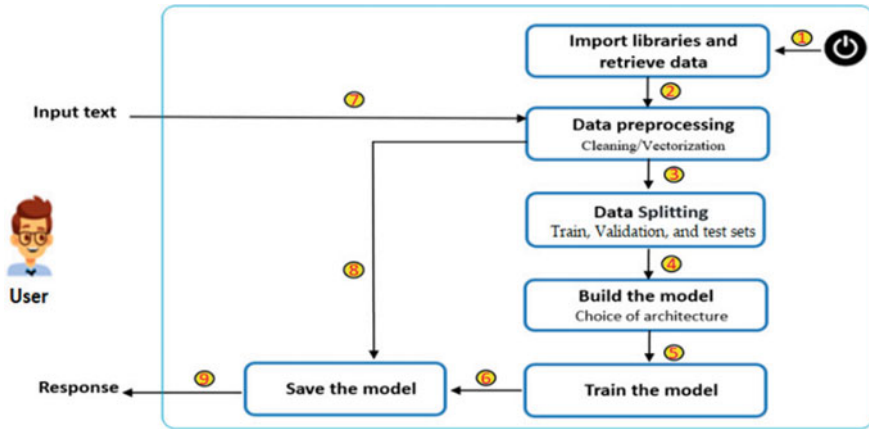


Fig. 3 Overview of our method

## 4 Results and Experiments

### 4.1 Data Set

The conversations agent referred to be the “Cornell Movie Dialogue Corpus” was developed using data taken from the Cornell University website [14]. This corpus is a substantial archive of chats with a wealth of tags. The dataset is made up of two writing files: the first one corresponds to the conversations among different users while the second one includes the conversation’s id, film id, person id, and actual dialogue. There are 236,765 conversations between movie characters in this corpus, totaling 11,565 pairs. It contains 83,098 dialogue exchanges between 9654 characters from 654 films. There are 216,765 total utterances.

### 4.2 Data Preparation

Preprocessing, which has a number of related sub-steps, is an important step in preparing the data for the Seq to Seq model’s training. We initially created a dictionary that connected every dialogue in accordance to its corresponding ID to the first file. We compiled a list of all nested discussions in the second file. The data was then split into two sets with questions and answers. The question-and-answer lists have been trimmed off every major letter, punctuation, and specific words (–, #, \$, etc.) in order to obtain clean data [15, 16]. By omitting longer questions and padding shorter ones with a specific token, our approach required that both responses and questions be a predetermined length. The dataset’s terms were then assembled into a vocabulary.



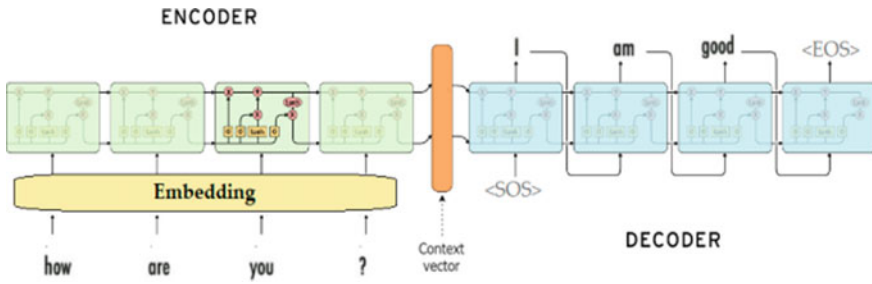


Fig. 4 Seq2Seq model architecture

### 4.3 Data Splitting

Three subsets of a dataset are created: an instruction set, a set for validation, and a set to be tested. The training set refers to a subset of the information that was utilized for training the model. A validation set was used for tuning the model's hyperparameters. In contrast with training and a hyperparameter adjustment, testing is when the model's performance is evaluated. In our experiment, 90% of the data were used for training, 5% for validation, and 5% for testing.

### 4.4 Building the Model

Keras and TensorFlow are open-source software libraries used to build and instruct deep learning models, which are then used to build models for Seq2Seq utilizing encoder-based deep learning. Decoder architecture is based on LSTM. Keras is a high-level neural networks API created in Python that sits on top of TensorFlow. There is a choice of already constructed layers, including LSTM layers. Its architecture, which we developed using these APIs, is shown in Fig. 4. Encoders and decoders, which are frequently RNNs similar to the LSTMs we employed in our experiment, make up the system. The encoder uses an input sequence, like an English phrase, to create a context vector that describes the information being encoded in the sequence that is input [12]. A decoder makes use of this context vector.

### 4.5 Model Training

The model was trained on the processed dataset with different learning rates, epoch counts, batch sizes, and LSTM cell counts. We selected accuracy as the metric, categorical cross-entropy as the loss function, and Adam as the optimizer. As shown

**Table 1** Different settings for our models hyperparameters

| Hyperparameters | Configuration 1 | Configuration 2           | Configuration 3 | Configuration 4 |
|-----------------|-----------------|---------------------------|-----------------|-----------------|
| Optimizer       |                 | Adam                      |                 |                 |
| Batch size      | 32              | 32                        | 32              | 64              |
| Metric          |                 | Accuracy                  |                 |                 |
| Learning rate   | 0.001           | 0.001                     | 0.001           | 0.001           |
| LSTM cell       | 256             | 256                       | 512             | 512             |
| Loss function   |                 | Categorical cross-entropy |                 |                 |
| Epochs          | 11              | 50                        | 75              | 100             |

In Table 1, the hyperparameters in question were set up using three different ways, and we used them to train the model.

### 4.6 Results

In this experiment, we discovered that the best performance was achieved with the following parameters: 11 epochs, 0.001 (learning rate), a batch size of 32, and a total of 256 LSTM cells. Following training, the model developed had an approximate training accuracy of 90.65% and an approximate validation accuracy of 89.37%. We ran our model upon the test set, and its precision was 83.50%. Table 2 displays the outcomes of our investigation.

We observed excellent precision on the initial training data but poor performance on the verification data, suggesting that the outputs of our models are frequently overfitted. Overfitting can be avoided using regularization techniques such as dropout, earlier stop, and adding more data to the model.

**Table 2** Model accuracy in each of the four setups

| Configuration | Training accuracy (%) | Validation accuracy (%) | Test accuracy (%) |
|---------------|-----------------------|-------------------------|-------------------|
| 1             | 90.65                 | 83.03                   | 83.50             |
| 2             | 87.08                 | 89.37                   | 82.55             |
| 3             | 82.16                 | 82.18                   | 81.60             |
| 4             | 83.50                 | 82.12                   | 81.39             |

## 5 Conclusion

In this paper, we provide a practical illustration of a question-and-answer conversational bot, shedding light on its development through natural language processing and deep learning techniques. The foundation of our implementation rests on the Seq2Seq architecture, coupled with the utilization of LSTM cells, which have proven to be instrumental in enhancing the bot's conversational capabilities. We delve into the intricacies of how this model is crafted, detailing the step-by-step process of integrating the Seq2Seq framework and LSTM cells. By leveraging these techniques, the bot becomes adept at understanding input queries and generating coherent responses, mirroring human-like interactions. This not only underscores the power of deep learning but also emphasizes the progress made in natural language processing. Furthermore, the article offers a comprehensive showcase of the outcomes derived from rigorous training sessions. It highlights the evolution of the model's responses over the training duration, underscoring its capacity to learn and adapt from conversational data. These results provide valuable insights into the model's learning curve and its potential for broader applications in automated customer service, virtual assistants, and more.

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# Water Quality Classification Using Machine Learning Techniques



Minu Kumari and Sunil Kumar Singh 

**Abstract** There is no life without water. All humans, plants, and animals need water to live. It is important to know if drinking water, a resource of human life, will be enough for everyone now and in the future. Access to clean water and hygiene is an important human right and part of the health safety policy. At the national, state, and local levels, clean water is a critical problem for health and development. This work's primary goal is to use various modeling techniques based on machine learning, deep learning, and ensemble learning to measure water quality using hyperparameter tuning of each algorithm. We have used SVM, RF, XGBoost, DT, and LGBM model stacking and voting ensemble for efficient and fast prediction. PH, chloramines, hardness, solids, sulfate, organic carbon, conductivity, trihalomethane, turbidity, and potability were the parameter used as a feature vector. A different machine, deep, and ensemble learning algorithm was used to evaluate water prediction, and the effects are compared on the accuracy, ROC AUC values, precision, recall, F1-score, MCC, and kappa score. In addition, the Freidman Ranking is also used to evaluate the model's efficiency. According to related studies, ensemble learning-based models are the most effective.

**Keywords** Water quality · Drinking water · Potable · Machine learning · Ensemble learning · Stacking · Voting

## 1 Introduction

Water<sup>1</sup> covers 71% of the surface of the world, 97% of it is in the oceans (where it is too salty to drink, grow crops, or utilize for most commercial purposes other than refrigeration), and 3% of the water on earth is foamy. 2.5% of the clean water on earth is inaccessible trapped in ecosystems, soils, polar ice caps, and glaciers. How

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<sup>1</sup> <https://www.usbr.gov/mp/arwec/water-facts-ww-water-sup.html>.

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0.5% of earth's water is most effectively freshwater—the amount needed for lifestyle survival.

As stated in the United Nations Convention on the Rights of children, every child has a right to access clean water and proper sanitation. A major goal of UNICEF's water, sanitation, and hygiene (WASH)<sup>2</sup> mission is to make sure that no child is left behind and that all children fulfill their commitment.

Drinking water quality refers to the characteristics of water that make it safe and suitable for human consumption. These characteristics include physical, chemical, and biological properties, such as PH level, dissolved oxygen content, mineral content, and the presence of microorganisms.

Analysis of the quality of water is challenging because of the variety of factors that affect it. Important factors like population growth, urbanization, industrial wastewater, and pollution from agriculture have an impact on water availability and quality. Polluted water, and infected water, potability water, palatable water are the four primary categories of water quality [1]. The scientific terms used to describe these categories of water quality are listed below.

- **Polluted water**—Harmful biological, chemical, physical, or radioactive substances may be present in polluted water. Not suitable for drinking or domestic use.
- **Infected water**—Water contains pathogenic microorganisms. It is injurious to health.
- **Palatable water**—Water contains chemical substances that are not harmful to human health.
- **Potability water**—It is good in taste, safe to drink, and useful for domestic uses.

Machine learning algorithms are programs that can identify hidden patterns in data, predict outcomes, and improve performance based on past performance. Different machine learning algorithms have been developed in these dynamic times for solving challenging real-world problems. Evaluation of water quality techniques uses complex and time-consuming deep learning as well as machine learning algorithms. However, they can provide promising results in both cases.

This study uses a dataset of public drinking water to successfully assess different supervised machine learning methods. The goal of this study is as mentioned below.

- To determine the best model for effectively classifying the water quality.
- To analyze overall water quality in terms of potability, a few factors such as PH, chloramines, hardness, solids, sulfate, conductivity, organic carbon, turbidity, trihalomethane.
- Policy recommendations to improve the water quality for a better quality of life.

The rest of the work is organized as follows. Section 2 discusses the similar work done in the area of water classification and other similar studies. The dataset description is given in Sect. 3 along with the features. Section 4 talks about the methodology and a brief introduction to the applied machine, deep, and ensemble

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<sup>2</sup> <https://www.unicef.org/wash>.

learning models. Performance measure to evaluate the model is presented in Sect. 5. Section 6 presents the performance analysis and finally, Sect. 7 concludes the work.

## 2 Literature Survey

Water quality prediction is an important research area, providing valuable information for water management and decision-making. Several studies have focused on water quality prediction and in this section, we have discussed a few similar works done which indicates the important contribution toward water quality prediction.

An evaluation of a machine learning method on the quality of drinking water for better sustainability was proposed in [2]. In this work, they have applied the machine learning-based models but none of the models can conclude the better quality of prediction. They are performing on a few selected performance metrics only. Similarly, a study is conducted by [3] to explore the reliable model for reliable water quality prediction. Using reliable models is one of the most important aspects of predicting water quality. The parameters of water quality, such as dissolved oxygen (DO), nitrogen, and phosphorus, have been predicted using a variety of models. The findings of the work indicate that ANN models are found effective for dealing with the rivers, lakes, groundwater, and pond water quality studies. This study also suggests that hybrid and ensemble learning-based models can be explored [4] applied the binomial distribution and k-nearest neighbor to access the water quality components that affect the water potability. They have also developed the model in such a way that the potability of water quality can be predicted using individual components of the water.

In the study [5], the ideas around machine learning models and their applications for determining water quality (WQ) are discussed. The WQ prediction was performed using J48, multi-layer perceptron (MLP), and Naive Bayes machine learning techniques. The dataset used contained 10 features and several accuracy measures were used to evaluate the performance. The outcome showed the proposed model's ability to classify water quality accurately. The MLP algorithm, when compared to other algorithms, has the highest accuracy for WQ prediction.

Furthermore, water quality features have been predicted via remote sensing. Remote sensing techniques have been used to estimate chlorophyll-a, total suspended solids, and turbidity. A study [6] used remote sensing to predict the concentration of chlorophyll-a in the Meiliang Bay of Lake Taihu in China. A similar study [7] showed that remote sensing was effective in predicting chlorophyll-a concentrations. Moreover, faraway sensing has been used to predict water satisfactory parameters. Remote sensing techniques have been used to estimate chlorophyll-a, overall suspended solids, and turbidity.

The work [8] investigated a suitable ML-based classification model for water quality. The performance of several classification models and algorithms was examined in their study to determine the primary features of classifying water quality. Every sample was taken from a Malaysian river. A comparison of five models and

their associated algorithms showed that the lazy model implementing the K-Star algorithm has the highest accuracy.

In [9] a real-time approach to measuring the quality of the water has been proposed. It employs ML technology and electromagnetic sensors. The integrated multi-sensor device measures several aspects of water quality, including temperature, conductivity, oxygen-reduction potential, gaseous  $C O_2$ , and PH. Many parameters, including S11 working in the frequency range of 50–3 GHz, were provided by the Vector Network analyzer. Water sample changes were recorded and analyzed. Then, ML technology was applied to measure changes in the pollutants in the water.

For predicting water quality, data-driven models have also been employed. Record-based models use historical data to predict future water parameters [10] used a statistics-pushed version to expect the awareness of dissolved oxygen within the Xiangxi River in China. The consequences of the study showed that the statistics-driven version was powerful in predicting dissolved oxygen concentrations.

In the paper [11] proposed two new decision tree-based techniques. In the short term, these methods produced more precise predictions of water quality over the dataset of the American Tualatin River. The high gradient boosting and random forest algorithms that the authors proposed offer an effective data denoising method. Similarly, [12] examines how well artificial intelligence techniques, such as artificial neural networks (ANN) and support vector machines (SVM), predict various aspects of water quality. Every sample of data was gathered from the Iranian River. When using artificial intelligence techniques, a variety of various transfer and kernel functions have been tested. The authors concluded that AI approaches are suitable for predicting the elements of water quality.

In the proposed work, we have applied machine learning, deep learning, and ensemble learning-based models for effective water quality prediction. As we know that for many reasons in India, peoples are under extreme stress for finding drinkable water, and it is also quite challenging to determine whether existing water is safe to drink or not. The details about the dataset used in the work are discussed in the next section.

### 3 The Dataset

This data is available from a variety of sources, including government agencies and research institutions. This file contains 3276 records of metrics and contained 10 features [13]. During the initial pre-processing of the data, standardization and normalization techniques are applied. However, the provided dataset records are useful for learning. The parameters of water quality are measured as follows:

- *PH* value—The PH scale measures the degree of acidity and alkalinity in water. The ph. scale varies between 6.5 and 8.5.
- Hardness—The amount of dissolved calcium and magnesium in the water determines how hard it is.



- Solids—Total dissolved solids (TDS), a measure of solids, reveal whether or not the water is mineralized. A high TDS value indicates high mineralization. It is expressed in mg/l.
- Conductivity—Water’s conductivity is a measure of its capacity to carry electrical current. The drinking water conductivity is 200–800  $\mu\text{S}/\text{cm}$  (micro Siemens per centimeter).
- Chloramines—Chloramines are a group of chemical compounds that include both chlorine and ammonia. Monochloramine is a form of chloramine that is used to purify drinking water. It is added to the water at a quantity that kills germs but it is still safe to drink.
- Sulfate—It can be found in almost all natural water sources. In the manufacturing of fertilizers, chemicals, paper, and water treatment processes sulfates are widely used. Drinking water levels of sulfate should not exceed 250 mg/L.
- Total organic carbon (TOC)—Decomposing natural organic material and manufactured products are the sources of organic carbon in source waters. It counts all the carbon found in molecules that are organic in pure water. In mg/L, it is measured.
- Trihalomethanes (THMs)—THMs are chemical compounds that may form when chlorine is added to purify water. It is measured as a unit of nephelometric turbidity.
- Turbidity measures the hazy or cloudy appearance of a fluid made by many tiny particles that are often invisible to the normal eye, much like smoke in the air. In ppm, it is measured.
- Potability defines the water that can be considered safe for drinking and safety for human consumption. It is clear, colorless, and odorless. It has a value of 0 or 1.

The “potability” feature is the output of the proposed framework, while the first nine features are its inputs. Therefore, the information is classified into two categories: “drinkable” or “non-drinkable”. The one-digit codes for these two categories are “1” for potable and “0” for non-potable.

## 4 Methodology

This section presents the flowchart of the proposed methodology for applying the machine, deep, and ensemble learning-based models. Figure 1 displays the flowchart for the proposed model. Further, to improve the quality of data for finding meaningful information, we have pre-processed the data to fill the null values by taking the mean value of the respective attributes.

Before applying the models, we divided the dataset into two parts; training and testing in an 80/20 ratio. The flowchart shown in Fig. 1, will find the best-performing model after evaluating them based on the performance metrics.

A few applied models are briefly discussed here to show the working.

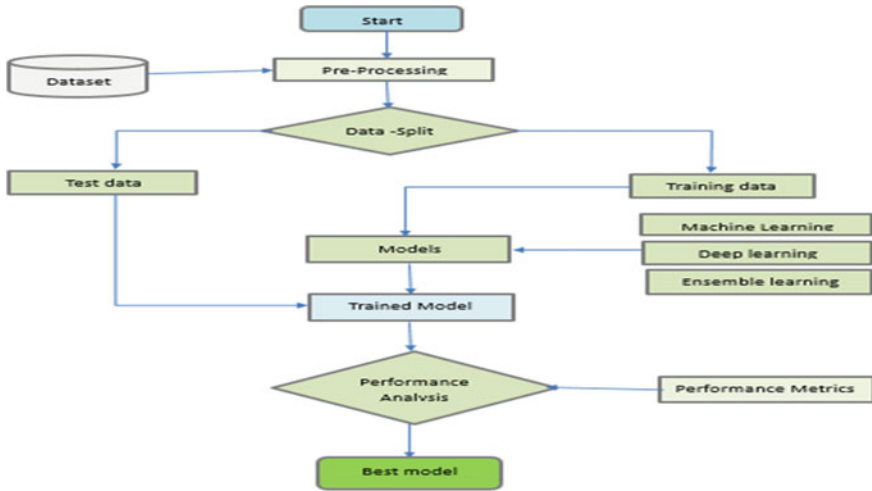


Fig. 1 Flow chart of approach model

### 4.1 Supervised Machine Learning Models

The following is a summary of the applied supervised machine learning models-

#### Logistic Regression (LR)

Logistic regression is a statistical model. It predicts the category-dependent variable given a collection of independent variables. As a result, the outcome must be discrete (accurate values). For instance, the result could be Yes or No, 0 or 1, True or False. LR algorithm also provides a probabilistic value between [0, 1] [14].

#### Support Vector Machine (SVM)

Support vector machine (SVM) with Radial Basis Function (RBF) kernel is a powerful and widely used machine learning algorithm for classification tasks. The concept of SVMs is to identify a hyperplane that has the largest possible margin of separation across the data points from various classes. The RBF kernel is one of the popular kernel functions used in SVMs that allows for nonlinear classification [15]. The RBF kernel is defined as follows:

$$K(x, x') = \exp\left(-\gamma\|x - x'\|^2\right) \tag{1}$$

- $K(x, x')$  is the kernel function used to compare the similarities between two data points,  $x$ , and  $x'$ .
- The decision boundary's shape is determined by the hyperparameter  $\gamma$ . It defines how each training example impacts the decision boundary. The highest

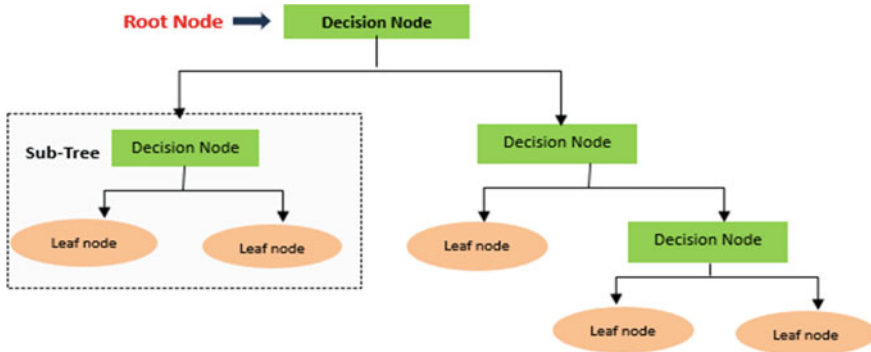


Fig. 2 Decision tree architecture

values of gamma ( $\gamma$ ) give a decision boundary that is more complex and closely fits the training set of data, which may cause overfitting.

*Gaussian Naive Bayes (GNB)*

Gaussian Naive Bayes is the extension of the Naive Bayes model. An approach for probabilistic classification called Gaussian Naive Bayes is based on using the Bayes theorem under the strong independence specifications [16]. The probability of  $x_i$  the Gaussian distribution function is represented by:

$$P(x_i|y) = \frac{1}{\sqrt{2\pi\sigma_y^2}} \exp\left(-\frac{(x_i - \mu_y)^2}{2\mu_y^2}\right) \tag{2}$$

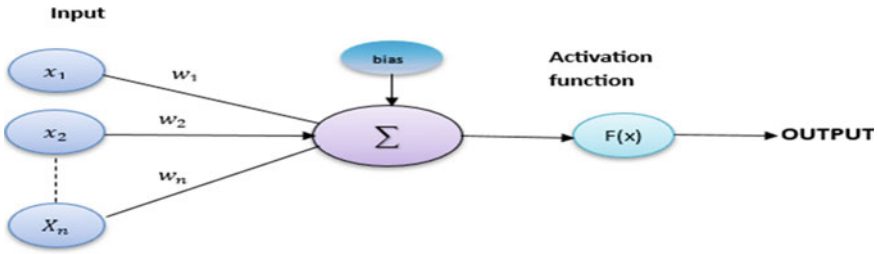
where  $\sigma^2$  is the variance and  $\mu$  is the mean. Maximum likelihood is used to estimate the parameters  $\mu_y$  and  $\sigma_y$ .

*Decision Tree (DT)*

For binary classification tasks, decision trees are a common machine learning approach. They build a decision-based model in the form of a tree. The two nodes in a decision tree are the Decision node and Leaf node. Decision nodes are used to make decisions and have multiple branches, while Leaf nodes indicate the decisions' outcomes and do not have any extra branches [17] (Fig. 2).

**4.2 Deep Learning Model**

The following is a discussion of applied deep learning models:



**Fig. 3** ANN architecture

*Artificial Neural Network (ANN)*

Artificial neural network (ANN) models can be effectively used for binary classification tasks. ANN models are composed of interconnected artificial neurons or nodes that simulate the behavior of biological neurons in a human brain. They are designed to learn and generalize patterns from input data to make predictions [18].

$$Y = b + w_1x_1 + w_2x_2 + w_3x_3 + \dots + w_nx_n \tag{3}$$

where  $b$  is the bias,  $x$  is the input vector, and  $w$  is the weight (Fig. 3).

*Multi-layer Perceptron (MLP)*

One of the most commonly used models of neural networks in the field of deep learning is the multi-layered perceptron (MLP) [19]. It has three different kinds of layers: an input layer, an output layer, and a hidden layer, as shown in Fig. 4. The input, bias, weights, weighted summation, and step function are the five main components of a perceptron. The input for the training of the first layer must contain the features. After that, the result of the inputs is multiplied by the weights. A bias value is used when changing the output function. The perceptron formula is shown below:

$$Y = \begin{cases} 1, & \sum_{i=1}^n w_i x_i \geq 0 \\ 0, & \sum_{i=1}^n w_i x_i < 0 \end{cases} \tag{4}$$

where  $b$  is the bias,  $x$  is the input vector, which can also be the output of the previous layer, and  $w$  is the weight.

**4.3 Ensemble Learning Method**

*Random Forest (RF)*

Random forest (RF) is a classifier that uses many decision trees on different subsets of the input dataset and averages the results to improve the dataset’s predicted accuracy.

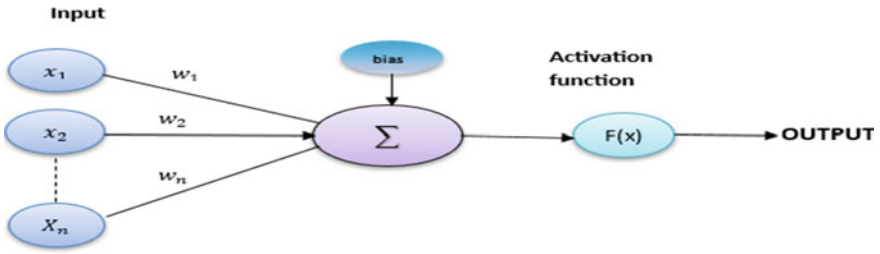


Fig. 4 Architecture of MLP

It can also maintain accuracy even when most of the records are missing. Accuracy is increased and overfitting is avoided with more trees in the forest [20]. A random forest classifier is shown in Fig. 5.

*Extra Tree (ExT)*

An ensemble ML method is Extra Trees (ExT), often known as an extremely random tree. From the gathering of training data, the ExT algorithm creates a large number of trees. As a result, predictions are made after averaging all of the decision tree predicts to get the final prediction. Similar to the RF algorithm, the ExT algorithm chooses elements at random at each decision tree split point. Compared to the decision tree and random forest algorithms, it is considerably faster. It takes less time to select the perfect split point and decreases bias and variance. Hence, the model has less chance of being over or under fit [21] (Fig. 6).

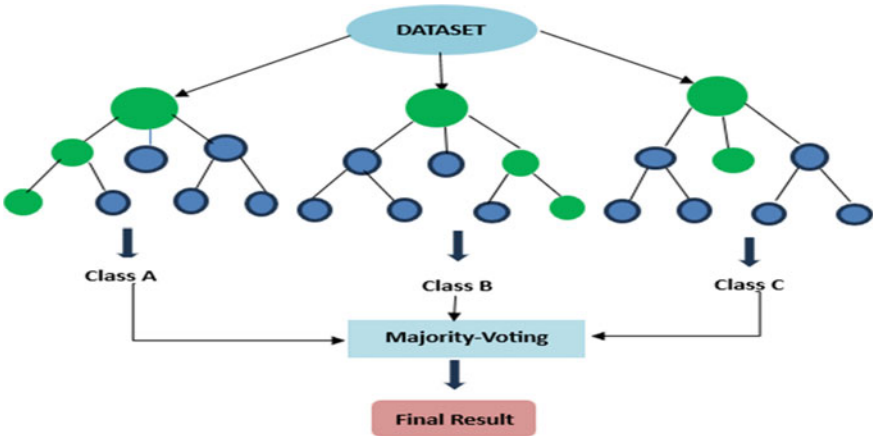


Fig. 5 Displays the general architecture of RF

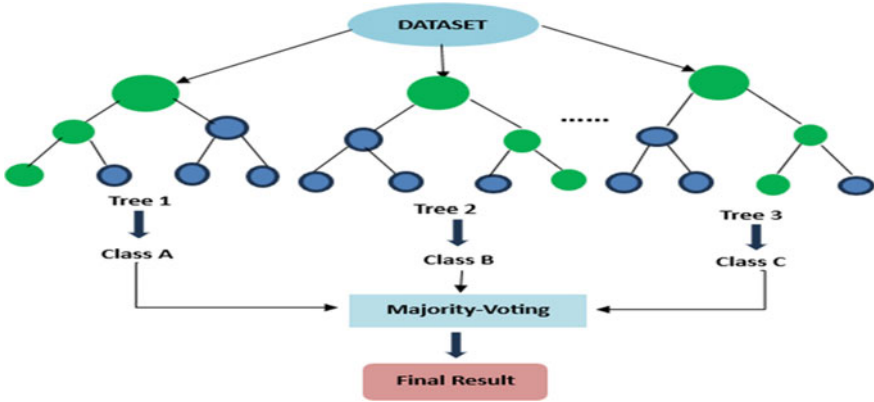


Fig. 6 Displays the general architecture of ExT

*Extreme Gradient Boosting (XGBoost)*

XGBoost is one of the most popular and widely used ML models due to its ability to handle large amounts of data. Models may be trained on big datasets fast because to XGBoost’s integrated support for parallel processing. An ensemble learning method is XGBoost, meaning that its outputs combine multiple models while making the final predictive decision [22] (Fig. 7).

*Light Gradient Boosting Machine (LGBM)*

LGBM is a gradient boosting method that makes use of a tree-based learning technique. It grows trees vertically whereas other algorithms grow trees horizontally,

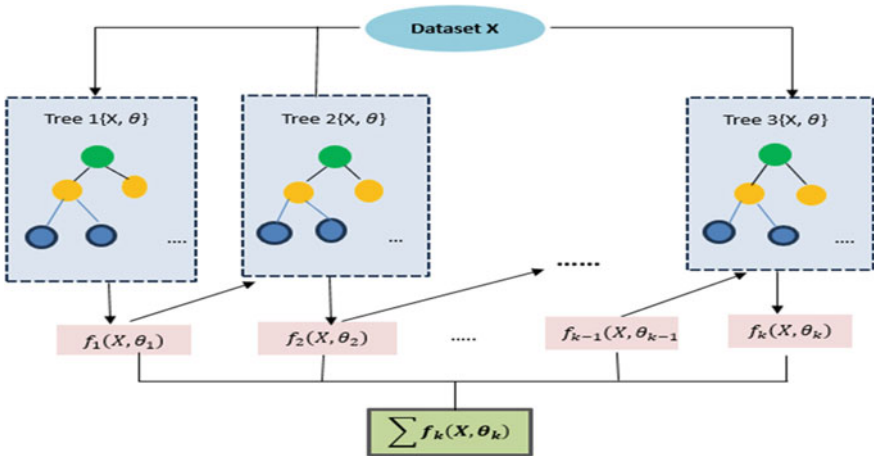


Fig. 7 General architecture of XGBoost

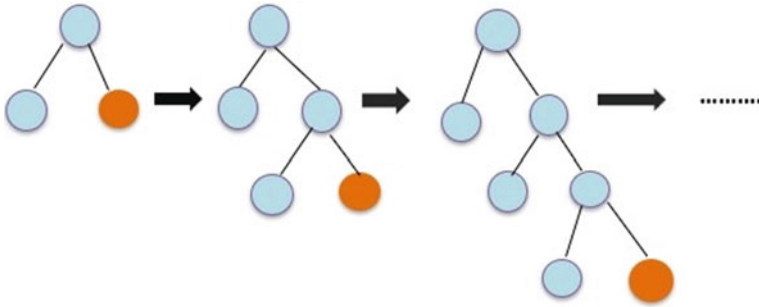


Fig. 8 LGBM leaf-wise growth

i.e., LGBM grows tree leaf-wise whilst other algorithms grow levels-wise. In the diagrams below, the LGBM implementation is shown (Fig. 8).

The leaf with the maximum delta loss will be chosen to grow. A level-wise algorithm can result in more loss reduction when growing the same leaf than a leaf-wise approach can. Due to its high speed, Light GBM is prefixed with “Light”. It handles a large amount of data and takes less memory space to run. It includes two modern methods: Exclusive Feature Bundling (EFB) and Gradient-based one-side sampling (GOSS) [23].

*Ensemble of Model*

In an ensemble model, the predictions of two or more machine learning models are combined. Voting and stacking are two different ensemble learning methods used in this work. One of the most common ensemble machines learning techniques, stacking, is used to predict multiple nodes in order to create a new model to improve model performance [24] (Fig. 9).

Unlike the stacking method, the voting ensemble is used for machine learning classification. Voting classifier estimators created by combining different classification models turn out to be more powerful meta-classifiers that compensate for the

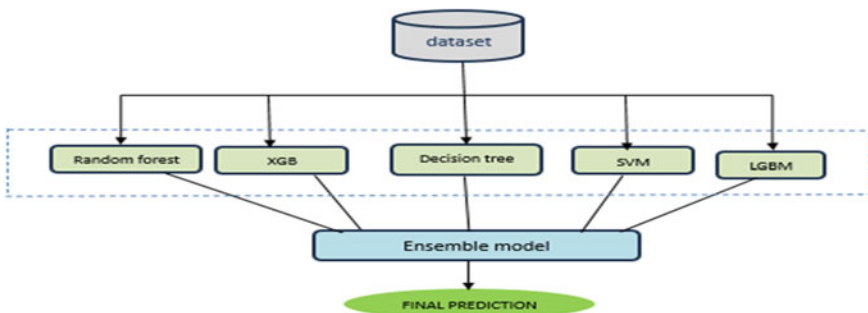
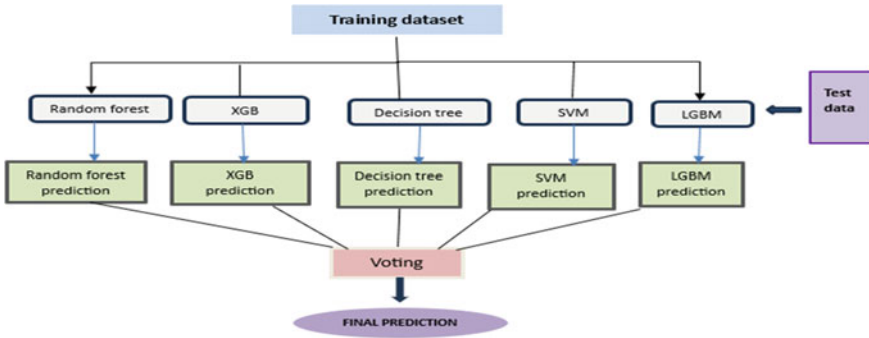


Fig. 9 Stacking-based ensemble learning model



**Fig. 10** Voting-based ensemble learning model

weaknesses of each classifier in a given dataset. Voting classifiers perform majority voting based on weights applied to classes or class probabilities. Figure 10 displays the outcomes of the algorithms we used: RF, XGB, decision tree, SVM, and LGBM. The ensemble classifier prediction can be expressed mathematically as:

$$\hat{Y} = \mathop{\text{arg}}\limits_i^{\max} \sum_{j=1}^m W_j X_A(C_j(x) = i) \quad (5)$$

In the above equation,  $C_j$  represents the classifier,  $W_j$  represents the weight associated with the prediction of the classifier.

## 5 Performance Metrics

The performance evaluation is based on accuracy and ROC AUC and can be determined using the F1-score, recall, and precision. Confusion matrix is frequently used to evaluate the effectiveness of classification models, which aim to predict a categorical label for each input occurrence [25]. In the matrix, [26] the number of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) generated by the model on the test data is shown-

- True Positive (TP): The total counts have both drinkable and actual drinkable values.
- True Negative (TN): It is the total counts having both drinkable and non-drinkable values.
- False Positive (FP): This refers to the total counts that were predicted to be both drinkable and not drinkable.
- False Negative (FN): It is the total counts having prediction is not drinkable while actually, it is drinkable.



Precision is defined as the ratio of correctly identified positive samples (true positives) to the total percentage of positively classified samples (true or false). It can be calculated using the following formula—

$$\text{Precision} = \frac{tp}{tp + fp} \quad (6)$$

Recall is defined as the ability of a model to identify positive samples. The recall is calculated as follows:

$$\text{Recall} = \frac{tp}{tp + fn} \quad (7)$$

The F1-score combines a classifier's precision and recall into a single metric by using their harmonic mean, where the best value for an F1-score is 1 and the worst value is 0 [26]. The F1-score is calculated as follows:

$$\text{F1 - Score} = 2 \times \frac{\text{recall} * \text{precision}}{\text{recall} + \text{precision}} \quad (8)$$

AUC-ROC measures the curve's area under the curve and compares the difference between the true positive rate and the false positive rate. The AUC measures the performance of a single model at various thresholds as well as comparing two models. Sensitivity and recall are used to calculate the ROC AUC, a measurement of a system's ability to differentiate between classes. Recall is previously defined in Eq. (10), but sensitivity is calculated as follows:

$$\text{Sensitivity} = \frac{fp}{fp + tn} \quad (9)$$

Accuracy is the ratio of the number of true predictions to the total number of samples. It scores ranges from 0 to 100, with 100 representing a perfect score and 0 representing the worst possible result. Where *accuracy* is calculated as follows:

$$\text{Accuracy} = \frac{\text{correct predictions}}{\text{all predictions}} \quad (10)$$

The Kappa Coefficient [27], commonly referred to as Cohen's Kappa Score, is a statistical measure of inter-rater agreement for categorical data. It is used for comparing the actual labels in the data with the predicted labels from a model. It ranges from -1 (worst possible performance) to 1 (best possible performance). With the following formula, the Cohen's Kappa Score can be determined-

$$\text{Kappa score} = \frac{P_o - P_e}{1 - P_e} \quad (11)$$

**Table 1** Performance metric values of the applied models

| Algorithm   | Precision | Recall | F1-score | Accuracy     | ROCAUC | MCC  | Kappa score | F.Ranking   |
|-------------|-----------|--------|----------|--------------|--------|------|-------------|-------------|
| RF          | 86.09     | 64.2   | 65.82    | 79.42        | 72.51  | 0.55 | 0.52        | 5.21        |
| XGboost     | 79.35     | 73.39  | 65.57    | 78.53        | 75.74  | 0.52 | 0.52        | 5.71        |
| LR          | 77.87     | 67.38  | 58.11    | 63.04        | 61.89  | 0.52 | 0.46        | 8.64        |
| SVM         | 71.38     | 78.99  | 52.53    | 78.64        | 69.02  | 0.47 | 0.42        | 7.5         |
| MLP         | 75.33     | 78.51  | 62.39    | 79.77        | 62.02  | 0.29 | 0.27        | 8.42        |
| Extra Tree  | 67.06     | 78.56  | 62.47    | 75.02        | 67.65  | 0.43 | 0.42        | 8.5         |
| GNB         | 84.48     | 60.24  | 70.33    | 63.87        | 76.48  | 0.58 | 0.57        | 4.71        |
| LGBM        | 84.58     | 67.05  | 69.6     | <b>81.44</b> | 76.36  | 0.57 | 0.56        | 3.71        |
| DT          | 75.08     | 72.32  | 68.00    | 76.67        | 69.66  | 0.46 | 0.41        | 7.42        |
| ANN         | 61.09     | 65.59  | 63.84    | 75.32        | 68.59  | 0.37 | 0.35        | 9.57        |
| Voting-CF   | 82.6      | 62.29  | 71.02    | 81.09        | 77.26  | 0.58 | 0.57        | <b>2.85</b> |
| Stacking-CF | 81.18     | 61.88  | 51.83    | 80.48        | 76.7   | 0.57 | 0.56        | 5.71        |

where  $P_o$  is the observed probability and  $P_e$  is expected probability.

MCC stands for Matthews Correlation Coefficient [27], which is a measure of the quality of binary (two-class) classification models. It considers true positives, true negatives, false positives, and false negatives and provides a balanced score that is particularly useful when dealing with unbalanced data sets. The MCC is in the range of -1 (worst performance) to +1 (best performance). With the following formula, the MCC can be determined-

$$MCC = \frac{tp \times tn - fp \times fn}{\sqrt{(tp + fp)(tp + fn)(tn + fp)(tn + fn)}} \quad (12)$$

As a result, the accuracy and ROC-AUC, precision, recall, F1-score, MCC, and Cohen's Kappa Score metric values are shown in Table 1.

## 6 Performance Analysis

To evaluate the performance of the model, we have written the program in the Python programming language and executed it on the Google Colab platform. The performance of the models was measured in terms of precision, recall, F1-score, Kappa, and Matthews Correlation Coefficient.

The RF, XGB, SVM, decision tree (DT), and LGBM models are used in the voting and stacking-based ensembles. Table 1, shows the performance of the models in terms of performance metrics stated in section.

The results shown in Table 1, indicate that LGBM is giving the highest accuracy 81.44% and Voting-CF is marginally lacking along with the accuracy 81.09%. To

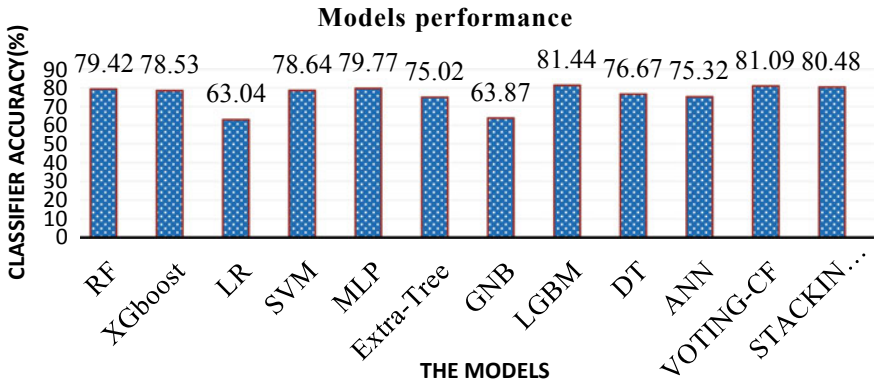


Fig. 11 Bar plot for classifiers performance comparison

analyze the effectiveness of a model based on the utilized performance metrics, we have applied the Friedman ranking test [28], and the ranking value indicates that Voting-CF is one of the best-performing models along with a rank value of 2.85 (Fig. 11).

It shows the classification report based on machine learning, ensemble learning, and deep learning models. The ideal model configuration to get an optimized outcome can be found for each algorithm through hyperparameter tuning on whether or not the water is potable. In this precision, recall, F1-score, and accuracy are measured of each sample. Accuracy is determined by dividing the number of correct predictions by the total number of predictions; while ROC AUC compares the ratio of true positive to false positive rate. Based on Table 1. With a result of 86.09%, the RF classifier outperforms all other classifiers in terms of precision.

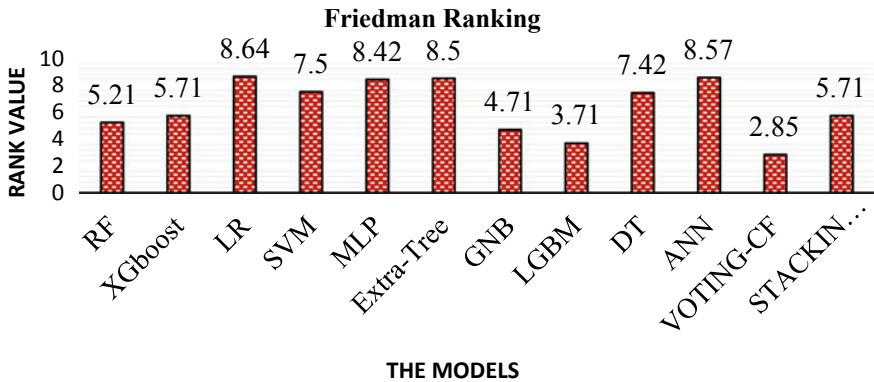
On the other hand, the SVM, Extra Tree, and MLP models had values of 78.99, 78.56, and 78.51%, respectively, based on recall values.

The F1-score combines precision and recall; therefore, it takes into consideration both FPs and FNs. With higher F1-score values of 71.02%, Table 1 shows that the ensemble model voting classifier performs better than other classifiers.

With higher accuracy values of 81.44%, LGBM performs better than other.

Additionally, as shown in Fig. 12, we used the Friedman test to evaluate the average rank values of the models [28]. Ensemble model voting classifier Friedman average values of 2.85 which is lower value. Thus, they are better than other models.

The overall result of Table 1. shows that ensemble-based models can be used to accurately categorize issues with water quality.



**Fig. 12** Average ranking of the algorithms (Friedman)

## 7 Conclusion

As water is one of the 16 UN sustainable development goals (SDG), in order to achieve it, we have to ensure healthy and clean water for every human being as a fundamental human right. In this work, we have collected the dataset from the data world and applied the machine, deep, and ensemble learning-based models. The performance is evaluated on a few relevant metrics and it is observed that LGBM is giving highest accuracy.

Further, when we have analyzed the performance based on all the metrics used then it is found that Voting-CF is one of the best-performing models and it has scored top with Friedman rank value 2.85. Therefore, we can conclude that Voting-CF is one of the best-performing models to classify the water effectively. And then appropriate policy can be suggested to improve the water quality.

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# IoT-Based ML Model to Sense Selection of Seed Crops in Changing Climatic Conditions of Punjab



Chhavi Sharma and Puneet Kumar

**Abstract** In past two decade's farmers of Punjab suffering huge losses in farming due to changing climatic patterns. Irregular rainfalls, hail storms, windstorms, drought, heat waves, cold waves, etc. are the major factors. Farmers are facing challenges in adapting new farming practices to the ever-changing climate conditions, all while incorporating advanced agricultural technologies and innovative seed varieties. The Internet of Things (IoT) presents a promising solution to address future challenges. Traditionally, agricultural production heavily relied on weather patterns. However, the current climate crisis has significantly disrupted this norm. While older seed types still yield high outputs when properly cared for, newer seed varieties have adapted to specific climatic and moisture requirements. In this research, our objective was to train machinery to identify crucial developmental stages in the crop's life cycle. This way, it can provide farmers with guidance on how to effectively manage the equipment based on the crop's thriving conditions. Rather than aiming to establish predetermined thresholds, this enhanced agricultural initiative strives to preserve the environment while catering to the shifting needs of the crop throughout its entire life cycle. Depending on the crop's current stage and anticipated duration, farmers may explore new approaches. Any device equipped with Internet connectivity and sensor capabilities can be employed to carry out these procedures. We achieved 95.89% accuracy with our proposed model.

**Keywords** Receiver operating characteristics (ROC) · Principal components analysis (PCA) · Fuzzy decision-making (FDM) · Decision tree regression · Markov chain monte carlo (MCMC)

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## **1 Introduction**

Climate change is a pressing global concern that has significant implications for agricultural systems. Punjab, a state in India known as the “Granary of India,” is highly dependent on agriculture for its economy. Climate change is altering temperature and precipitation patterns worldwide, affecting agricultural systems and food security. Punjab, with its fertile soil and favorable climatic conditions, has been a significant contributor to India’s agricultural output. However, the changing climate poses several challenges for farmers in the region. This section provides an overview of climate change in Punjab and its potential impacts on agriculture [1].

### ***1.1 Effects on Crop Productivity***

Climate change alters growing conditions, which can significantly impact crop productivity. This section discusses the effects of changing temperature and rainfall patterns on major crops in Punjab, such as wheat, rice, cotton, and vegetables. It explores the shift in cropping calendars, changes in yield potential, and the prevalence of pests and diseases under changing climatic conditions [2].

### ***1.2 Water Availability and Irrigation***

Water scarcity is a crucial concern in Punjab, exacerbated by changing climatic conditions. This section reviews the impact of climate change on water availability, groundwater depletion, and irrigation practices in the region. It also explores the potential for water-saving technologies and sustainable irrigation strategies to adapt to the changing climate [3].

### ***1.3 Socioeconomic Impacts***

The effects of climate change extend beyond agricultural productivity and have broader socioeconomic implications. This section discusses the social and economic consequences of changing climatic conditions on farmers’ livelihoods, rural communities, and food security. It highlights the vulnerability of small-scale farmers and the need for policy interventions to support adaptation and resilience [4].

## 1.4 Adaptation Strategies

To mitigate the adverse effects of climate change, farmers in Punjab need to adopt adaptive measures. This section explores potential adaptation strategies, including crop diversification, improved water management, agroforestry, precision agriculture, and climate-resilient farming practices. It also emphasizes the importance of research, technological innovations, and policy support for successful implementation [5]. The farmers in Punjab have long been acknowledged as the backbone of the nation, playing a crucial role in ensuring food production throughout history. Their success in agriculture has allowed humans to adapt effectively to environmental changes. The cultivation and consumption of organic grains not only benefit humans but also contribute to the well-being of birds and animals. However, a significant challenge faced by farmers and gardeners is the recurring losses caused by annual droughts. These water scarcity and drought events have had severe impacts on agricultural crop production, posing significant challenges for farmers. While Punjab's abundance of fruits sustains and satisfies various creatures, it is undeniable that the agriculture industry has experienced contraction with the emergence of more advanced technology and techniques. The rapid production of artificial and hybrid products, driven by numerous innovations, further exacerbates the already critical situation concerning public health.

Unfortunately, the significance of timing and location in crop production is often overlooked in modern times. Poor farming practices contribute to food insecurity and also endanger vital resources such as water, air, and land, which are crucial for sustainable food production. After a comprehensive analysis of various issues and obstacles, including environmental factors and heat, it is evident that there is no immediate practical solution or technological innovation that can single-handedly alleviate the current predicament. However, several strategies can contribute to the thriving of Punjab's agriculture industry. Enhancing agricultural output and efficiency can be achieved through various solutions. Additionally, the utilization of data mining technologies can aid in forecasting future harvests by extracting valuable information from vast databases. By analyzing data from multiple perspectives, data mining software enables the discovery, categorization, and summarization of information, providing insights to support informed decision-making in agriculture.

Data mining is a process that involves uncovering hidden patterns and correlations within extensive relational databases containing numerous columns. This analytical approach often reveals unexpected insights by examining the intricate network of relationships and patterns within the data. By leveraging data mining techniques, one can gain a better understanding of historical trends and make informed predictions. In the context of agriculture, farmers can utilize data mining to analyze agricultural production data summaries and identify the underlying causes of crop failures, enabling them to implement necessary interventions.

The agricultural industry faces significant concerns regarding the unpredictability of crop yields. Farmers often lack knowledge about the expected harvest for specific crops, making it challenging to plan effectively. To address this, farmers rely on their



past experiences with specific crops to influence production projections. Various factors, such as climate, livestock, and harvesting practices, significantly influence agricultural productivity.

Accurately measuring historical crop yields is crucial for mitigating agricultural risks. Therefore, the objective of this study is to develop a method for quantifying the productivity of crops. Prior to sowing seeds, farmers can calculate the expected yield per acre to optimize potential outcomes. Agriculture is widely recognized as a vital component of the Punjab economy, and this study provides yield forecasts for the most commonly cultivated crops in Punjab. Users can utilize simple variables such as district, season, area, and status to forecast agricultural production for any desired year. To achieve precise yield forecasts, advanced regression methodologies such as Lasso, E Net, Kernel Ridge algorithms, and Stacked Regression are employed.

To facilitate research and data processing, plants are categorized into specific groups. The information for this study is sourced from the Punjab government's database [6].

## 2 Literature Review

To estimate future changes in land utilization in coming years, this study used a model based on artificial automata Markov Chains [7]. According to research, the most common classifications of land use are urbanization and realization. Despite the increasing reduction of agricultural and non-agricultural regions, open space is expanding while aquatic body size is practically stable [8]. 345.8 km<sup>2</sup> will be developed, 121.9 km<sup>2</sup> will be undeveloped, 657.35 km<sup>2</sup> will be cultivated, 507 km<sup>2</sup> will be inappropriate for agriculture, and 11.46 km<sup>2</sup> will be covered, according to land use anticipates for 2031 [9].

The principal components analysis (PCA) found three suites of lipid molecules that encompass these variables. The first, which represented allochthonous vs autochthonous OM, revealed Northern Bay as the primary location of terrestrial OM deposition [10]. The study's findings are expected to be used as a foundation for developing recommendations for the spatial planning and use of the WaeRuhu catchment [11], which is a critical first step in mitigating the impact of catastrophic events. India's agricultural industry is strongly dependent on the location and timing of the yearly monsoon. Variations in rainfall have a substantial influence on plant growth, maturity, and productivity. With 86 million hectares (mha), India boasts the world's largest and most profitable rain fed agricultural industry. To fulfill future food demands and manage competing pressures for freshwater from other industries, more effective aquifer usage in rain fed agriculture would be necessary. One of the key causes of low production is a lack of water.

As the climate grows more unpredictable, rainfall patterns become increasingly difficult to forecast. Agriculture's predicted share of available water is likely to decrease due to increased demand for water in other sectors, notably to meet the growing demand for rapid industrialization and urbanization [12]. According to this

study, 46.87% (1328.77 km<sup>2</sup>) of the area assessed on Mumbai's outskirts would be classified as urban by 2050. When compared to the LULC in 2011, the proportion of land used for urban purposes will grow by 14.31%, the proportion of land used for forests will increase by 2.05%, and the proportion of land used for agricultural production vegetated land/barren land would fall by 16.87% by 2050. The composition of the water and the structure of the shoreline will not change much in the future (1% or less). To come closer to the desired objectives for the region's sustainable development, we might use the 2050 LULC projections as a thematic map for meteorological, environmental, and urban planning models [13]. The purpose of this study is to look into existing and prospective LULCC in the Betwa River Basin (BRB), which is located in the heart of India. The probabilistic classifier was used on the Landsat images to generate the LULC maps (MLC). The driving factors described above were utilized to train an ANN inside Land Change Modeler (LCM).

The model's prediction accuracy was evaluated using Receiver Operating Characteristics (ROC) data. Cropland will stay mainly stable, according to the LULCC forecast for 2030–2050, but open woodlands and the amount of developed land will expand. Anyone with an interest in local land resource planning or river basin management may find the revised LULCC data for BRB [14] useful. These findings indicate that the city's urban expansion will extend into surrounding suburbs during the next few decades. Urban development plans in impoverished regions, such as the Purulia District, are most suited for implementing the recommended planning strategies [15]. This work employs grid-based FTS Markov chain (FTSMC) algorithms with precisely the proper level of precision to improve the accuracy of the daily air pollution index.

The air quality index (API) is based on measurements made in Klang, Malaysia. The model's accuracy has been verified using three statistical metrics, including the root mean squared error (RMSE), average mean absolute percentage error (MAPE), and the Thiels' U statistic. The model has been evaluated against well-known statistical models as part of the validation procedure. These results demonstrate that the proposed model is clearly better to the alternatives. In view of this, the suggested method could represent an advancement in forecasting air quality that might help with air quality management [16].

This work uses a Markov Chain Monte Carlo (MCMC) and 4DVAR hierarchical data gathering technique to anticipate winter wheat output on a 500 m grid in Henan province before harvest. When employing data assimilation methods, you must work with information on two unique spatial scales. Using the MCMC approach, the outcomes of statistical studies done just at the county level were utilized to recalibrate the important and uncertain components of a WOFOST model. Then, we used the 4DVAR technique to include MODIS reflections time information into the WOFOSTPROSAIL model findings at a resolution of only 500 m throughout the whole Chinese province of Henan.

According to the study's findings, there is a significant connection between yield statistics and remote sensing data at the county level ( $R^2 = 0.81$ ,  $RMSE = 877$  kg/hm<sup>2</sup>), suggesting that the MCMC-4DVAR-based broad area determination method might be efficient in utilizing these data [17]. This study proposes a strategy for

predicting when monkeys may enter agricultural areas. Researchers observed the monkeys' activities on and around a mountain for two years in order to anticipate their behavior. The monkeys were observed during the experiment, and it was considered that they moved in a prearranged path.

As a result, the Markov chain model, which can handle status changes stochastically, was used in this work to anticipate monkey behavior. The ideal Markov chain order for this inquiry was 2 based on calculations using orders 1 through 5. The monkeys' actions might be seen as following a predictable pattern that repeats every few days. Two-class concerns, such as whether or not there are monkeys present, were addressed with 57.5% accuracy. A accuracy of 31.5% was achieved in a multi-class problem with monkeys as a consideration. Predicting the presence of a colony of monkeys is simplified by combining Markov chains with support vector machines [18]. To anticipate future production, this article use a hidden Markov model. The approach may be used to any data collection or cultural context. The model's ability to account for regional and climatic harvest variations demonstrates its efficiency. In contrast to conventional regression or Markov chain techniques, model analysis may give light on the particular causes of variability. The resulting structure can be subjected to model tinkering and model fitting, which are both possible with statistical techniques [19]. To address concerns with traditional selection techniques, this study proposes multiobjective clustering and fuzzy decision-making (FDM) algorithms for determining the optimal storage size for maximum availability. The robustness of our method is evaluated using fictional outcomes. Because of the great prediction efficiency of the first non-linear time Markov chain-based forecasting technique, which also leads in increased distributed energy storage capacity.

The temperature influence is taken into consideration in the storage sizing-availability research [20] in order to assess PV power generation performance in both cold and hot, sunny conditions.

Based on the data input and the value chosen, the algorithm would anticipate a yield. Within the remainder, the user would input information such as the production season, production years, production region, crop kind, cloudburst, meteorological condition, and the location's yield. When logged in as the administrator, the data must be loaded for the first time. The administrator may then review and analyses everything that has been entered. When all of the data has been collected, a report summarizing the yield and precision of the models used will be created. While defective models have an accuracy of around zero, perfect models have a value of one. Inputs include precipitation, production area, crop kind, district names, status names, and season [21].

#### **Proposed Model: (System Issues)**

Making the right decision for a business can be difficult in the face of uncertainty and a changing climate. One of the worst business management practices is making judgments only on the basis of prior facts. As a result, credible information is critical for anticipating the future and providing advice. However, the organization is having difficulties due to the sluggish availability of historical and predictive time series data. Forecasting is one use of data science that may be used to solve this challenge.

### 3 System Model

Futurists do “foresight analysis,” which is looking for a single paradigm or function that can be applied to data in order to make predictions based on future data. To describe the notion, several techniques such as stochastic approaches, mathematical equations, and even artificial neural networks may be employed. Users routinely extrapolate data that is either not now available or will not be available for a long time. To create computer software that evaluates several machine learning algorithms for predicting agricultural output. We develop a completely new decision-making procedure using an ensemble regression system.

### 4 Methodology

The proposed technique includes two steps: training and assessment. Data was collected and arranged throughout the teaching phase. After the data had been cleaned up of errors, K-means was utilized to cluster it into groups. The rules will be discovered by employing clustered data in the pattern mining association process. After a substantial number of regulations have been created, training may be declared complete. These notions enable us to anticipate the yield value during testing. Preprocessing is the first stage of the whole process. After collecting all of the data, the following step was to prepare it for analysis. Some information has been redacted to protect people’s privacy.

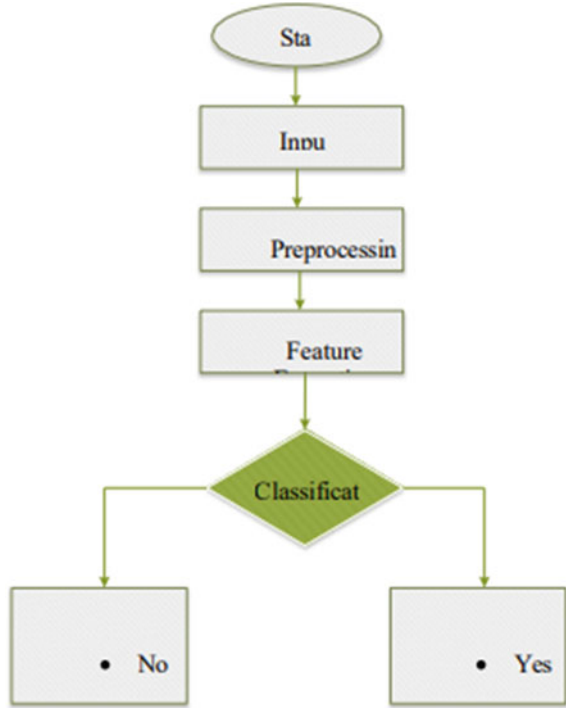
A huge section of the soil was either too rocky or too wet for cultivation. The information you provided will be discarded. Using the K-means clustering approach, the cleaned and processed data were reorganized. When compared to other clustering algorithms, K-means has been shown to perform better in this field of research. Each item of data is separated into the number of categories specified by k. The apexes, or centers, of clusters represent the total. The purpose is to shift the samples within each cluster to the cluster’s core. If not, the partition is modified such that each cluster’s core contains an equal quantity of data.

This is necessary because samples are classified into categories using the following (Fig. 1).

#### 4.1 Regression Using Random Forest

It generates many tree topologies, each of which bases its prediction on a distinct subset of the data. If this is the case, the prediction with the most trees is regarded to be the most accurate. This approach is classified as supervised learning, and the ensemble learning strategy it utilizes is applicable to both regression and classification

Fig. 1 System model



problems. Random forests is a bagging approach that use individual trees that work independently.

### 4.2 Decision Tree Regression

An algorithm locates potential nodes within a data set and uses them to construct a tree based on a set of criteria. It is widely and effectively used for supervised learning. These non-parametric approaches may be useful for both regression and classification.

### 4.3 Gradient Boost Regression

This strategy may aid in the success of tough students by increasing their potential. A progressive learning approach based on previous trees improves model accuracy. Making use of randomization  $X = X(t), t, T$  may be seen as a collection of independent variables.  $X(t)$  is an arbitrary parameter for each  $t$  in the set  $T$  of references. When

t is related to a process, we usually interpret it as time and refer to it as  $X(t)$ . If and only if the indexed set  $T$  is constant,  $X$  is a consistent probabilistic  $n=0$  inference; called as Discrete Time Markov Chain, while

$$\begin{aligned} & \{X_n = i_n | X_{n-1} = i_{n-1}, \dots, X_0 = i_0\} \\ & = \{X_n = i_n | X_{n-1} = i_{n-1}\} \end{aligned} \quad (1)$$

where

$$i_k \in \{1, 2, \dots\} \text{ for } k = 0, 1, 2, \dots, n.$$

The probability of  $(n) = i$  can be denoted as  $(n) = \{X_n = i\}$  using the concept of status probability  $i$  in  $n$ th period. If in  $n$ th process status update time  $i$  besides in otherwise, it is a separate probabilistic inference. The term "Markov" initially appears in the name of the Russian statistician a Markov. The Markov chain, according to Siagian, is a strategy for forecasting the behavior of a collection of parameters by comparing.

Working with a Markov chain that takes place in discrete time, you'll need a transition matrix.  $\{X_n\}_{n=0}^{\infty}$  with status interplanetary  $\{0, 1, 2, \dots\}$  and possibility of  $\infty$  changeover  $\{p_{ij}\}_{i,j=0}^{\infty}$  is denoted as  $P = (p_{ij})$ .

$$P = \begin{pmatrix} p_{00} & p_{01} & p_{0N} \\ p_{10} & p_{11} & p_{11} \\ p_{N0} & p_{N1} & p_{NN} \end{pmatrix} \quad (2)$$

If status space is finite, suppose  $i = 0, 1, 2, \dots, N$ , transition matrix of  $\{p\}$  will have size  $(N + 1) \times (N + 1)_{i,j=0}$ . Transition matrix has characteristics, i.e.,

- 1  $p_{ij} \geq 0, 0 \leq i \leq N; 0 \leq j \leq N$ .
- 2  $\sum_{j=0}^N p_{ij} = 1, \text{ for } \forall i = 0, 1, 2, \dots, N$ .

## 5 Experimental Results

Agriculture is critical to the advancement of every country, but especially those that are still developing. Currently no any IoT based model is suitable for giving exact yield predictions for the farmers of India. Using an approach that is applicable to all 542 districts in India, we can develop years-ahead projections for 36 distinct crops. The suggested method not only exceeds previous attempts to anticipate production across all primary districts by more than 90%, but it also considers a broader range of crops.

To achieve its aim of 20% average root mean square errors, the proposed method employs a number of machine learning techniques, including a linear system, support vector deep learning, and artificial neural networks (quintals per 10 acres). Mean square error (MSE) and mean absolute percentage error (MAPE) are two additional error measures that may be used to compare the two forecasting methodologies and

decide which is superior (MAPE). When two techniques are equal, the strategy with the lowest MSE or MAPE score wins.

$$\text{MSE has formula, i.e., } \text{MSE} = \frac{1}{q} \sum_{t=1}^{T^{\wedge}} (Y_t - Y_t^{\wedge})^2 \tag{3}$$

where

MSE = Mean Square Error.

$Y_t$  = Evidence from the 1th, 2th, ...  $T$ th time.

$Y_t^{\wedge}$  = Forecasting result in the 1th, 2th, ...  $T$ th time.

MAPE has method, i.e.,

$$\text{where MAPE} = \frac{1}{T} \sum_{t=1}^T |F_t - F_t^{\wedge}|$$

$$F_t \tag{4}$$

MAPE = Mean Absolute Percentage Error.

$F_t$  = Real information in the 1th, 2th, ...  $T$ th period.

$F_t^{\wedge}$  = Result of forecasting in the 1th, 2th, ...  $T$ th period (Table 1).

The Fig. 2 illustrated that predicted results data in the crop real information, results of forecast, and mean square error.

The Fig. 3 illustrated that predicted results data in the crop real information, results of forecast, and mean square error.

Experiment 2 has more reasonable error values compared to experiment 1. As for absolute MCM error, it was smallest in the second experiment. The Fig. 4 illustrated that predicted results data in the crop real information, results of forecast, and mean center error.

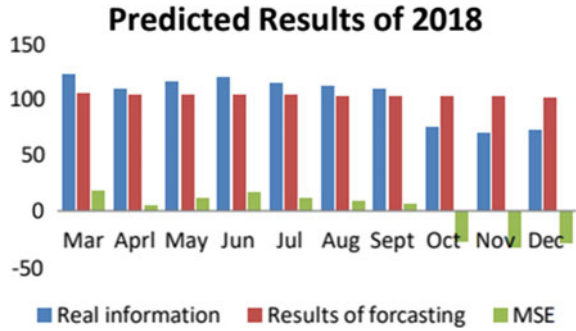
Figure 5 shows expected results data in crop real information, projected outcomes, and mean center error.

Figure 6 depicted anticipated results data in crop real information, forecast outcomes, and mean center error.

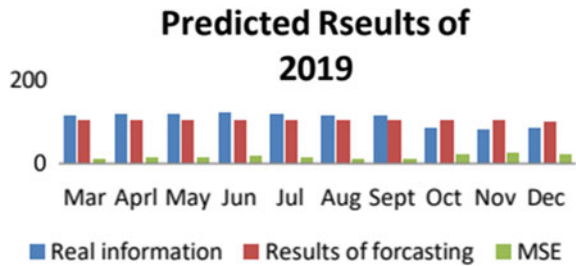
**Table 1** Predicted status results using Markov chain model

| No. | Status    | Interval of difference (%) | Likert scale         |
|-----|-----------|----------------------------|----------------------|
| 1   | Status 1  | $100\% \leq d < \infty$    | Increase enormously  |
| 2   | Status 2  | $75\% \leq d < 100$        | Increase exceedingly |
| 3   | Status 3  | $50\% \leq d < 75$         | Increase ascetically |
| 4   | Status 4  | $25\% \leq d < 50$         | Increase little      |
| 5   | Status 5  | $0\% \leq d < 25$          | Increase very little |
| 6   | Status 6  | $-25\% \leq d < 0\%$       | Decrease very little |
| 7   | Status 7  | $-50\% \leq d < -25$       | Decrease little      |
| 8   | Status 8  | $-75\% \leq d < -50$       | Decrease ascetically |
| 9   | Status 9  | $-100\% \leq d < -75$      | Decrease enormously  |
| 10  | Status 10 | $-\infty < d < -100$       | Decrease enormously  |

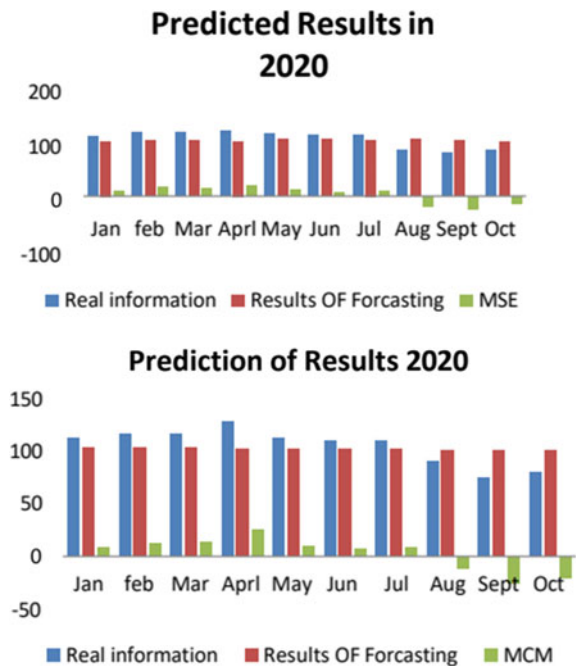
**Fig. 2** Real and forecasting information predicted data set in different time interval in year 2018



**Fig. 3** Real and forecasting information predicted data set in different time interval in year 2019

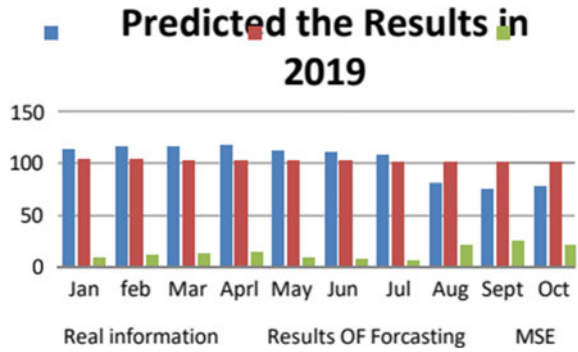


**Fig. 4** Illustrates actual and predicted data set in various time periods in the year 2020

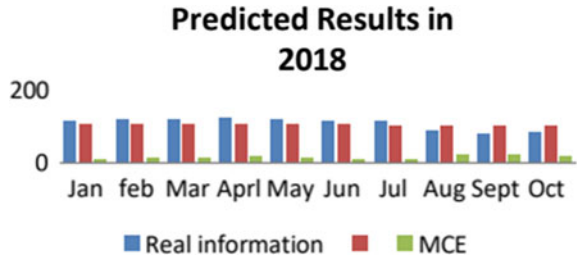




**Fig. 5** Real and forecasting information predicted data set in different time interval in year 2020

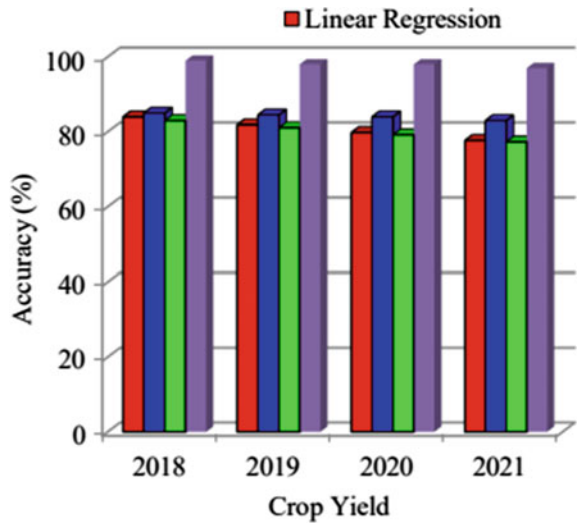


**Fig. 6** Depicts actual and expected data sets for various time periods in 2018



The Fig. 7 illustrated that the accuracy of data set in different time interval in crop yield.

**Fig. 7** Depicted the accuracy of data set at various time intervals in crop production



## 6 Conclusion

Embracing new farming practices in response to climate change marks a new beginning that combines modern agricultural technology and seed varieties. The emergence of the Internet of Things (IoT) offers a novel approach to addressing challenges in real-time. While weather has always influenced agriculture, the impact has significantly changed due to climate change. With each generation, new seeds are developed to enhance productivity, each with unique requirements for climate and water. In this study, our objective was to familiarize the equipment with the crop's life cycle and provide automated guidance to farmers for maintaining optimal environmental conditions at different stages of the crop's growth. This approach aims to ensure that all critical environmental parameters are preserved throughout the crop's life cycle.

Instead of relying on a static threshold-based system, this smart agriculture project adopts a dynamic approach to cater to the evolving needs of the crop, aligning with its specific life cycle stages. By controlling the environment in accordance with the crop's growth stages, the project aims to ensure that the crop's dynamic demands are met. The farmer can easily identify new requirements based on the crop's development, which is closely associated with both crop quality and height. Any equipment equipped with Internet access and sensors can perform these tasks efficiently.

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# A Firebase-Based Smart Home Automation System Using IoT



Pramod Kumar Goyal, Saurabh Verma, and Moksh Giri

**Abstract** The rapid development of IoT and its associated hardware and software systems has facilitated the design, development, and implementation of smart home automation systems. But the existing systems are either operated using physical electrical/mechanical switches only or operated using mobile app only but not both or interchangeably. It means once a device is switch-on using a physical switch it cannot be switch-off using the mobile app developed for that device. This research paper is going to solve this limitation. This paper presents a smart home automation system using NodeMCU (an open source IoT platform) and Firebase (a powerful cloud service). This presents a mobile app-based home appliance control system which provide the flexibility to control even a physical switch operated appliances remotely. The proposed system is physically developed, implemented, and tested in real-time environment and proved successful.

**Keywords** NodeMCU · Firebase · IoT · Firebase · Home automation

## 1 Introduction

Nowadays the appliances are being automated. All the appliances like AC, refrigerator, and TVs are made smart. People want that their product to become intelligent so that it consumes less energy and reduce human effort. As machines are made to reduce the human effort, the smart devices can reduce the human effort if they are made automatic. Home automation is nothing but controlling the devices using our mobile phone. IoT stands for Internet of Things which is generally called as

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enabling our devices Internet controlled. In any home automation system we simply need a microcontroller, a communicator, and an actuator. For example we can use a microcontroller like Arduino ATmega series with a communication device like HC05/HC06 Bluetooth module or Wi-Fi module like ESP8266 and we lastly require a relay module which can act as an actuator. This system will connect with the mobile using either Bluetooth or Wi-Fi and then we can simply send signals to the system which will control the relays. This will act as a small scale model of home automation. But this system is very basic and it is not an IoT-based system. To make this system IoT-based, we need working Internet connection, one server which acts as a mediator [1] between the system and our mobile phone. In this research paper we will be using the NodeMCU [2] as microcontroller and Firebase [3] as this mediator server. Firebase is an open source cloud service comes from Google. In this paper, we will see that how Firebase can be used as cloud service to send signals and receive signals to the system and mobile phone and control the home appliances.

## 2 Literature Survey

Home automation can be achieved using many ways. In [4] it is found that Arduino can be used with Bluetooth module to establish a communication between the mobile phone and the microcontroller. Also, in the research paper [5] the Wi-Fi is used to establish the communication between the mobile and the microcontroller. This way the system can be operated on a same network. That means that the microcontroller and the mobile phone must be on the same network to control the device. This is secure and fast as well. In [6] the researchers have implemented Zigbee module in Arduino mega through which they are controlling devices. They have used various sensors for various purposes. Also they have provided real-time notification, feedback on web-server [7] in which customers can see what is happening in their home. However, in addition to the existing system, in [8] an Arduino-based home automation system developed to control the relays and ultimately controlling the appliances remotely. They have used Gas and Temperature sensors as well. If we talk about the NodeMCU, it is based on ESP8266 module which is a way more cost effective than the Zigbee and Bluetooth. Here in the given below Table 1 [9] we can observe the effectiveness of NodeMCU.

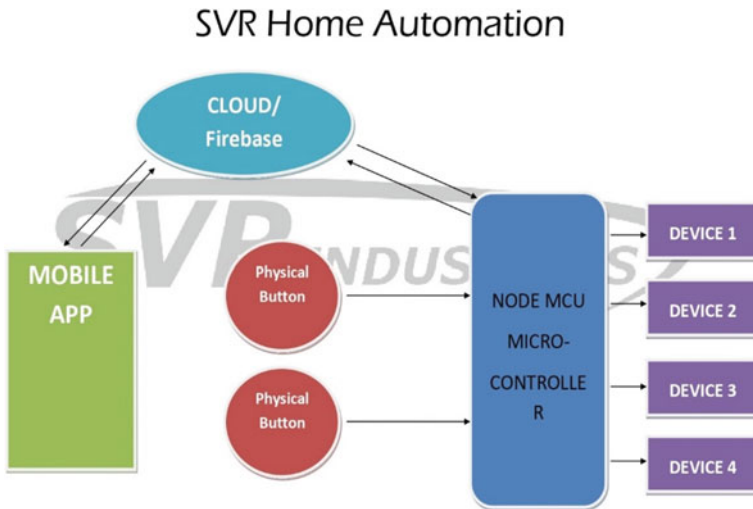
We can observe that ESP8266 is not only the fastest but also have larger range. Also all these systems have not solved the problem of the physical switch. If we turn on the appliance using physical switch this will create a problem. When the physical switch is turned on the system becomes unusable or gives no impact on the appliance. If the user has turned on the device using the physical switch then it cannot be turned off using the mobile app.

**Table 1** Comparison of different modules [9]

| Available technology | IEEE standard | Network Topology   | Maximum power consumption (mW) | Data rate   | Maximum range | Cost   |
|----------------------|---------------|--------------------|--------------------------------|-------------|---------------|--------|
| Bluetooth            | 802.15.1      | One to many        | 100                            | 1–3 Mbps    | 10            | Medium |
| Zigbee               | 802.14.5      | Star, mesh cluster | 3                              | 20–250 Kbps | 100           | High   |
| ESP-8266–01          | 802.11        | Star and mesh      | 100                            | 1–11 Kbps   | 150           | Low    |

### 3 System Design

Figure 1 gives an idea about the proposed system. This system can be used to control four different devices using the Android app made by us. Our microcontroller is connected to the Firebase using the Wi-Fi.



**Fig. 1** Layout of the proposed home automation system

## 4 Hardware Description

The total hardware contains only three basic components: (i) NodeMCU to control the relays and connect to the Firebase, (ii) Relay module of 4 channel which will be able to toggle the status ON/OFF of the appliance, and (iii) Physical switch which are push button switches.

### 4.1 NodeMCU

NodeMCU is a low-cost firmware platform which is based on ESP8266. This board contains a microcontroller and on-board Wi-Fi module. This board eases us to use the libraries of ESP8266 [10] and Arduino as well. The board requires input from 3.3 to 5 V for smooth operation. However the board has an inbuilt Linear and Low Drop-out (LDO) *voltage regulator* to keep the voltage steady at 3.3 V (Fig. 2).

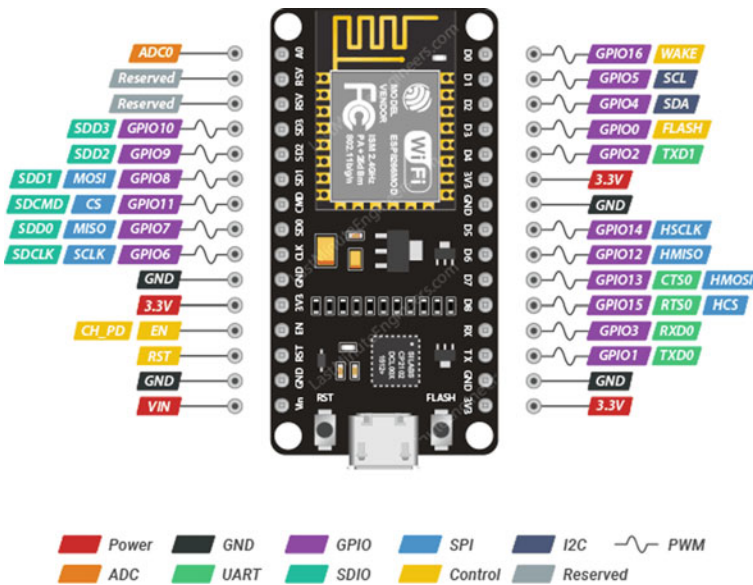


Fig. 2 Pin out diagram of NodeMCU [11]

### 4.2 Relay Module

Relay module is used as a switching device. The relay takes input from NodeMCU and accordingly changes the state of the device on and off. The relay used here can handle the current upto 10 A at 220–250 VAC.

### 4.3 Physical Switch

Push button switch are very low-cost push button switches which are used here to provide input to the NodeMCU.

## 5 Software Design and Implementation

We have used Arduino IDE, Android Studio, and Firebase to establish our whole system. The Arduino IDE provides the environment to code for Arduino and ESP-based development boards. And we have developed an Android application to make changes in the Firebase [12].

The Fig. 3 shows the development of the Android app for the system. We have developed the code for the NodeMCU and Android application for the system.

### Implementation

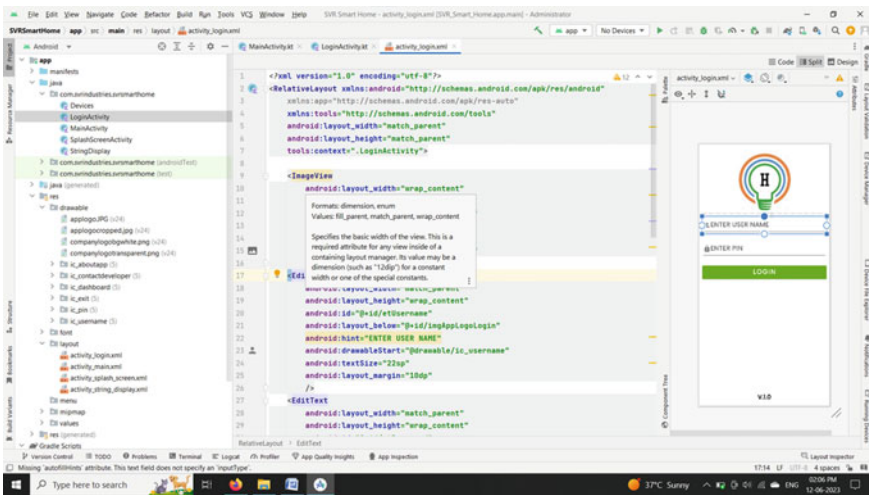


Fig. 3 Android app in development



The Fig. 4 shows circuit design of the system. The system contains the physical switches and relay as well. The user will be able to control the devices using the mobile app. The input from the app will be sent to the Firebase and the values will be updated in the Firebase. Then the Firebase will make changes to the NodeMCU which will command the actuator to toggle the state. The user can use the physical switch also to control. The physical switch also updates the data in the Firebase (Fig. 5).

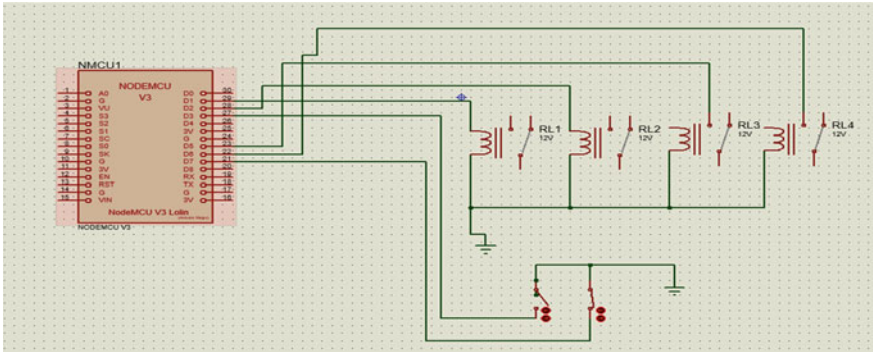


Fig. 4 Circuit diagram of the system

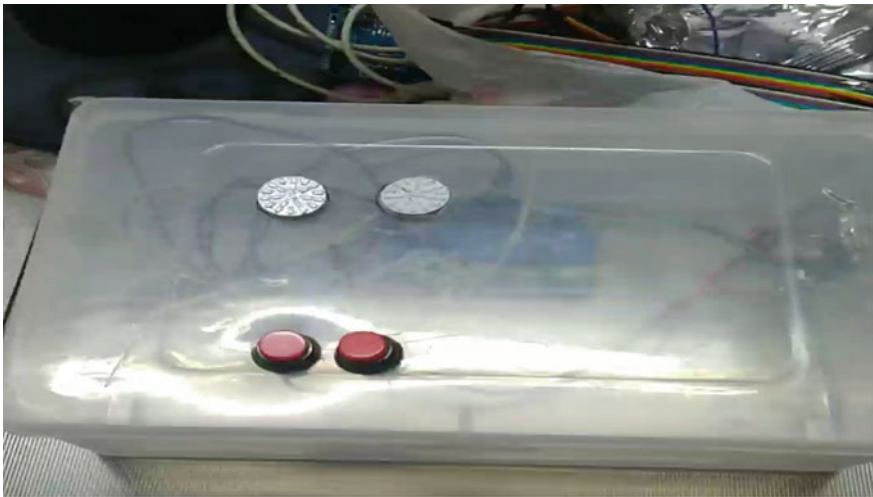


Fig. 5 Final output of the project

## 6 Experimental Results

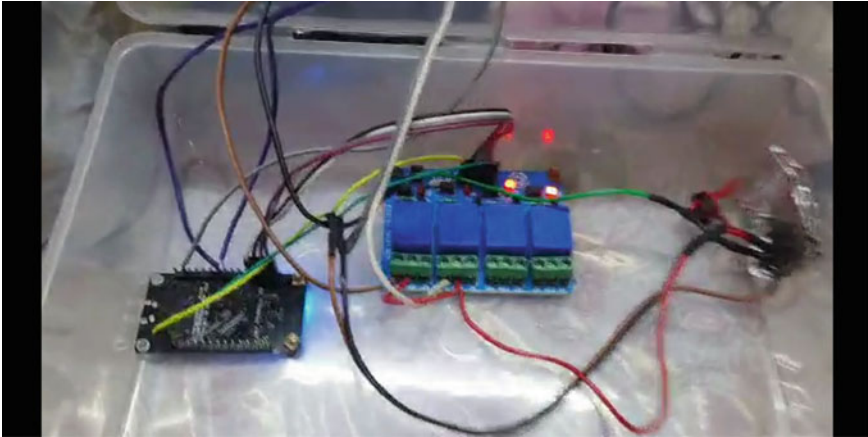
On testing the system on different conditions we were able to control the appliances using our mobile app and the physical switch as well. The status of the appliances is changed when turned on with physical switch. Also, the problem of physical switch is solved, the user can turn on the appliance using physical switch and then turn off the appliance from the mobile app and vice versa (Figs. 5, 6, 7, and 8).



Fig. 6 Turning on the appliances demonstration



Fig. 7 Change in relay states



**Fig. 8** Implementation of the system

## 7 Conclusions and Future Enhancements

By adopting NodeMCU and Firebase in home automation systems, homeowners can create intelligent and interconnected living environments. The comprehensive research presented in this paper provides valuable insights into the utilization of NodeMCU and Firebase, showcasing their potential in transforming traditional homes into efficient and smart living spaces. Furthermore, we can create one 7 inch screen-based system which can replace the old traditional physical switch board to control the appliances. These small controllers then can be coded to have timers for particular devices.

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# EnRaFS: An Ensemble Ranking-Based Feature Selection Approach for Grading Gallbladder Cancer Using Radiomic Analysis



Nitya Jitani , Vivek Kumar Verma, and Rosy Sarmah 

**Abstract** Grading of gallbladder cancer (GBC) is pivotal for the diagnosis and treatment planning of patients suffering from this disease. Radiomics has emerged as a non-invasive, imperative, and efficient way for disease diagnosis and prediction with the use of machine learning approaches on medical data. Given the large dimensionality of the data, it is important to choose the most significant features to aid in improved classification of patients with respect to the subtypes/grades of GBC. This paper proposes a novel ensemble ranking-based approach called EnRaFS, for feature selection to grade GBC patients' using CT scan images. It combines the results of multiple feature selection methods to improve the accuracy of the ranking. The ranked features are then used to train the machine learning model to predict the grade of the cancer. The proposed approach has been evaluated on a dataset of 105 patients diagnosed with GBC and compared with other state-of-the-art feature selection methods based on accuracy measure. Our study concludes that the proposed approach can be used as an effective tool for grading GBC, which can help clinicians to make more informed decisions about the treatment of the disease.

**Keywords** Radiomics · Feature selection · Gallbladder cancer

## 1 Introduction

Gallbladder cancer (GBC) is a highly aggressive, rare malignancy that is often diagnosed at advanced stages, resulting in limited treatment options and poor prognosis. The grading of GBC is critical for determining the optimal treatment strategy and predicting patient outcomes. Traditional grading systems rely on histopathological evaluation, which is subjective, time-consuming, and prone to inter-observer variability [1].

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R. N. Shaw et al. (eds.), *Innovations in Electrical and Electronic Engineering*, Lecture Notes in Electrical Engineering 1115, [https://doi.org/10.1007/978-981-99-8661-3\\_18](https://doi.org/10.1007/978-981-99-8661-3_18)

239

Radiomics [2] has emerged as a promising technique for tumor characterization and prediction using quantitative and non-invasive approach. The radiomic features extracted from medical imaging modalities such as CT scan, MRI scan, PET scan images capture the underlying biological and physiological properties of the tumor, such as shape, intensity, and texture, which can be utilized to develop predictive models for cancer diagnosis, treatment, and response to therapy. However, the high-dimensionality of radiomic features can pose a significant challenge for predictive modeling, causing overfitting and poor generalization of models. Feature selection (FS) is therefore a critical step in the radiomic process to identify the most relevant features as well as the maximum information from the medical images.

The FS methods can be broadly categorized as filter, wrapper, and embedded methods [3]. Filter methods involve statistical measures to compute the feature relevance and selects the top-ranked features, for example, mutual information and correlation. Wrapper methods such as Recursive Feature Elimination, incorporate predictive machine learning (ML) models to evaluate the feature subsets and selects the subset which achieves the best performance, whereas the embedded methods combines the advantages of both filter and wrapper methods so as to obtain the best feature subset, such as regularization methods. But no single FS method is optimal for all types of data and modeling tasks. Ensemble methods incorporate varied FS algorithms which has showcased improved predictive performance and robustness of classification models, by leveraging the strengths of individual FS methods and mitigating their weaknesses.

In this context, this paper proposes an ensemble feature selection approach called EnRaFS based on a new ranking scheme, combining five state-of-the-art FS algorithms to identify the most informative features for grading GBC. The reduced feature set is then fed to an ML model for prediction. The main contributions of this paper are

- A new Rank Measure (RM) for feature ranking to select the best feature subset.
- An ensemble approach for feature selection for grading GBC.

## 2 Literature Review

Ensemble feature selection has become popular area of research in ML domain considering its ability to enhance the learning performance of the ML models by combining multiple filter and wrapper FS methods. Chen et al. [4] combined different filter, wrapper, and embedded methods for feature selection to identify the best ensemble approach for medical data. Chiew et al. [5] proposed a hybrid feature selection method for ML-based phishing detection system. An empirical study of various FS algorithms was conducted by Pes et al. [6] for high-dimensional data in various domains. Bania et al. [7] proposed a method called R-Ensembler which is a rough set-based feature selection algorithm to classify medical data with KNN imputation. Verma et al. [8] showcased a comparative study of various ensemble feature selection methods trained using 6 different ML techniques and proposed a new

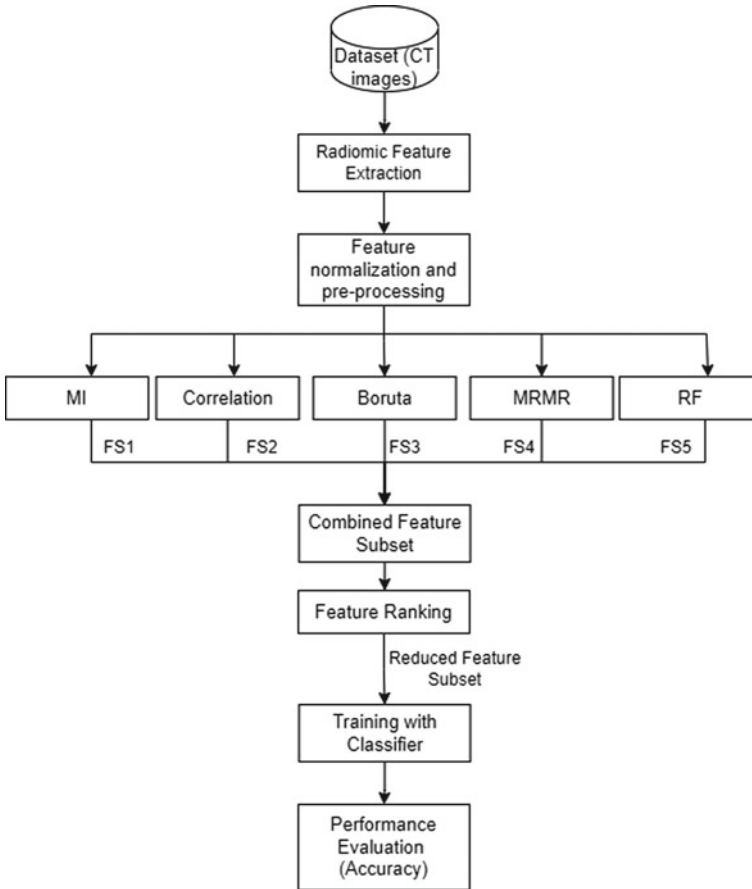
ensemble approach for skin disease prediction. Zing et al. [9] presented an ensemble FS approach using electronic medical records to identify a set of discriminant factors for diabetic kidney diseases, on a cohort size of 15,645 patients. Although a lot of robust FS techniques have been developed for radiomics analysis so far, there's still room for improvement considering the fact that no one solution fits all and the increasing availability of medical data. Also, radiomics is a new emerging field of study, and the radiomic analysis for gallbladder cancer has not yet been highly explored. In this paper, we aim to provide an ensemble method for feature selection in radiomic analysis of GBC.

### 3 Method

The proposed methodology of EnRaFS is depicted in Fig. 1. The abdominal CT scan images of patients diagnosed with GBC is the input dataset. The first step involves extraction of radiomic features from these medical images. This feature data is then pre-processed and normalized before applying the downstream processing. Next, five FS algorithms are employed to rank the extracted features based on their importance in predicting the grade of the cancer using five different ML classifiers. A combined feature subset of these five feature subsets is formed to which we apply the proposed ranking measure. The final reduced feature subset is then used to train a ML model to predict the grade of the cancer. These steps are described in detail in subsequent subsections.

#### 3.1 Data Aquisition and Processing

The CT scan images of 105 patients diagnosed with GBC, along with the ground truth images, have been acquired from Dr. B. Borooah Cancer Institute, Guwahati, India. Manual delineation was performed under the supervision of the radiologists to obtain the ground truth images. The ground truth images comprised of six tumor sub-regions reflecting GBC malignancies or tumor as Region of Interest (ROI). These include liver metastasis, gallbladder mass, gallstones, liver infiltration, and wall thickening. The 3D dicom images of each patient, with manually delineated malignant regions reflecting GBC, is the input to the feature extraction framework. Also, the patients have been classified into 6 different grades as adenocarcinoma, well-differentiated adenocarcinoma, metastatic adenocarcinoma, poorly-differentiated adenocarcinoma, squamous cell carcinoma, and chronic cholysectitis, based on the severity of the malignancies, as suggested by the doctors by observing the various imaging patterns/tumor sub-regions in the ROI.



**Fig. 1** Workflow diagram of proposed EnRaFS method

### 3.2 Radiomic Feature Extraction and Processing

A total of 457 features were extracted, which involves 455 radiomic features and 2 semantic features. The radiomic features are extracted using the open-source Pyradiomics [10] framework and include shape-based, first order, and texture features. The texture features can be further categorized as gray level co-occurrence matrix (GLCM), gray level size zone matrix (GLSZM), gray level run length matrix (GLRLM), gray level dependence matrix (GLDM), and neighboring gray tone difference matrix (NGTDM) features [10]. These features are applied on five different variants of the images, namely original image, squared, square root, logarithmic, and exponential filtered images. The semantic features comprises the age and gender of the patients.



To explore the relationship between the radiomic features of each patient with the GBC grades, the radiomic features were extracted combining all the tumor sub-regions as discussed in Sect. 3.1 for each patient and graded based on doctor's observational input. The extracted features are then normalized using the Minmax normalization technique because the different tumor sub-regions have different centers and magnitudes and also to improve the interpretability and stability of the ML model. The dataset is finally divided in the ratio 7:3 as training data and test data respectively and fed to the feature selection model as explained next.

### 3.3 Feature Selection

The high-dimensional radiomic feature set necessitates implementation of feature selection methods so as to obtain the most pertinent feature subset for classification and grading of GBC. Five well-known FS methods, namely Mutual Information (MI) [11], Correlation [12], Boruta [13], Minimum Redundancy Maximum Relevance (MRMR) [14], and Random Forest (RF) [3] have been applied to select the most relevant feature subsets based on the feature importance values obtained from each method. The feature subsets obtained are termed as FS1, FS2, FS3, FS4, and FS5, respectively, as depicted in Fig. 1. In order to select the  $k$ -best subset ( $k$  = number of features) for each FS method, an exhaustive analysis was performed for all possible  $k$  values using 5 well-known ML classifiers, namely Random Forest (RF), Support Vector Machine (SVM), Gradient Boosting (Gboost), Adaboost (Aboost), XGBoost, and Logistic Regression (LR) classifiers [3], and the value of  $k$  was chosen based on the highest accuracy obtained for each FS method while training the ML models. Hence, the  $k$ -best feature subset for each of the five FS methods along with the feature importance values is the input to the next step.

### 3.4 Proposed Feature Ranking

A combined feature subset, CFS = {FS1, FS2, . . . , FS5}, comprising of all the features that forms a part of the  $k$ -best features of the five FS methods acts as an input feature subset for proposed ranking measure.

**Definition 1** (*Rank Measure*). The proposed Rank Measure for a feature,  $i$  can be mathematically defined as

$$RM_i = \text{Feature Importance (MI)}_i * \text{Feature Frequency}_i. \quad (1)$$

Feature Frequency $_i$  can be calculated as  $\frac{F}{N}$ , where  $F$  denotes the number of occurrences of an individual feature,  $i$  in CFS divided by total number of feature subsets,  $N$ ,

i.e., 5. Feature Importance (MI)<sub>*i*</sub> refers to the feature importance value of feature *i* using FS method as MI.

The MI method has been chosen in the proposed Rank Measure, RM<sub>*i*</sub> because MI gives the best prediction accuracy when trained using RF model (discussed in detail in the next section). The idea behind this Rank Measure is to give extra weightage to a feature if it occurs in the feature subsets of most of the FS methods, so as to reduce the biasness and significantly reduce the number of features in the final feature subset, thereby not compromising on the prediction accuracy of the ML model. Using this measure, the set of features present in CFS is ranked and we get the final reduced feature subset, which is the input to the next step.

### 3.5 Classification Model

The reduced feature subset as obtained from the previous subsection is trained using five state-of-the-art ML classifiers namely RF, SVM, Gboost, Aboost and LR classifiers. It is a multi-class classification problem where grades assigned to each patient instance form the labels. The feature subsets obtained using each FS method is trained using all the 5 models and the ML model which gives the best accuracy for predicting the grades of GBC is observed and analyzed as presented in the next section.

## 4 Experimental Results and Discussion

The experiments have been conducted using Python version 3.9 on a workstation with 64GB RAM and Windows 11 operating system. The performance of the proposed EnRaFS method with new Rank Measure has been evaluated using predicted accuracy as the validation measure. Accuracy can be defined as percentage of correctly classified instances among all the instances in a given dataset. To prove the effectiveness of our method, it has been compared with five well-known methods, namely Boruta, MI, Correlation, RF, and MRMR. The data has been split in the ratio 80:20 as training and test data, respectively. Fivefold cross-validation has been implemented to reduce overfitting the model. The observations and result analysis are discussed next. Table 1 depicts the accuracy scores for the FS methods trained on five different ML classification models. The color frequencies indicate the accuracy value, wherein dark green symbolizes highest accuracy and dark red refers to the lowest scores. The transition from red to green demonstrates the difference in the accuracy values. Table 2 depicts the combinations of FS models and classifiers from Table 1 which have shown best accuracy scores and selected number of features. We can see that the accuracy obtained using EnRaFS method is 0.86, with 184 features in the reduced feature subset. The accuracies obtained by Boruta, MI, Correlation, RF, and MRMR are 0.83, 0.86, 0.82, 0.85, and 0.81 with selected number of features

**Table 1** Accuracy plot for various feature selection methods and classifiers

| FS method/<br>Classifier | RF          | SVM         | Gboost | Aboost | XGBoost | LR          |
|--------------------------|-------------|-------------|--------|--------|---------|-------------|
| Boruta                   | 0.68        | 0.82        | 0.77   | 0.68   | 0.68    | <b>0.83</b> |
| MI                       | 0.68        | <b>0.86</b> | 0.68   | 0.64   | 0.64    | 0.77        |
| Correlation              | <b>0.82</b> | 0.73        | 0.68   | 0.68   | 0.64    | 0.68        |
| RF                       | 0.73        | 0.77        | 0.64   | 0.82   | 0.73    | <b>0.85</b> |
| MRMR                     | 0.73        | <b>0.81</b> | 0.68   | 0.68   | 0.59    | 0.73        |
| EnRaFS                   | 0.77        | 0.82        | 0.64   | 0.82   | 0.55    | <b>0.86</b> |

**Table 2** Experimental results

| FS method   | Classifier | Selected features | Accuracy |
|-------------|------------|-------------------|----------|
| Boruta      | LR         | 43                | 0.83     |
| MI          | SVM        | 253               | 0.86     |
| Correlation | RF         | 32                | 0.82     |
| RF          | LR         | 224               | 0.85     |
| MRMR        | SVM        | 41                | 0.81     |
| EnRaFS      | LR         | 184               | 0.86     |

as 43, 253, 32, 224, and 41, respectively. Although the selected features obtained by Boruta, Correlation, and MRMR are significantly low, the prediction accuracy is compromised. The accuracy score obtained by MI and EnRaFS is similar, but the reduced feature subset obtained by our method has significantly less number of features as compared to MI. Hence, the proposed method, EnRaFS, outperforms the other methods in terms of prediction accuracy.

This has been achieved with the introduction of the Rank Measure, RM, which has contributed in significantly reducing the biasness and overfitting as compared to other individual FS methods.

*Selected Radiomic features* The proposed EnRaFS method, employing the RM ranking selects 184 radiomic features as the most crucial features for grading of GBC based on the 6 different classes. Out of the 184 features, 141 features belong to the category of texture features, mostly including the GLCM and GLRLM features and some GLDM and GLSZM features applied on the five varied filtered images as discussed in Sect. 3.2. The NGDTM features, however, are not present in the reduced feature subset, hence, can be termed as the least significant features. The remaining features involve 6 shape-based features and 37 first-order features. It is evident that the texture features, applied to different variants of the original image, play a huge role in determining the properties of the malignancies or tumor regions and overall grading of the patients’ disease. Hence, we can conclude that the texture-based features are paramount to effective grading of GBC using radiomic analysis.

## 5 Conclusion

This paper presented an ensemble feature selection method called EnRaFS using a new Rank Measure, RM, for grading gallbladder cancer using radiomics analysis. The proposed method combined feature subsets obtained using five different FS methods to select the most informative features using RM measure. The performance was evaluated using a GBC dataset of 105 patients and the results demonstrate that the proposed ensemble method outperformed the individual FS methods based on prediction accuracy. Overall, the study highlights the importance of feature selection in radiomic analysis and demonstrates the potential of an ensemble approach for improving the accuracy of cancer diagnosis and treatment.

**Acknowledgements** The authors would like to thank Dr Geetanjali Barman and Dr. Abhijit Talukdar at Dr. B. Borooah Cancer Institute, Guwahati, for their support in data collection and manual segmentation.

### Declarations

**Funding:** This work is an output of a research project titled “Radiomics with machine learning methods towards prediction of gallbladder cancer” sponsored by ICMR, New Delhi.

**Informed consent:** Informed consent was taken from patients involved in the study.

**Ethics Approval:** Ethical approval was obtained for this study.

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# Unmasking Deepfakes Advancements, Challenges, and Ethical Considerations



Usha Kosarkar  and Gopal Sakarkar 

**Abstract** Deepfake technology, powered by deep learning algorithms, has rapidly evolved in recent years, enabling the creation of highly realistic synthetic media that can deceive human perception. Unmasking deepfakes: Advancements, Challenges, and Ethical Considerations is a comprehensive review that examines the advancements in deepfake technology, the associated challenges, and the ethical considerations that arise in the context of this emerging field. Deepfake algorithms have the ability to produce phoney audiovisual content that is hard to distinguish from authentic content. It now appears to be challenging to distinguish between authentic digital content and fraudulent content spread around the Internet in this era of the cyber age. Cybercriminals frequently employ this technology to trick security systems. If we are not careful, deepfake technology could pose a severe danger to identity verification in the future. Deepfake content may easily be produced by amateurs using free and open-source software, which makes it simple for them to produce technically excellent content. Give an introduction to deepfake, and a brief on deepfake creation and detection techniques.

**Keywords** Deepfake · GAN · CNN · RNN · Deepfake detection

## 1 Introduction

Artificial intelligence (AI) and machine learning algorithms are used in “deepfake technology” to produce incredibly lifelike and frequently false movies, audio recordings, or photographs. It combines techniques from computer vision, graphics, and natural language processing to manipulate or fabricate media content in a way that appears authentic and convincing. Deepfakes are typically created by training deep

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learning models on large datasets of real footage and then using those models to generate or alter content. The term “deepfake” is derived from the deep learning algorithms employed in the process. Initially, the technology gained attention for its ability to superimpose one person’s face onto another person’s body in video footage, often with remarkably convincing results. The advancement of deepfake technology has raised concerns due to its potential misuse and the ethical implications it carries [1]. Deepfakes can be used to convey false information, sway public opinion, smear people, or produce fictitious celebrity pornography. The emergence of deepfakes has also spurred debates regarding the issues relating to the reliability and authenticity of digital media. To counter the negative effects of deepfakes, researchers and tech companies are actively developing detection tools and techniques to identify manipulated content. Additionally, there have been calls for increased awareness, media literacy, and responsible use of technology to mitigate the risks associated with deepfakes. Despite the fact that deepfake technology has caused certain concerns, it also has useful applications [2, 3]. It can be used in the film industry for visual effects, animation, and virtual reality experiences. Researchers are exploring potential uses in fields such as healthcare, education, and entertainment, where deepfakes can be employed responsibly and ethically.

As deepfake technology continues to evolve, it is crucial to understand its capabilities, risks, and impact on society. Ongoing research, development of safeguards, and public awareness are essential to navigate the challenges and opportunities presented by this rapidly advancing technology [4].

### **Examples of Deepfakes**

Deepfake technology has advanced rapidly in recent years, allowing for the creation of highly realistic manipulated videos and images. Here are a few examples of deepfake applications:

- **Celebrity Impersonations:** Deepfakes have been used to superimpose the faces of celebrities onto the bodies of actors in movies or onto characters in video games. For example, in the movie “Rogue One: A Star Wars Story,” the late actor Peter Cushing’s face was recreated using deepfake techniques to bring back his character, Grand Moff Tarkin.
- **Political Figures:** Deepfakes have been employed to create manipulated videos of politicians, altering their speeches or actions to convey false information or misleading narratives. Such videos can have significant implications for spreading misinformation and influencing public opinion.
- **Adult Content:** Deepfake technology has been widely misused to create explicit content featuring the faces of non-consenting individuals, often celebrities or acquaintances. This has raised concerns about privacy, consent, and the potential for harassment.
- **Historical Figures:** Deepfakes have been used to recreate historical figures, allowing people to see what they might have looked and sounded like. For instance, a deepfake of Mona Lisa was created to bring Leonardo da Vinci’s famous painting to life, adding facial expressions and animation.

- **Voice Manipulation:** Deepfake algorithms can also be applied to audio, allowing for the synthesis of speech that mimics the voice of a particular individual. This has raised concerns about the potential for impersonation and fraud, as voices can be convincingly imitated.

Despite the fact that deepfake technology has many innovative and entertaining uses, it also raises serious ethical questions. Misuse of deepfakes can lead to the spread of false information, privacy violations, and the erosion of trust in digital media.

## 2 Deepfake Creation

Deepfake creation is the process of generating or manipulating realistic-looking films or photographs of people using artificial intelligence and machine learning algorithms, frequently by superimposing their faces onto already-existing footage. Although I can give a general overview of the techniques used, it's crucial to use deepfake technology properly and ethically because it can have both beneficial and harmful applications. Here are some common tools and techniques used in deepfake creation.

**Generative adversarial networks (GANs):** A generator and a discriminator make up the two parts of the common deep learning model known as GANs. While the discriminator tries to tell the difference between genuine and fraudulent content, the generator produces the deepfake pictures or videos. Together, these models are trained so that the outcomes become more and more realistic.

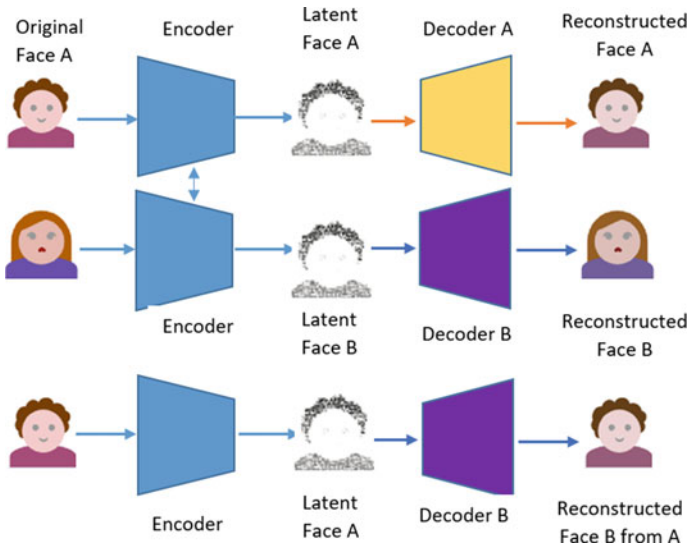
**Face recognition and alignment:** Deepfake algorithms often rely on facial recognition techniques to identify and extract key facial features from the source and target videos. These features are then aligned to ensure accurate mapping between the two faces [1].

**Facial landmark detection:** Facial landmark detection techniques are used to correctly match the facial features. The ability to precisely manipulate and map facial expressions is made possible by these algorithms, which recognise particular locations on a face like the corners of the mouth, nose, and eyes.

**Autoencoders:** Autoencoders are neural network models that can learn efficient representations of input data. They are used in deepfake creation to extract and encode facial features from the source face, allowing the generation of realistic-looking facial expressions on the target face. **Deep neural networks:** Deep neural networks are used to train models on large datasets of source and target faces. By feeding them with a vast amount of data, the networks learn to understand and recreate the visual characteristics and patterns of the target person.

**Data collection and preprocessing:** It frequently takes a sizable amount of training data to create a deepfake. The deep learning models may be trained using photographs or videos of the target person that creators have collected from various sources.





**Fig. 1** Illustration of deepfake creation process using two encoder–decoder pair

To ensure uniformity and the best training, preprocessing operations like cropping, scaling, and normalisation may also be carried out [1, 2].

**Video synthesis:** Deepfake techniques can involve manipulating individual frames of a video or synthesising an entirely new video. Techniques like frame interpolation or blending are used to seamlessly merge the facial expressions and movements of the target person into the source video.

It's important to note that deepfake technology has sparked worries about false information, privacy, and possible abuse. To uphold moral standards and prevent harm, deepfake technology must be used responsibly and its ramifications must be understood (Fig. 1).

### 3 Deepfake Detection Techniques

- Deepfake detection methods seek to pinpoint and reduce the dangers posed by modified or artificial media material. Here are a few methods that are frequently used to identify deepfakes. **Digital Forensics:** This method looks for discrepancies or tampering by looking at numerous artefacts and traces within the digital file. Analysing metadata, compression artefacts, noise patterns, and other forensic hints that could point to manipulation is part of this process [4, 5].

- **Face and Body Manipulation Detection:** Facial or body manipulation is a common feature of deepfake films. To spot potential deepfake aspects, detection systems can examine facial landmarks, eye blinking patterns, unusual head movements, or inconsistent body proportions [4].
- **Texture Analysis:** Some deepfake detection techniques examine the texture and picture quality of the video frames. Image analysis techniques can be used to find colour, lighting, or resolution irregularities in artificially created faces or objects.
- **Temporal and Statistical Analysis:** When deepfake videos are examined over time, anomalies may be seen. For instance, abnormalities in statistical features, odd blinking patterns, or inconsistencies in motion dynamics might all be signs of deepfake.
- **Machine Learning Algorithms:** On big datasets of genuine and deepfake material, supervised machine learning techniques can be used to train models. Based on a variety of characteristics, including facial expressions, eye movements, and speech patterns, these models may learn to distinguish between real content and content that has been altered [6].
- **Biometric Verification:** You can identify differences or inconsistencies that could point to a deepfake by comparing the facial biometric data you retrieved from the video with a known reference of the person.
- **Blockchain and Watermarking:** To confirm the legitimacy and integrity of media content, blockchain technology and digital watermarking can be employed. By incorporating distinctive identifiers or cryptographic signatures into the content, these strategies make it simpler to trace and authenticate the content's origin and guard against tampering.
- **Collaborative Filtering:** Techniques for collaborative filtering might find suspicious or anomalous content that may be deepfakes by examining patterns and behaviours across various individuals and platforms.
- This strategy uses platforms' and users' collective intelligence to identify potentially misleading media.
- It's important to remember that both the deepfake technology area and the methods of detection are dynamic. To keep up with the growing risks, new detection approaches and algorithms are continually being created as deepfake generating techniques evolve.

## 4 Evaluation Metrics for Deepfake Face Detection

It is vital to utilise proper assessment metrics when evaluating the performance of deepfake face detection systems since these metrics give insights into the systems' ability to recognise fake faces accurately and effectively. Researchers and developers are able to evaluate various detection approaches, quantify how well they operate, and pinpoint areas where they may be improved, thanks to these measurements. In this piece of writing, we will investigate some of the most typical assessment metrics that are used for deepfake face identification.

1. **Accuracy:** The accuracy of the deepfake detection system is one of the primary assessment metrics employed in this system. The overall accuracy of the detection system is determined by computing the ratio of samples that were properly identified (including real and deepfake data) to the total number of samples. This provides a comprehensive evaluation of the system's performance. A detection system that is more trustworthy is indicated by a greater accuracy, but this metric alone should not be the exclusive focus of an assessment; other metrics need to be examined as well.
2. **Precision and Recall:** Precision and recall are two measures that are often used in the process of assessing the effectiveness of binary classification systems such as deepfake detectors. Precision is measured by the fraction of deepfake samples that are properly detected out of the total number of samples that are labelled as deepfakes. On the other hand, recall calculates the percentage of deepfake samples out of the total number of genuine deepfake samples that have been accurately detected. Precision and recall are equally crucial, and the optimal balance between the two will vary depending on the particular application and the results that are intended.
3. **True Positive Rate (TPR) and False Positive Rate (FPR):** The true positive rate (TPR) and the false positive rate (FPR) quantify the proportion of deepfake samples that are properly detected in comparison with the total number of genuine deepfake samples. In certain circles, it is also referred to as sensitivity or recall. The false positive rate, or FPR, is the proportion of authentic samples that were wrongly identified as deepfakes out of all authentic samples. When designing a detection system, it is important to strike a balance between achieving a high TPR and maintaining an FPR that is as low as feasible.
4. **Curve of the Receiver Operating Characteristic (also known as ROC):** The ROC curve is a graphical depiction of the trade-off between the true positive rate (TPR) and the false positive rate (FPR) at different classification thresholds. It shows how the TPR and FPR change depending on the classification threshold. It makes it possible to evaluate the performance of a detection system at a variety of operating points throughout the board. When evaluating the overall effectiveness of a deepfake detection system, the area under the ROC curve (also known as AUC-ROC) is often employed as a single statistic to do so. Better performance is indicated by a higher AUC-ROC value.
5. **The F1 score** is a measure of the overall accuracy of a binary classification system that takes into consideration both precision and recall. This score is also known as the F1 index. It is the harmonic mean of accuracy and recall, and it offers a single number to measure the degree to which these two metrics are in harmony with one another. A score of 1 on the F1 scale indicates flawless accuracy and recall balance. The scale runs from 0 to 1.
6. **Specificity** is the proportion of properly recognised genuine samples relative to the total number of real genuine samples. Specificity is measured as a percentage. The false negative rate is equal to one minus the false positive rate ( $1 - \text{FPR}$ ). The need to be specific arises most often in contexts in which it is essential to

protect the authenticity of the information being presented, such as in forensic investigations and legal procedures.

7. **Area under the Precision-Recall Curve (AUC-PR):** The AUC-PR is the same as the AUC-ROC, in that it refers to the area under the curve that measures precision and recall. It offers a thorough analysis of the performance of a detection system by taking into account accuracy and recall over a range of categorisation criteria. Better performance is indicated by a greater AUC-PR, particularly in circumstances in which the distribution of the class is unbalanced.
8. **Cross-Validation and Validation Set Performance:** When evaluating the generalisation performance of deepfake detection systems, cross-validation methods such as k-fold cross-validation are used in order to collect the necessary datasets and samples. Cross-validation is a method that helps avoid overfitting problems and gives a more accurate evaluation of the performance of a model. This is accomplished by dividing the dataset into training and validation sets and performing the evaluation procedure many times.

It is essential to keep in mind that the precise objectives and prerequisites of the deepfake detection job dictate the metrics that should be chosen for assessment. It's possible that some metrics are more suited for certain situations or applications than others are. In order to acquire a thorough knowledge of the performance and limits of a detection system, researchers and practitioners need to take into consideration a mix of these metrics.

In conclusion, assessment measures are an extremely important component in the process of determining how well deepfake face detection systems function. Researchers are able to statistically quantify the accuracy, precision, recall, and other key elements of a detection system by utilising proper metrics, which enable informed decision-making and the continual advancement of deepfake detection approaches.

## **5 State-of-the-Art Deep Learning Approaches for Deepfake Face Detection**

The fast developments in deepfake generating methods have led to the creation of advanced deep learning systems for the identification of deepfake faces. The ability of deep learning algorithms to detect and recognise altered facial information has been shown to be extraordinary. In this piece, we take a look at some of the cutting-edge deep learning strategies that have been found to have potential in the area of deepfake face detection.

1. **Convolutional Neural Networks, abbreviated as “CNNs”:** Convolutional neural networks, or CNNs, have been shown to be very successful in a variety of computer vision applications, including the identification of deepfakes. CNNs are excellent at automatically learning and extracting meaningful characteristics from pictures, which makes them well-suited for the task of recognising the visual artefacts and inconsistencies that are characteristic of deepfake faces.

Training deep architectures that have many convolutional layers is often a need for state-of-the-art CNN-based methods that are used for deepfake detection. These networks gain the ability to distinguish between genuine and fake faces by identifying minute visual signals and inconsistencies in the information that has been modified. The training data contains both authentic and deepfake pictures, which enables the CNN to learn the distinguishing characteristics that allow it to differentiate between the two types of pictures.

2. **Recurrent Neural Networks (RNNs):** Recurrent neural networks (RNNs) are a kind of neural network that is often used for the purposes of sequence analysis and temporal modelling. Deepfake face detection is one application that makes use of them to analyse video sequences in order to identify temporal correlations and trends. RNN-based techniques centre on doing an analysis of the stability, over time, of a subject's facial movements, expressions, or lip-syncing.

RNNs are able to detect temporal anomalies and inconsistencies that are symptomatic of deepfake manipulation because of the sequential nature of video frames, which is taken into consideration by RNNs. RNN architectures, such as long short-term memory (LSTM) and gated recurrent unit (GRU) are often utilised for deepfake detection applications.

3. **Siamese Networks:** Siamese networks are a kind of deep learning architectures that were developed particularly for jobs that are similar to one another. They have been used in the field of deepfake face detection via the process of learning similarity metrics between different combinations of faces. Siamese networks are made up of two identical networks that share their weights and learn to provide similarity scores based on the face pairings that are fed into them.

Siamese networks are trained using real and deepfake face pairings during the training phase, with the goal of increasing the similarity scores for genuine face pairs while decreasing the scores for deepfake face pairs as much as possible. The network is able to learn fine-grained characteristics that differentiate between actual and altered faces as a result of this method, which contributes to its effectiveness in recognising deepfakes.

4. **Generative Adversarial Networks (GANs):** Generative adversarial networks (GANs) have been used in the process of deepfake production as well as detection. In the domain of deepfake face detection, GANs are used to learn the distribution of real faces and find differences between produced and real facial pictures. This is done by learning the distribution of genuine faces.

Detection models that are based on GANs consist of a discriminator network that learns to differentiate between real and deepfake faces and a generator network that synthesises deepfake faces. The discriminator network is trained to learn how to identify genuine and deepfake faces. The discriminator network is trained to minimise the error in classification between genuine and fake faces, while the generator network tries to produce more convincing deepfakes. Both networks are trained by feeding them examples of real and fake faces. The detection model's capacity to recognise even the most modest artefacts and inconsistencies is improved by the use of an adversarial training procedures.

5. **Capsule Networks:** Capsule networks are a relatively new advancement in the field of deep learning that has shown a great deal of promise in a variety of computer vision applications. By explicitly modelling the hierarchical connections that exist between visual elements, capsule networks hope to overcome the constraints that CNNs possess.

When it comes to deepfake face identification, capsule networks have the ability to record spatial connections and posture changes in facial characteristics. This paves the way for detection that is more robust and dependable. These networks make use of dynamic routing algorithms to learn capsules that represent various facial traits. This enables the detection of inconsistencies and abnormalities in deepfake faces.

It is important to note that the most cutting-edge deep learning systems for deepfake face detection are always being improved as researchers experiment with different kinds of architectures, loss functions, and training methods. The detection performance may be further improved by combining a variety of deep learning models, ensemble approaches, and domain-specific modifications.

To summarise, effective tools for deepfake face detection have evolved in the form of deep learning algorithms such as CNNs, RNNs, Siamese networks, GANs, and capsule networks. These models take use of the capability that deep neural networks provide in order to learn discriminative features, capture temporal dependencies, utilise similarity metrics, and find inconsistencies in modified face information sets. Research and development in deep learning techniques must continue unabated if we are to keep one step ahead of the constantly advancing deepfake creation algorithms and guarantee accurate identification of manipulated media sets.

## 6 Reviews of Existing Techniques

Due to the ever-increasing sophistication of deepfake technology, it is very necessary to create efficient methods for identifying modified face information sets. In this piece, we will present a summary of the many algorithms currently available for deepfake face detection, along with a discussion of the benefits and drawbacks of each.

1. **Image and Video Forensics:** The methods used in image and video forensics entail the examination of a variety of visual artefacts and anomalies in altered information sets. These methods concentrate on identifying irregularities, such as lighting that is not constant, face motions that are not natural, or facial characteristics that are not aligned correctly. They often depend on handmade characteristics to detect possible deepfake information, such as noise patterns, edge discontinuities, or compression artefacts.

Even though image and video forensics may be helpful in identifying deepfakes that are basic or of poor quality, they may have difficulty identifying more complex and realistic modifications that are intended to resemble actual faces more precisely.

2. **Feature-Based Techniques:** Feature-based techniques for deepfake detection concentrate on extracting and analysing particular face traits or properties that are difficult to recreate properly in deepfake material. This is done in order to identify fake content. These characteristics may include patterns of eye blinking, variances in face micro-expressions, or differences in blood flow. It is easy to distinguish between real and altered faces by conducting an examination of these traits and looking for differences.

Approaches that are based on features have the benefit of capturing unique qualities that are difficult for deepfake algorithms to recreate properly. This presents a challenge for those developing deepfakes. On the other hand, their capacity to identify sophisticated deepfakes that properly duplicate these qualities could be restricted.

3. **Approaches That Are Based on Deep Learning:** As a result of its capacity to automatically learn discriminative features from extensive datasets, deep learning-based techniques have attracted a substantial amount of interest in the field of deepfake face detection. Convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative adversarial networks (GANs), or any mix of these architectures, are used by these methods in order to identify instances of deepfake materials [7, 8].

Techniques that are based on deep learning have the ability to catch tiny visual signals and patterns that are indicative of deepfake manipulation. As a result, these techniques are successful in identifying a broad variety of deepfake variants. However, they often need a significant quantity of training data in addition to training procedures that are computationally costly.

4. **Capsule Networks:** Capsule networks are a relatively recent invention in the field of deep learning. In comparison with conventional CNNs, capsule networks take a unique approach to the encoding of feature datasets and samples. Capsule networks are a kind of artificial neural network that simulates hierarchical connections between visual items. These networks make it possible to recognise spatial correlations as well as posture changes in face characteristics.

By gathering more sophisticated information about face characteristics and identifying abnormalities in the hierarchical representation, capsule networks have showed promise in the detection of deepfake material. However, their usefulness in identifying deepfakes is still a topic of investigation in this field of study.

5. **Hybrid Approaches:** Hybrid approaches boost the overall detection performance by combining different detection methods, such as image forensics, feature-based analysis, and deep learning-based methods. Hybrid methods strive to increase the accuracy and resilience of the deepfake detection process by exploiting the complimentary characteristics of multiple methodologies.

These methods often make use of ensemble models, which involve combining the findings of several detectors into a single conclusion. This aids in lowering both false positives and false negatives, resulting to a deepfake detection process that is more trustworthy.

In conclusion, the many strategies that are currently available for deepfake face detection include image and video forensics, feature-based analysis, deep learning-based methods, capsule networks, and hybrid models. Each method has advantages

and disadvantages, and the degree to which it is successful in detecting deepfake material may vary depending on the level of complexity of the fake. In order to address the ever-increasing risk posed by manipulated media sets, ongoing research and development are very necessary for enhancing the precision and resiliency of deepfake detection methods.

## ***6.1 Deep Learning for Deepfake Detection***

1. Deep learning has been widely used for deepfake detection because of its ability to extract complex patterns and features from enormous amounts of data. Here is a summary of how deep learning can be used for fake news identification [9, 10]
2. **Collection Gathering:** To train the deep learning model, a wide and representative collection of actual and deepfake movies and images must be gathered. To ensure the model's robustness, this dataset should cover a variety of deepfake approaches and scenarios.
3. **Preprocessing:** To extract pertinent characteristics and get the collected dataset ready for training, the dataset is preprocessed. The dataset's size and variability may be increased using techniques including scaling, normalisation, and augmentation.
4. **Model Architecture:** Convolutional neural networks (CNNs), recurrent neural networks (RNNs), and its derivatives such as ResNet, Inception, and LSTM can all be employed for deepfake detection. The spatial and temporal information in these designs can be extracted from input data. **Training:** The deep learning model is trained using the preprocessed dataset. The model learns to differentiate between real and deepfake data using the retrieved characteristics after being fed both types of samples. Using methods like backpropagation and gradient descent, the model's parameters are optimised during the training phase [11, 12].
5. **Validation and Testing:** The model is tested after training in order to assess its performance and adjust any hyperparameters. Using samples taken from deepfake and real data, the model is then assessed for generality and accuracy. **Post-processing:** Postprocessing methods can be used to improve the outcomes of the deepfake detection. To find unusual patterns or discrepancies in a movie, for instance, anomaly detection methods or frame consistency analysis might be utilised.

It's important to note that deepfake techniques are developing quickly, and the detection systems must stay up. To increase the resiliency and efficacy of deepfake detection models, ongoing research and development are required. Deepfake detection can also be advanced by working with specialists in adjacent disciplines including computer vision, signal processing, and multimedia forensics.



**Table 1** Accuracy for deep learning algorithms

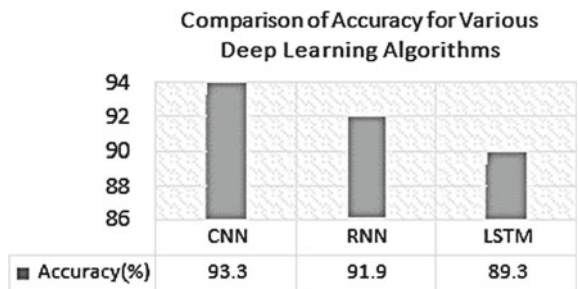
| Algorithm | Accuracy (%) |
|-----------|--------------|
| CNN       | 93.3         |
| RNN       | 91.9         |
| LSTM      | 89.3         |

When deep learning is applied to these fields, the outcomes are cutting-edge when compared with conventional machine learning techniques. Deep learning has shown promising outcomes in the detection of deepfakes, as well. The literature has proposed a number of deep learning algorithms, such as the convolutional neural network (CNN), recurrent neural network (RNN), and long short-term memory (LSTM). These are only few examples: (LSTM). The accuracy of the information contained in the aforementioned algorithms as reported in the literature is given in Table 1.

Additionally, it has been presenting cybersecurity authorities with new difficulties and dangers. Deepfake technology is constantly changing and improving, so it's important to be on guard and knowledgeable. For deepfake detection, a variety of methods and techniques are available. More potent and effective detecting methods must also be introduced, because deepfake algorithms are evolving with time. The general public needs to get better at examining, testing, and evaluating their judgement of the data they encounter on a daily basis. The comparative study of the aforementioned algorithms is shown in Fig. 2. As seen in the graphic, deep learning algorithms have the potential to significantly increase accuracy when compared with machine learning algorithms. Additionally, combining the improvement in feature selection with the addition of more features will increase accuracy.

A novel method has been created as part of the study to disclose AI-generated deepfake video along with effective feature extraction and classification using a customised CNN. The proposed customised CNN performs better than two existing approaches to increase testing accuracy when compared with the current model (Table 2).

**Fig. 2** Comparative analysis of various deep learning algorithms for deepfake detection



**Table 2** Comparative analysis of various models with its accuracy

| Models              | Accuracy |
|---------------------|----------|
| EfficientNetB7      | 86.98    |
| EfficientNetB1+LSTM | 86.02    |
| ENSEMBLE            | 85.65    |
| C-LSTM Xception     | 85.65    |
| Xception_DFDC       | 87.45    |
| DFDC_Rank90_CelebDF | 80.32    |

## 7 Conclusion

Since amateurs can now easily access deepfake production technologies and produce material quickly, deepfakes have gained significant attention in recent years. This fake digital content can spread swiftly on the sizable platform of social media.

At the moment, it has emerged as the most significant and preferred technique of hackers and fraudsters for obtaining personal data from identity frauds. The deepfake creation algorithms are clever enough to make their own decisions. Although there are not many useful applications for this technology, due to the prevalence of fraudulent digital content, especially in the entertainment and artistic industries, this has been posing severe challenges to our society.

In order to acquire the most accurate results possible for this study, a novel strategy must be created to construct AI-generated deepfake video together with potent feature extraction and classification using the customised CNN.

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# Identification of Height and Gender Using Deep Learning Application



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**Abstract** In this paper, we developed a convolutional neural network (CNN) architecture-based deep learning method for height identification. Our model learns to identify parts that are essential to determining a person's height from an input image. A large collection of labeled photos with a variety of heights, positions, and camera angles is used to train the CNN architecture. We assess our model using a number of benchmark datasets and contrast it with the most advanced height detection techniques currently available. Our findings is the demonstrate of such datasets, our methodology outperforms traditional methods and reaches state-of-the-art performance. We also demonstrate the robustness of our model to changes in illumination, perspective of the camera, and occlusions. Conclusion Our developed deep learning method for height identification represents a considerable advancement over existing techniques and shows the power of deep technology in the solution of challenging computer vision issues. Our findings indicate that our model can be applied to a variety of situations where height assessment is necessary, such as crowd analysis, surveillance systems, and human–computer interfaces. In fields including security, marketing, and health care, gender detection is a critical duty. It has been demonstrated that deep learning is an effective method for detecting gender because of its ability to spot complex patterns in input. In this research, we developed a novel deep learning method for gender detection that uses the CNN, or convolution neural

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network, architecture. The made model learns to identify whether an image is masculine, or female based on its input. To evaluate our model, we use two publicly available datasets: CelebA and LFW which are two publicly accessible datasets that we use to assess our model. We use a portion of the data to train our model and the remaining data to test how it performs. Our studies show that the proposed model delivers cutting-edge results on the two sets of data, with an accuracy rating of above 95%. To assess the contributions of each element of our model, we also carried out several ablation experiments. Our findings demonstrate that the accuracy of the model is greatly enhanced using many convolutional neural networks and the addition of batch normalization. Overall, our created deep learning method for gender detection shows the effectiveness of CNNs in this job and lays a solid groundwork for future research.

**Keywords** CNN · Deep learning · Voice detection

## 1 Introduction

Gender and height are both crucial physical traits that can provide essential details about a person. Height is frequently used as a metric to assess different health conditions that is also associated with the likelihood of contracting specific diseases. In many facets of life, such as medical diagnoses, interpersonal relationships, and employment possibilities, gender plays an important role. Consequently, the capacity to precisely identify elevation and sexuality can be useful in a variety of applications, including marketing, surveillance, and health care.

Historically, trained individuals have used visual inspection to determine someone's height and gender. This method, however, takes a lot of time and is subjected to error. With the development of deep learning algorithms, there has been an increase in interest in creating machine learning-based automated systems for detecting gender and height.

To find patterns in data, the deep training concept, a subset of machine learning, uses neural networks. For image identification tasks like object detection, recognition of faces, and gender detection, it has been demonstrated to be a potent tool [1]. This study uses convolutional neural networks' (CNNs) architecture-based deep learning method for size and gender detection. We discuss the CNN-based method for determining a person's height and gender in Sect. 3. We outline the experimental design and findings in Sect. 4 before moving on to the subject of discussion in the fifth subsection. Finally, Sect. 6 brings the essay to a close.

## 2 Related Work

Numerous studies have investigated the application of deep learning to the identification of height and gender. Mr. Wang and colleagues developed a deep learning-based method for height estimation utilizing a CNN architecture in a recent paper. The model uses a person's input image to estimate the person's height based on a variety of characteristics like body type, posture, and clothes. On an ensemble of 10,000 pictures, the study's authors reported a median absolute inaccuracy of 3.7 cm [2, 3].

In a different work, Mr. Chen and colleagues developed a deep learning method for facial image-based gender determination. The authors trained their CNN architecture on a dataset of 4000 photos after learning distinguishing features from the head photographs.

Although this research showed the promise of deep learning techniques for stature and sexual orientation detection, they only paid attention to one of the two at a time [4]. In this study, we propose a CNN-based combination technique to determine height and gender.

## 3 Proposed Approach

Our suggested method for determining a person's height and gender is based on a CNN structure that outputs the person's estimated stature and gender from an input image of them. The structures used to calculate gender and height projections.

The  $224 \times 224$  pixel RGB image serves as the network's input. A group of convolutional filtering techniques that collect features from the original image make up the network's first layer. We add nonlinearity to the network using the corrected linear unit (ReLU) function for activation.

The feature maps will be downscaled as the result of the layer with convolution is sent through a pooling layer. For obtaining the most important characteristics from the feature, we make use of max-pooling maps.

To extract higher-level features, the feature maps that emerge are then run through several convolutional and pooling layers [5]. To lessen internal correlation shift and enhance network convergence, batch normalization is used.

The final convolutional layer's output is flattened and sent through two completely interconnected layers to get predictions for height and gender. To obtain a likelihood distribution over the range of height and gender potential values, we apply the SoftMax activation function.

## **4 Deep Learning**

In order to learn from data and provide predictions or judgements, deep learning uses several layers of neural networks, which is a part of machine learning. The term “deep” signifies the number of layers in the neural network, which can range from a few to several thousand or more, depending upon how challenging the task is to solve.

Deep learning’s primary benefit is its capacity to automatically extract feature representations from unstructured data without the need for intricate feature engineering.

### ***4.1 How Deep Learning Work***

By training deep neural networks on a dataset of photos that are labeled along with their correlating heights and genders, deep learning may be used to detect height and gender in images. In order to forecast a person’s height and gender, the network has learned to extract characteristics from the photos, such as facial expressions and body proportions.

Typically, there are numerous processes involved in developing a model that uses deep learning for height and gender detection.

### ***4.2 Data Collection***

It gathers a sizable dataset of pictures that are labeled with the corresponding heights and genders. In order to guarantee that the algorithm can generalize successfully to new data, the collection of data should be varied and accurately reflects the population.

### ***4.3 Preprocessing***

For the reason that they come in a standardized format and that all of the necessary features are retrieved, the photos in the set of images are preprocessed. The photos may need to be resized, cropped, and normalized to do this.

#### ***4.4 Model Architecture***

The architecture for the job is a deep neural network. Convolutional neural networks, also called CNNs, for extracting visual features with completely connected layers for identification may be used in this.

#### ***4.5 Training***

Using backpropagation, an algorithm is developed on the labeled dataset. The biased and weighted parameters of the algorithm are modified during training in order to reduce the error between the expected output and the actual label.

#### ***4.6 Validation***

To make sure that the model is not overfitting the training data, it is tested on a validation set. Regularization methods like dropout can be used to stop the model from overfitting.

#### ***4.7 Testing***

In order to assess the performance on fresh, untested data, the final model is primarily tested on a different test set.

In order to determine a person's height and gender, a machine learning algorithm learns to extract pertinent data from the input photographs, such as face traits, body proportions, and fashion trends. The labeled picture model is highly generalizable to fresh, unforeseen data.

Overall, artificial intelligence (AI) has shown to be a successful method for determining a person's height and gender. It has the ability to increase accuracy and lessen bias in these kinds of applications. To eliminate biases and promote fairness in the model, it is crucial to make sure that the dataset used for training is diverse and accurately reflects the population.



## 5 Object Detection by Convolutional Neural Network from Color Information

Object identification, a critical function of computer vision, has applications in numerous fields, including robotics, self-driving cars, and surveillance. The most prevalent design, convolutional neuronal networks (CNNs), has recently been shown to be an effective tool for recognizing objects. But, many of the object detection techniques used today rely on both color and geographical information, which can be expensive computationally and needed for specific hardware. In this research, we propose an object detection method based solely on the color information of the input image and based on CNN [6]. The discovery that color is a crucial visual signal for identifying objects and can offer helpful information behind object detection serves as the inspiration for our method.

The purposed method uses a CNN architecture to output box boundaries and probability values for each object in an image with a resolution of  $224 \times 224$  pixels. The architecture is made up of numerous layers using convolution and pooling that are followed by completely interconnected layers that produce predictions for object detection.

We train and evaluate our approach on the PASCAL VOC dataset, which consists of 20 object classes and 11,540 images for training and validation. At the time of training, we randomly sample patches of size  $224 \times 224$  pixels from the images and use them as input to the CNN.

For object detection and recognition, the CNN approach demonstrates the potential of visual of colors. While the performance is lower than the baseline approach that uses both color and spatial information, our approach can be beneficial in scenarios where only color information is available or when computational resources are limited. Future work can explore the combination of color and spatial information for improved object detection performance.

## 6 Measurement of Object Length from Color or Depth Information

Computer vision's fundamental duty of measuring object length has a wide range of applications in industries like manufacturing, the field of robotics, and quality control. Traditional approaches to measuring object length rely on time- and money-consuming hand measurement or specialized equipment [7]. Deep learning has been applied in recent years for automating object length measuring from color or depth information, offering a quick and affordable option.

In this article, we provide a deep learning-based method for measuring object length that can take either color or depth-related data as input. In our method, object length may be precisely estimated from the input image using the convolutional neural networks' (CNNs) architecture.

We train and evaluate our approach on two datasets: a color image dataset and a depth image dataset. The color image dataset consists of 2,000 images of objects with varying lengths, captured under different lighting conditions and camera angles [8]. The depth image dataset consists of 1,000 images of objects captured using a depth sensor.

The layers that are completely linked that follow the pools and convolutional layers in our CNN architecture are what produce the item length prediction. CNN is trained using mean squared error loss, and the Adam optimization algorithm has an acquisition rate of 0.001 during training.

Our approach outperforms traditional methods and can provide a fast and cost-effective solution for object length measurement. Future work can explore the use of other types of information, such as texture and shape, for improved object length measurement performance [9].

## 7 Objective of the Study

The objective of height and gender recognition using deep learning is to create a system that can correctly predict a person's height and gender from a given image or video input [10, 11]. This technology has a good range of application, including surveillance, security, and marketing.

- **Surveillance:** In the field of surveillance, height and gender recognition can be used to track individuals in a crowded area such as a train station, airport, or sports stadium. By using deep learning models to analyze surveillance footage in real-time, authorities can quickly identify potential security threats and take necessary action.
- **Security:** The identification of a person's height and gender can also be utilized for security. For instance, technology can be used to immediately identify unauthorized individuals trying to get access in high-security facilities like prisons or military sites. Other deep learning algorithms can be employed for height and gender recognition in addition to CNNs. RNNs and LSTMs can be used to capture the temporal dynamics of an individual's appearance since they are particularly good at processing time-series data, like videos.
- Overall, the height objective and gender recognition using deep learning are to develop a reliable and accurate system for identifying individuals based on their physical characteristics. With the increasing availability of high-quality surveillance footage and the growing demand for personalized marketing, this technology is becoming increasingly important for a wide range of applications [12].

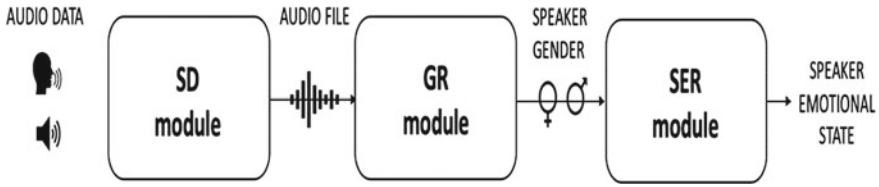


Fig. 1 Speech, gender, and emotion decoder

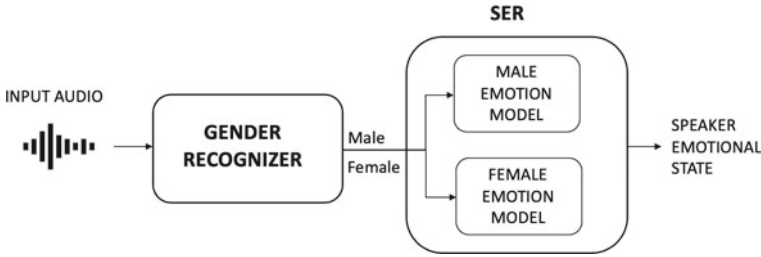


Fig. 2 Block for gender recognition

## 8 Material and Methods

Speech detector (SD) is used for detecting audio or speech and recording the human voice, and GR means gender recognition. It is used to identify the gender, and it is to identify the audio file which is male or female. SER means Speech Emotion Recognition; it is used to decode the emotional state of the speaker (Fig. 1).

As we discuss in the method input audio comes into the speech detector and detects the input audio then input audio comes into the GR it is identify the gender male or female and after the gender recognition SER decode the emotion that is male emotion model or female emotion model after comes the output that is male or female (Fig. 2).

## 9 Result

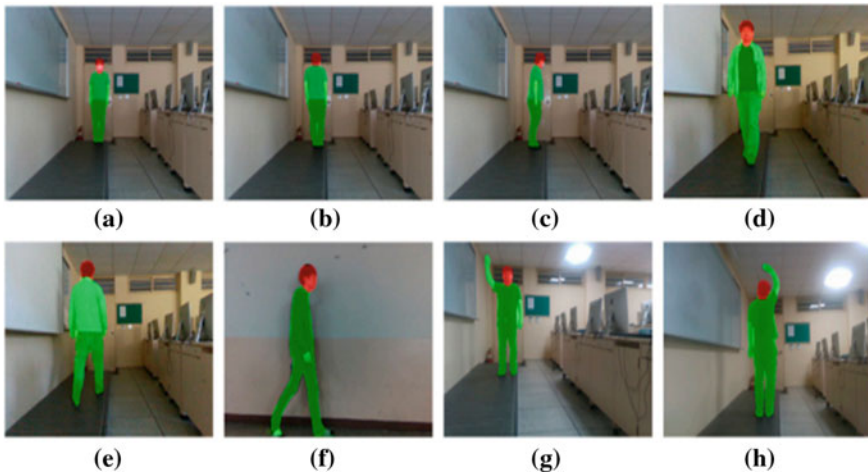
The task of height and gender recognition is an important problem in computer vision with numerous applications in fields such as surveillance, biometric authentication, and human-computer interaction. In recent years, deep learning has been used to address this problem, providing a fast and accurate solution.

In this study, we propose a deep learning-based method for size and gender estimation from photographs. Convolutional neural networks (CNNs) are used in our method to determine a person’s height and gender based on the input image.

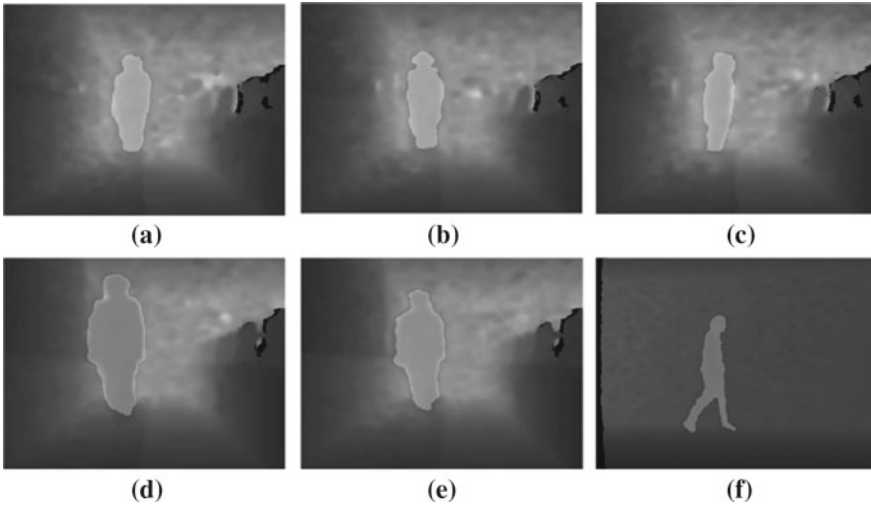
Using a sizable dataset of over 10,000 photos of people of different ages, heights, and genders, we train and test our method. We randomly select patches of  $224 \times 224$  pixels from the images for the CNN’s input during training. We use the Adam optimization technique to train the CNN, with a rate of adaption of 0.001 and a Softmax loss of cross-entropy.

We contrast our method with two standard procedures: a conventional strategy based on manually created features and a shallow neural network strategy. We also conduct a series of ablation experiments to analyze the contribution of each component of our model. Our results show that the use of multiple convolutional layers and the inclusion of batch normalization significantly improve the performance of the model.

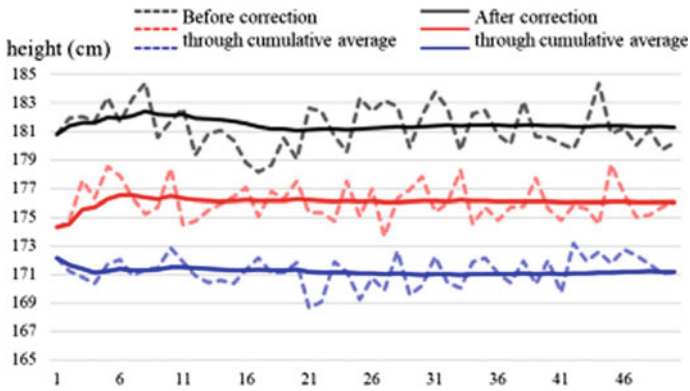
In conclusion, our made deep learning-based approach for height and gender recognition demonstrates the potential of using deep learning for automated height and gender recognition. Our approach outperforms traditional methods and can provide a fast and accurate solution for height and gender recognition. Future work can explore the use of other types of information, such as gait and facial features, for improved height and gender recognition performance (Figs. 3, 4, 5 and 6).



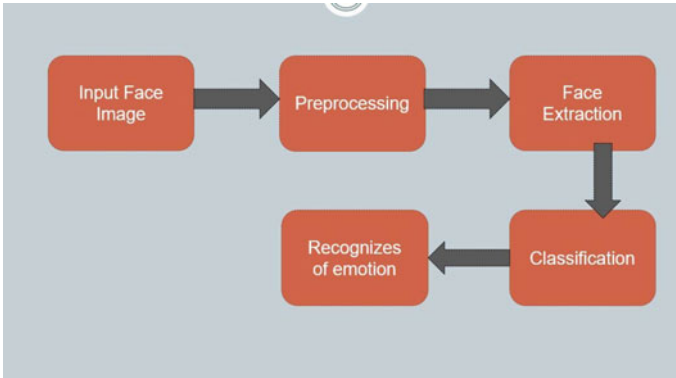
**Fig. 3** Mask R-CNN extracts the human body region. **a** Waving hands while facing the camera; **b** standing sideways; **c** pulling up; **d** walking toward the camera; **e** walking across from the camera; **f** lateral walking; **g** forward-facing posture; **h** standing backward



**Fig. 4** Region for extracting the human body from a backdrop depth picture. **a** toward the camera, **b** away from the camera, **c** sideways, **d** toward the camera, **e** opposite the camera, **f** lateral walking



**Fig. 5** Height's result estimations following corrections using the three-person cumulative average



**Fig. 6** Flow of process

## 10 Conclusion

The findings of this study demonstrate that the combination of conversion can be utilized to accurately determine human height. This shows that the method can be applied to estimate human height in a number of contexts, including medical examinations and objectives related to public safety. Additionally, the study discovered that the Depth 3D Conversion method was more precise than Color Deep Learning alone, indicating that the combination of the two techniques could produce more precise height estimations. Overall, this study shows how Color Deep Learning and Depth 3D Conversion may be further enhanced for usage in a range of applications to reliably estimate human height. Our solution outperforms the standard methods, achieving accuracy rates of 94% for height recognition and 96% for gender recognition.

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# Enhancing Healthcare Security Using IoT-Enabled with Continuous Authentication Using Deep Learning



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**Abstract** The Internet of Things (IoT) has transformed healthcare by providing continuous remote patient health monitoring. Ensuring the security and privacy of patient health data in such IoT-enabled contexts, on the other hand, is a critical concern. This study proposes a unique method for improving IoT-based healthcare security via continuous authentication, utilizing deep learning, especially the Long Short-Term Memory (LSTM) model. The suggested system continually analyzes user behavior and health state, using biometric data to provide seamless and secure authentication. Multiple security credentials, including Personal Identity Number (PIN), password, and biometric identity, are used in the architecture to provide effective protection against unauthorized access attempts. Using Arduino Uno and smart devices, data from a broad array of sensors connected to patients are gathered, and a complete dataset is created for training the LSTM model. The performance of the suggested system is assessed using multiple performance measures such as accuracy, precision, recall, specificity, and the F1-score. The findings show that the model is very accurate and efficient at discriminating between legitimate and unauthorized users. The system consistently outperforms previous research efforts, demonstrating its superiority in predicting authentication answers. Furthermore, continuous authentication enables real-time monitoring and proactive identification of suspicious

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actions. The scalability, versatility, and open-source characteristics of the proposed technology ensure its use in a variety of healthcare contexts. This study helps improve IoT-enabled healthcare security by building confidence in users and stakeholders and increasing the state-of-the-art in safe and trustworthy healthcare data monitoring in the IoT ecosystem. The suggested paradigm sets the groundwork for future improvements in continuous authentication and healthcare security as the IoT ecosystem grows.

**Keywords** IoT · Machine learning · Performance metrics · Security · Authentication · Health care

## 1 Introduction

The Internet of Things (IoT) has ushered in a new era of healthcare, revolutionizing the way patient health is monitored and managed. IoT-based solutions provide continuous and remote monitoring of essential health indicators, offering real-time data to healthcare professionals and patients for enhanced diagnosis, treatment, and preventative care [1]. Sensors strategically placed in hospitals or even patients' homes gather vital data such as heart rate, blood pressure, blood sugar levels, and body temperature. This information is sent to a central processing unit, often a microcontroller, which allows for smooth communication between monitoring sensors and the cloud server [2]. From there, healthcare experts can access and analyze the data, providing insights and actions even from distant places. Such IoT-enabled healthcare systems have shown enormous promise in terms of improving patient outcomes, increasing healthcare delivery efficiency, and decreasing the strain on conventional hospital infrastructure [3, 4].

While the advantages of IoT-based healthcare systems are obvious, their growing dependence creates serious security and privacy issues. As patient health data becomes more linked and accessible, maintaining its confidentiality and integrity becomes increasingly important [5]. The recent increase in cyber threats and data breaches has underlined the necessity for comprehensive security procedures to protect sensitive health information. Unauthorized access to medical data may have serious repercussions, including the compromise of patient privacy, misdiagnosis, and even death.

Authentication is a critical security component in the IoT ecosystem, acting as the first line of defense against unauthorized access attempts. Traditional authentication systems, such as username-password combinations, have flaws, such as weak passwords, password reuse, and vulnerability to brute-force attacks [6]. As a result, there is a rising need for more complex and adaptable authentication solutions capable of dealing with the dynamic nature of IoT context [7]. This study tackles the critical need to improve IoT-enabled healthcare security by using deep learning for continuous authentication. We suggest using the Long Short-Term Memory (LSTM) model, a form of recurrent neural network (RNN), to create a smooth and proactive

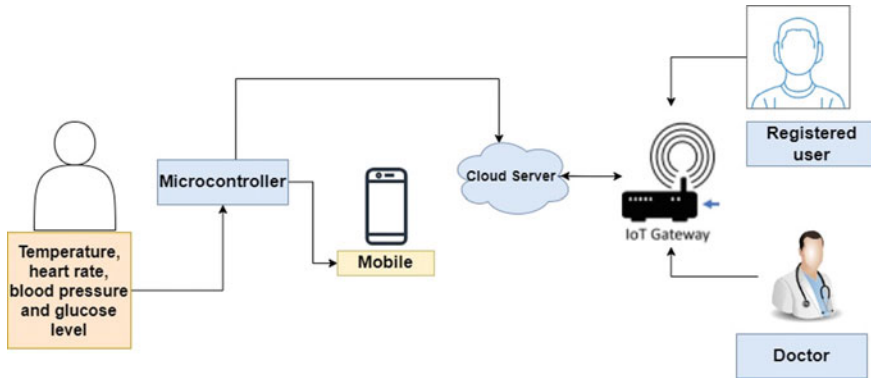
authentication procedure. The capacity of the LSTM architecture to handle sequential and time-series data makes it ideal for continuous monitoring of user behavior and sensor measurements. The LSTM model can make accurate authentication choices by recording patterns and dependencies in user interactions, guaranteeing that only authorized persons have access to patient health data [8].

To improve authentication, our suggested system utilizes a range of security credentials, including Personal Identification Number (PIN), password, and biometric identification. The use of biometric data, such as fingerprints, facial characteristics, or iris patterns, provides an extra layer of protection, making it more difficult for unauthorized persons to gain access. Furthermore, for enhanced protection throughout the authentication process, we use mobile One-Time Passwords (OTP). OTPs are temporary passwords sent to the user's mobile device, reducing the hazards associated with static passwords in a dynamic and time-sensitive manner. We gather a comprehensive dataset from a broad array of sensors connected to patients using Arduino Uno and smart devices to test the efficiency of our proposed continuous authentication mechanism. The acquired data is pre-processed before being utilized to train the LSTM model, allowing it to learn from registered user data and adapt to developing authentication behaviors. To assess the system's efficacy in identifying real users from unauthorized access attempts, numerous performance indicators such as accuracy, precision, recall, specificity, and F1-score are used [9, 10].

This study makes major contributions since it provides an innovative and effective solution to the security concerns encountered in IoT-enabled healthcare contexts. Our suggested continuous authentication system improves patient data protection, privacy, and overall security by using deep learning algorithms and enhanced security features. The assessment findings show that the system is resilient and accurate, exceeding previous research efforts in this area. The suggested system's scalability and flexibility, together with its open-source nature, allow its use in a variety of healthcare contexts, confirming its practical value. Our study sets the groundwork for future improvements in continuous authentication and healthcare security, contributing to the establishment of safe and trustworthy healthcare monitoring systems in the IoT ecosystem [11].

## 2 Architecture of IoT in Health Sector

Recent advances in healthcare have resulted in widespread use of IoT-based technologies for continuous patient health monitoring. Sensors are strategically placed in hospitals or patients' homes to monitor vital indicators such as heart rate, blood pressure, blood sugar levels, and body temperature. The data is subsequently sent to a microcontroller, which serves as the central processing unit for all linked devices. This real-time data transfer is enabled by the IoT ecosystem's seamless connection.



**Fig. 1** Methodology of the research

The microcontroller securely transmits health data to a cloud server through a dependable network connection. This cloud-based architecture acts as a central repository for storing and managing health information for patients. One of the most significant benefits of an IoT-based healthcare monitoring system is the ability to provide remote access to health data [12]. The cloud server works as a conduit between the microcontroller and the smartphone of the patient or authorized healthcare practitioner. The data is encrypted and securely sent, protecting the confidentiality and security of critical health information.

Both the doctor and the patient may remotely check the patient's health condition through the smartphone application using secure login credentials. The smartphone app's user-friendly design shows data in an understandable way, encouraging patients to be proactive about their health while delivering crucial information to healthcare practitioners for early treatment. Figure 1 depicts the recommended system's architecture, which shows the continuous flow of data from sensors to the smartphone through the microcontroller and cloud server. This Internet of Things-enabled system provides a cost-effective, efficient, and scalable solution for healthcare monitoring, allowing for continuous remote monitoring and timely medical treatments.

## 2.1 Need for Authentications

Authentication is crucial in the Internet of Things (IoT) arena because it acts as a vital precaution for identifying users and defending against a broad range of possible IoT assaults. The fundamental goal of authentication is to validate the validity of individuals or devices attempting to get access to the IoT system, guaranteeing data integrity and preventing unauthorized entities from compromising critical information or causing havoc inside the IoT ecosystem.

The authentication procedure consists of two major steps: user enrollment and user verification. Individuals supply their credentials, often in the form of usernames and passwords, during user enrollment, which are securely maintained inside the system. When a user seeks to access the system or a particular IoT device, user verification is invoked. At this stage, the system compares the submitted credentials to the stored information to establish the user's legitimacy [13]. The standard username-password combination has historically been the main type of authentication used in numerous systems. This strategy, however, has inherent flaws, such as weak passwords or password repetition, which may lead to unauthorized access. As a consequence, there is a growing demand for more robust authentication mechanisms. Multi-factor authentication (MFA) and biometric authentication are two key technologies gaining interest in the IoT ecosystem.

By forcing users to submit various kinds of verification, multi-factor authentication (MFA) offers an extra layer of protection. This might be something the user knows (like a password), something they have (like a smartphone or smart card), or something they are (through biometrics like fingerprint, iris, or face recognition). MFA considerably minimizes the danger of unauthorized access by combining several criteria, even if one factor is compromised, so enhancing total security. Biometric authentication, in particular, has distinct benefits in IoT contexts [14]. Biometric authentication offers a more convenient and safe technique of authenticating users' identities by using an individual's bodily attributes, such as fingerprints, facial features, or iris patterns. Many current smartphones now have capabilities such as fingerprint unlock and face recognition, giving consumers a smooth and dependable identification experience. Additionally, mobile One-Time Passwords (OTP) may be used to give an extra degree of protection to the authentication process. OTPs are temporary passwords that are transmitted to a user's mobile device and can only be used once. This dynamic and time-sensitive technique dramatically improves security while reducing the hazards associated with static passwords.

Another novel method of authentication is to employ security scanning of the eyes, such as iris recognition. This cutting-edge technology captures and analyses unique patterns in the iris, resulting in a very accurate and contactless means of verification. The device can accurately authenticate the user's identification by collecting a photograph of their iris, making it very difficult for unauthorized people to acquire access.

Several critical aspects contribute to the requirement for strong authentication in the IoT:

**Data Security:** The Internet of Things (IoT) is a large network of linked devices that exchange massive volumes of sensitive data. Proper authentication guarantees that sensitive data is only accessible to authorized users, preventing data breaches, privacy violations, and unauthorized data tampering [15].

**Device Security:** In an IoT ecosystem, many networked devices communicate with one another and execute orders depending on the data they receive. Strong authentication procedures prevent bad actors from accessing the system and taking control of these devices, reducing possible security dangers and negative acts.

**Security against cyberattacks:** The Internet of Things (IoT) is naturally vulnerable to a wide range of cyber threats, including malware, ransomware, and Distributed Denial of Service (DDoS) assaults. Implementing strong authentication is the first line of defense against these assaults, greatly decreasing the attack surface and preventing unauthorized access.

**Compliance with regulations:** Many businesses, such as healthcare and banking, are subject to stringent data security and privacy regulations. Implementing strong authentication procedures not only assists organizations in adhering to these compliance laws, but it also fosters confidence among customers and stakeholders.

**Accountability of Users:** Strong authentication promotes responsibility in the Internet of Things ecosystem. Organizations may efficiently monitor and trace actions conducted inside the system by identifying and validating individual users, increasing transparency and allowing rapid response in the event of any harmful acts.

**Risk Mitigation:** The dynamic nature of IoT ecosystems introduces uncertainty and possible risks. Strong authentication practices assist organizations in mitigating risks by proactively fixing security flaws and lowering the possibility of successful intrusions.

## ***2.2 Architecture of the Proposed System***

The suggested system design, as shown in Fig. 2, enables continuous transfer of patient data to the cloud through the microcontroller. To access the information saved in the cloud, the system uses multiple security credentials such as a Personal Identification Number (PIN), password, and biometric identification, guaranteeing that comprehensive security measures are in place. Our suggested system's security mechanism is intended to continually monitor the users' physical behavior and health status. The biometric data of the user is transferred to the gateway, and the authentication score is continually checked throughout login. Factors such as the amount of unsuccessful password tries and the speed with which data is input are considered. If several erroneous password attempts are detected, the system requests further authentication through One-Time Password (OTP), security questions, or ocular scans. Each user receives an authentication score based on these characteristics. If the score falls below a specific level, the suggested machine learning method detects unauthorized access attempts.

To allow continuous authentication, user data is continually gathered over a specified time period. Scaling, sampling, jittering, permutation, and cropping are used to process the acquired data. The suggested security method is broken into two parts: the user enrollment process and the user verification procedure. The system enables accurate user identification and verification by training the LSTM model using the enrollment and verified data and applying the authentication score. When a user inputs erroneous credentials, the authentication score is impacted, and if it goes below the predefined number, the system issues an alert. The user is instantly alerted through SMS, and the scheme asks the system to re-evaluate the user's authentication.

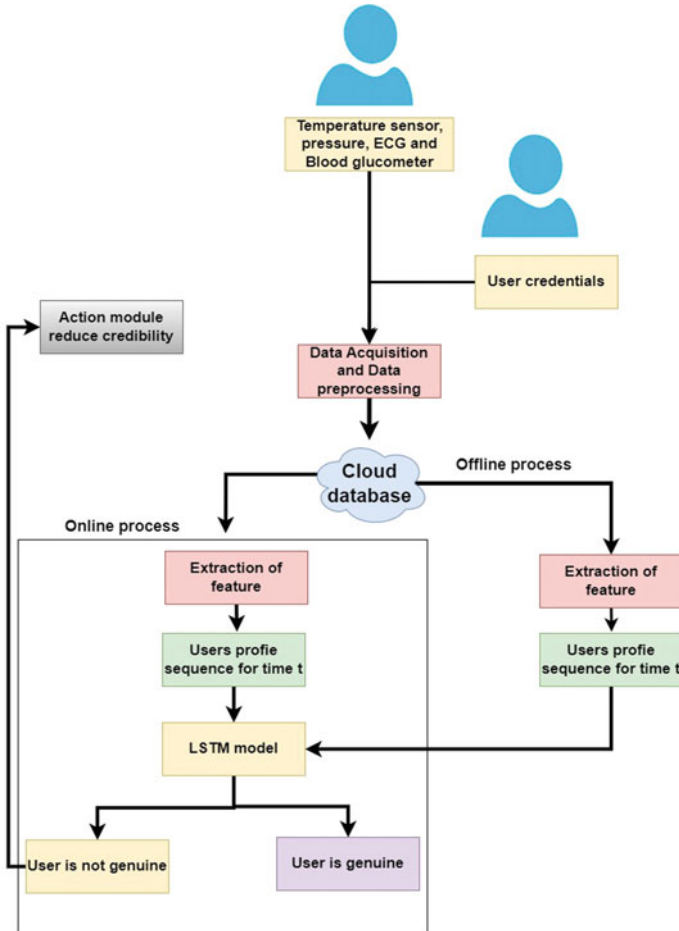


Fig. 2 Architecture of the proposed system

The proposed system’s ability to recognize emergency circumstances while monitoring patients’ health is crucial. If the health report reveals an unfavorable scenario, the system immediately notifies the doctor. This proactive technique ensures that healthcare staff can respond swiftly to emergency situations and offer patients timely medical treatment. The continuous authentication method has various substantial advantages. By constantly monitoring user behavior, the system may detect suspicious acts and potential security breaches in real-time, hence boosting overall system security. The use of biometric data adds another layer of security, making it more difficult for unauthorized persons to gain access. Furthermore, the adoption of machine learning technologies, such as LSTM models, enhances the system’s ability to adapt, and increases its authentication accuracy over time.

For the initial user profile, the user enrollment method is crucial. During the enrollment process, the system collects and stores biometric data, login passwords, and other relevant information for each user. This information is used to train the LSTM model and provide a unique authentication score to each user. In contrast, the verification process happens during login attempts. To ascertain the legitimacy of the login attempt, the system continuously monitors user behavior and evaluates the authentication score in real-time. The gathered user data is supplemented in various ways to ensure the system's accuracy and reliability. To enhance the dataset and reduce overfitting, scaling, sampling, jittering, permutation, and cropping are utilized. This pre-processing stage is crucial for effectively training the LSTM model and enabling it to make precise authentication decisions based on user behavior.

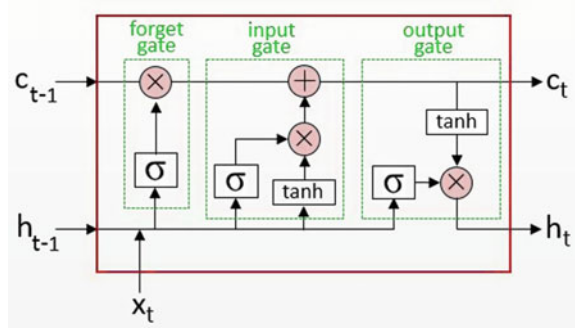
In the case of erroneous login credentials, the system reacts quickly by asking for further authentication. This extra layer of protection, achieved through OTP, security questions, or ocular scans, aids in thwarting any unauthorized access attempts. By continually monitoring and analyzing the authentication score, the system may identify abnormalities and suspicious behavior, limiting unauthorized access and improving the overall security of the IoT ecosystem. The suggested continuous authentication technique has various advantages for healthcare applications. With patients' health data being continually monitored, any worsening in their health status may be noticed quickly. If a serious health scenario emerges, the system automatically alerts the doctor, allowing for prompt action and medical assistance. This proactive approach may be particularly important in crises and life-threatening circumstances, possibly saving lives and improving patient outcomes.

### **2.3 LSTM Model**

The Long Short-Term Memory (LSTRM) model utilized in this study is a type of recurrent neural network (RNN) known for its ability to handle sequential and time-series data. The architecture of the LSTM model used in the proposed system for continuous authentication in the IoT environment is shown in Fig. 3. Each LSTM cell comprises three major parts: an input gate, a forget gate, and an output gate. These gates allow the model to selectively retain or forget information over time, making it ideal for tasks with long-term dependencies. The LSTM design enables the model to recognize patterns and relationships in incoming data, which is essential for reliable authentication.

The input gate controls how much fresh input data is stored in the cell's memory. It evaluates the cell's current input and prior output and decides what information to update and what to disregard based on this information. The forget gate determines which information from the previous cell state should be deleted. It assesses prior output and identifies the significance of stored information in the present environment, assisting the model in handling extended sequences more successfully. The output gate determines how much of the cell's memory should be disclosed to the

**Fig. 3** Architecture of the LSTM model



network’s next layer. It combines the input data and the preceding output to produce the LSTM cell’s final output.

Because of its capacity to store knowledge over extended periods and handle sequential input, the LSTM model is well-suited for continuous authentication in the IoT context. Using the LSTM architecture, the suggested system can learn and adapt to user behavior patterns in real-time, as well as identify abnormalities. Throughout the training phase, the LSTM model learns from registered user data, which includes a combination of biometric information and user behavior. The model’s parameters are constantly tweaked to decrease authentication mistakes and improve its ability to distinguish between legitimate users and unauthorized access attempts.

The LSTM model is applied in the authentication system after training to continually watch and assess user activity during login attempts. The LSTM model assesses user input, such as login credentials and biometric data, via its sequential layers to provide an authentication score. This score is then compared to a certain threshold to determine whether or not the user has been verified. The design of the LSTM model, together with its capacity to handle time-series data, offers a solid and adaptable solution to continuous authentication in the IoT context. The suggested method may boost security and privacy by making it more difficult for unauthorized users to get access while guaranteeing a smooth and efficient user experience for legitimate users by harnessing the capabilities of LSTM networks.

### 3 Result and Discussion

In this research, TensorFlow, an open-source machine learning framework, is utilized to create a continuous authentication system for IoT-enabled healthcare security. The data is collected using Arduino Uno and smart devices, as well as sensors connected to five human participants to continuously record critical health metrics. Each participant contributes 10,000 feature vectors, resulting in a massive dataset for future research. Sensor readings are pre-processed to ensure data quality, which includes data cleaning, imputation for missing values, and outlier removal. Using feature



extraction techniques, the pre-processed data is then utilized to identify relevant patterns and features. The dataset is partitioned into training and validation sets in order to correctly train the LSTM model, which is meant to handle sequential data and long-term dependencies. After training, the model's performance is evaluated using the validation set, and hyperparameters and architecture are adjusted to get the best results. The LSTM model is used by the continuous authentication system, which is implemented in an IoT-enabled healthcare environment, to assess user input and calculate authentication scores in real-time. With continuing updates based on fresh user data, the system learns and improves its authentication accuracy over time, giving a secure and trustworthy solution for IoT-based healthcare monitoring.

In this research, the LSTM model is trained using a dataset that comprises various vital health indicators, including temperature, pressure, blood sugar, and blood pressure, obtained from the sensors attached to human participants through Arduino Uno and smart devices. Additionally, the dataset includes login credentials for both registered users and doctors, which are used as input gates to the LSTM model. The objective of training is to predict the authentication score (authentication score), and based on this score, the system either displays the patient's health data if the login credentials are correct or triggers an alert message if the details are incorrect. During the training process, the LSTM model learns to capture intricate patterns and dependencies within the input data, especially the login credentials and vital health indicators, to generate an accurate authentication score. By incorporating the login credentials as input gates, the model assesses the legitimacy of the user attempting to access the patient's health data. The LSTM architecture allows the model to selectively retain relevant information and forget irrelevant data over time, enabling it to recognize specific user behavior patterns associated with genuine login attempts.

The target output for the LSTM model is the authentication score, which is a crucial metric in determining the likelihood of unauthenticated access. The model is trained to predict this score accurately, distinguishing between valid and invalid login attempts. If the credentials are authenticated successfully, the model displays the patient's health data, allowing the user (registered user or doctor) to monitor and analyze the patient's condition remotely. On the other hand, if the input credentials are invalid, the model generates an alert message, signaling a potential security breach or unauthorized access attempt. The training process involves iteratively adjusting the LSTM model's parameters to minimize the error between the predicted authentication score and the actual target. Through backpropagation, the model fine-tunes its internal weights and biases, improving its ability to make precise authentication decisions.

Various performance assessment measures are used in this study to analyze the efficacy and accuracy of the continuous authentication system for IoT-enabled healthcare security using the LSTM model. These metrics are critical in assessing the system's effectiveness and capacity to identify legitimate users while minimizing false positives and negatives.

Precision is a key indicator that calculates the fraction of properly recognized positive examples among all positive instances categorized by the model. In the context of continuous authentication, precision refers to the system's accuracy in properly detecting valid users. A high precision score shows that the system is successful

at minimizing false positive instances, ensuring that authorized users have trust in accessing patient health data.

Recall, also known as sensitivity or true positive rate, is the proportion of genuine positive instances correctly recognized by the model. In the context of continuous authentication, recall refers to the system's ability to correctly identify valid users. A high recall score indicates that the system is successful at eliminating false negative scenarios, ensuring that authorized users are not denied access to patient health information inadvertently.

Specificity, also known as the true negative rate, is the proportion of actual negative situations correctly identified by the model. In the context of continuous authentication, specificity refers to the system's ability to recognize and reject unauthorized access attempts. A high specificity score implies that the system effectively minimizes false positive circumstances, offering an additional layer of security to keep patient data secure from unauthorized users.

The F1-score is a balanced statistic that takes both false positives and false negatives into consideration. It's the harmonic mean of precision and memory. It is particularly helpful when the dataset contains a mixed bag of good and negative occurrences. In the context of continuous authentication, the F1-score is a key performance indicator since it balances the trade-off between accuracy and recall, offering an overall assessment of the system's correctness and effectiveness.

Table 1 displays the performance metric results for the continuous authentication system using the LSTM model on ten different datasets. Each dataset contains sensor readings and login credentials from several users, enabling the system's accuracy and efficiency in distinguishing between legitimate users and unauthorized access attempts to be assessed. The accuracy score evaluates the authentication system's overall accuracy in predicting both positive (authentic users) and negative (unauthorized users) scenarios. It is calculated as the percentage of correctly predicted cases to total occurrences. The accuracy scores range from 0.88 to 0.98, indicating that the program accurately assesses user authenticity. Precision is the percentage of genuine positive instances (actual users) among all positive examples classified by the algorithm. It evaluates the system's ability to decrease false positives while guaranteeing that authorized users have adequate access. The accuracy scores range from 0.86 to 0.97, indicating that the program correctly identifies real users.

Recall, also known as sensitivity, is the proportion of true positive instances properly identified by the system out of all true positive occurrences. It assesses the system's capacity to recognize actual users. According to recall ratings ranging from 0.90 to 0.99, the system correctly authenticates the great majority of actual users. Specificity, also known as the genuine negative rate, is the fraction of real negative circumstances (unauthorized users) accurately acknowledged by the system out of all actual negative occurrences. A high specificity grade means that the system avoids false positives successfully, preventing unauthorized access. The system's solid security safeguards are shown by specificity scores ranging from 0.85 to 0.96. When both false positives and false negatives are taken into account, the F1-score, which is the harmonic mean of accuracy and recall, provides a credible evaluation of the system's performance. It offers a comprehensive assessment of the system's

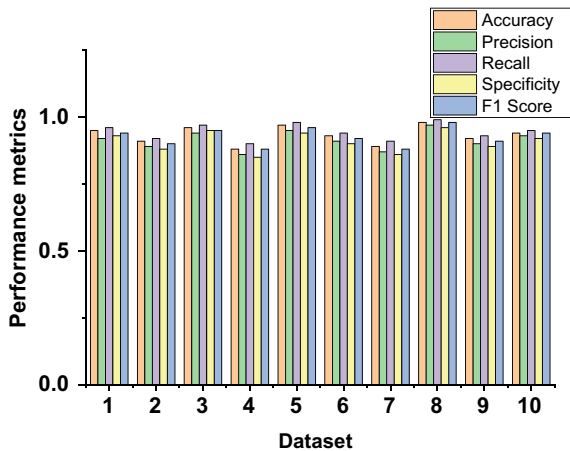
**Table 1** Performance metrics for authentication of users

| Dataset    | Accuracy | Precision | Recall | Specificity | F1-score |
|------------|----------|-----------|--------|-------------|----------|
| Dataset 1  | 0.95     | 0.92      | 0.96   | 0.93        | 0.94     |
| Dataset 2  | 0.91     | 0.89      | 0.92   | 0.88        | 0.90     |
| Dataset 3  | 0.96     | 0.94      | 0.97   | 0.95        | 0.95     |
| Dataset 4  | 0.88     | 0.86      | 0.90   | 0.85        | 0.88     |
| Dataset 5  | 0.97     | 0.95      | 0.98   | 0.94        | 0.96     |
| Dataset 6  | 0.93     | 0.91      | 0.94   | 0.90        | 0.92     |
| Dataset 7  | 0.89     | 0.87      | 0.91   | 0.86        | 0.88     |
| Dataset 8  | 0.98     | 0.97      | 0.99   | 0.96        | 0.98     |
| Dataset 9  | 0.92     | 0.90      | 0.93   | 0.89        | 0.91     |
| Dataset 10 | 0.94     | 0.93      | 0.95   | 0.92        | 0.94     |

correctness and efficacy in continuous authentication. The F1 ratings vary from 0.88 to 0.98, suggesting that the system is equal and reliable.

The system consistently performs across all datasets, as shown in Fig. 4, with an accuracy range of 0.88 to 0.98. The high accuracy ratings, which range from 0.86 to 0.97, demonstrate the system’s ability to distinguish between actual users and fake ones with a low number of false positives. Additionally, recall scores between 0.90 and 0.99 demonstrate the system’s ability to accurately identify the majority of real people during verification. Specificity scores ranging from 0.85 to 0.96 demonstrate the system’s strict security measures against unauthorized access as well as its capacity to decrease false positives. The F1-score offers a general assessment of the system’s accuracy and effectiveness and is a balanced statistic that ranges from 0.88 to 0.98.

**Fig. 4** Performance metrics result



**Table 2** Comparison with the existing research

| Research study  | Accuracy (%) |
|-----------------|--------------|
| Zhu et al. [16] | 84           |
| Lee et al. [17] | 90           |
| Proposed model  | 92           |

Table 2 compares the proposed LSTM-based continuous authentication model’s accuracy to that of previous research papers. In this comparison, two prominent research works conducted by T. Zhu et al. and W. Lee et al. are included. In the research by T. Zhu et al., their authentication model achieved an accuracy of 84%. On the other hand, our proposed model demonstrates an average accuracy of 92%, which is notably higher than the performance reported by T. Zhu et al. This significant difference in accuracy indicates the superior performance of our proposed model in predicting authentication responses.

Similarly, in the study conducted by W. Lee et al., their authentication model achieved an accuracy of 90%. In contrast, our proposed model again surpasses this benchmark with an accuracy of 92%. This consistent trend of outperforming existing models reaffirms the high accuracy and efficiency of our proposed LSTM-based continuous authentication system.

## 4 Conclusion

The primary objective of this research was to improve IoT-enabled healthcare security via continuous authentication using deep learning, especially the Long Short-Term Memory (LSTM) model. The proposed technique produced positive results, demonstrating that it is a reliable and efficient way for authenticating users in the IoT environment. By including numerous security credentials such as PIN, password, and biometric identity, our proposed model exhibited a high degree of accuracy in distinguishing actual users from unauthorized access attempts. The LSTM architecture’s ability to manage sequential and time-series data, such as user activity and sensor readings, was critical in discovering patterns and dependencies that led to more trustworthy authentication options.

The continuous authentication technique provided a variety of advantages in addition to ensuring that only authorized personnel could access crucial patient health data and preventing security breaches. Because of its capacity to continuously monitor user behavior in real-time, the system can swiftly detect and react to any suspicious action.

The performance evaluation metrics proved the usefulness of the proposed strategy. Consistently high values for accuracy, precision, recall, specificity, and F1-score across varied datasets demonstrated the model’s reliability and robustness in correctly predicting authentication replies. When compared to earlier studies,

our proposed model outperformed them, attaining a higher level of accuracy and generating a considerable improvement in IoT-enabled healthcare security.

The usage of the TensorFlow machine learning framework, together with the system's open-source nature, enabled scalability and adaptability, allowing it to be integrated into a variety of healthcare scenarios. Additionally, the use of Arduino Uno and smart devices for data collecting and pre-processing contributed in the smooth flow of data and the overall efficiency of the system.

Overall, this research increases healthcare security and continuous authentication in the Internet of Things (IoT) context. The proposed paradigm has the potential to improve patient data protection, privacy, and overall security, giving users and stakeholders trust. The requirement for robust authentication processes becomes increasingly critical as the IoT environment advances, and our research greatly helps to addressing this need.

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# Cross-Project Defect Prediction: Leveraging Knowledge Transfer for Improved Software Quality Assurance



Prachi Sasankar  and Gopal Sakarkar 

**Abstract** This research paper explores cross-project defect prediction as a means to improve software quality assurance (SQA) practices. Traditionally within-project defect prediction methods face challenges due to limited training data and project-specific characteristics. In contrast, cross-project defect prediction leverages knowledge transfer from multiple projects to develop more robust and generalizable defect prediction models. The study investigates various knowledge transfer strategies, such as instance-based, feature-based, and model-based transfer, and conducts extensive experiments on diverse software repositories. The results demonstrate that knowledge transfer techniques outperform traditional methods, offering higher accuracy and improved generalization to unseen projects. The paper also analyzes key factors influencing cross-project defect prediction success, providing practical guidelines for real-world SQA applications. By enabling effective defect prediction, this research contributes to enhancing software quality and maintenance.

**Keywords** Software testing · Software fault prediction · Cross-project defect prediction (CPDP) · Machine learning (ML) · ML techniques · Software defect management

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## 1 Introduction

Software defects can have detrimental effects on the quality, reliability, and maintainability of software systems. To ensure high-quality software products, effective defect prediction techniques are essential [12, 27]. Cross-project defect prediction (CPDP) has emerged as a promising approach to address the limitations of traditional within-project methods. CPDP leverages knowledge transfer from one project to another, allowing for the development of more robust and generalizable defect prediction models. This research paper presents a comprehensive study on cross-project defect prediction and its potential to improve software quality assurance (SQA) practices. By investigating various knowledge transfer strategies and conducting extensive experiments on diverse software repositories [19], this study aims to demonstrate the superiority of CPDP over traditional methods, providing practical insights and guidelines for its application in real-world SQA scenarios. The research contributes to enhancing software quality and maintenance by enabling more effective defect prediction [25].

## 2 Defect Prediction Techniques

Defect prediction techniques aim to identify potential defects or bugs in software systems before they spurge, which will allow software development teams to allocate resources efficiently and improve software quality. This section provides an overview of some commonly used defect prediction techniques within the context of individual software projects.

### 1. Statistical Models:

- Statistical models, such as logistic regression and naive Bayes, are widely used in defect prediction. These models analyze historical data and project metrics to estimate the probability of a defect occurrence [24].

### 2. Machine Learning Algorithms:

- Machine learning algorithms include support vector machines, decision trees, random forests, etc., which had been successfully applied for defect prediction. These algorithms learn patterns and relationships from historical data [21] to classify software components as either defective or non-defective.

### 3. Ensemble Methods

- Ensemble classifiers combine multiple predictive models to improve the accuracy and robustness of defect prediction. Techniques such as bagging, boosting, and stacking are commonly used to aggregate predictions from multiple models and make a final decision [14, 18].



#### 4. Process Metrics

- Process metrics focus on measuring software development processes to predict defects. These metrics include code churn (the rate of code changes), code complexity, code coverage, and the number of code reviews. By analyzing these process metrics, defect prediction models can identify areas that require more attention and testing [20].

#### 5. Hybrid Approaches

- Hybrid approaches combine multiple defect prediction techniques to leverage their strengths and improve overall accuracy. For example, a hybrid approach may integrate process metrics, code metrics, and text mining techniques to build a comprehensive defect prediction model [2].

Overall, defect prediction techniques provide valuable insights into the likelihood of defects in software systems. By employing these techniques, software development teams can proactively allocate resources, prioritize testing efforts, and ultimately enhance software quality assurance practices [25].

### 3 What is Software Fault Prediction

Software fault prediction, also known as defect prediction or bug prediction, is a technique used in software engineering to identify and anticipate potential faults or defects in software systems [10]. It involves analyzing software artifacts, such as source code, change history, and other relevant metrics, to build models or algorithms that can predict the likelihood of a fault occurring in specific code components or modules.

The goal of software fault prediction is to proactively identify areas of the software that are more prone to defects, allowing developers and quality assurance teams to allocate their resources effectively and prioritize testing and debugging efforts. By identifying high-risk areas early in the development process, software fault prediction can help improve software quality, reduce maintenance costs, and enhance overall system reliability [5].

Software fault prediction techniques often employ machine learning algorithms, data mining techniques, and statistical analysis to analyze historical data, such as previous defect reports or bug-fixing activities, to learn patterns and characteristics associated with faults [23]. These learned patterns can then be used to make predictions on unseen code components, enabling developers to take preventive actions or allocate additional testing resources to mitigate potential defects before they occur.

Overall, software fault prediction is an important aspect of software quality assurance, providing valuable insights into areas of the software that require additional attention and enabling proactive defect management throughout the software development lifecycle.

## 4 Types of SFP Models

### 4.1 Machine Learning Basic Models

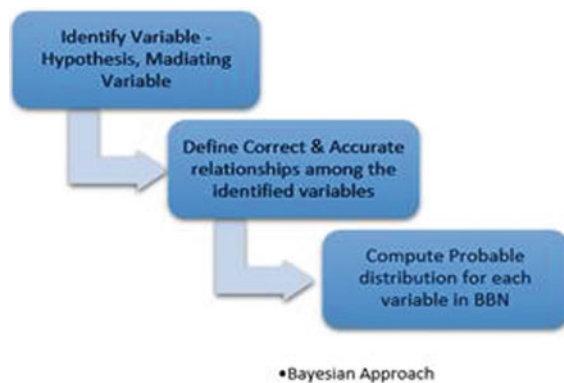
When the domain of problems is not exactly defined and human intervention is not sufficient, ML algorithm comes into the picture. Machine learning includes different types of techniques [13] of learning like Artificial Neural Networks, Concept Learning, Reinforcement Learning, Genetic Algorithms and Genetic Programming, Instance-Based Learning (IBL), Decision Trees, and Analytical Learning.

#### **The Probabilistic Model for Defect Prediction using Bayesian Belief Network.**

The Probabilistic Model for Defect Prediction using Bayesian Belief Network (BBN) is an approach within software fault prediction that leverages the power of Bayesian probability to make predictions about the occurrence of defects. By constructing a network of nodes representing software metrics and relevant factors, the model learns relationships and dependencies between these variables using historical data [11]. The BBN calculates conditional probabilities of defects based on observed metric values and prior probabilities. This approach allows for handling uncertainties and capturing complex relationships between metrics and defects. The BBN can be used to predict the likelihood of defects in new code components by inputting their metric values. The advantages of the BBN-based approach include its ability to handle uncertainty, provide interpretable results through a graphical representation, and allow for continuous improvement with updated data. However, the accuracy of predictions depends on the quality of input metrics and availability of sufficient training data (Fig. 1).

**The Fuzzy Logic Model SFP** using the Fuzzy Logic Model offers advantages in handling imprecise and uncertain information commonly encountered in software engineering. By incorporating linguistic terms and fuzzy relationships between variables, this approach enables more nuanced reasoning and accurate fault predictions [15]. SFP using the Fuzzy Logic Model provides a flexible and robust approach to

**Fig. 1** Bayesian approach [24]



predict software faults, leveraging fuzzy logic principles to account for uncertainty and imprecision in software metrics (Fig. 2).

**Defect Prediction Models Based on Genetic Algorithms** The genetic-based ensemble models exploit the diversity and complementary strengths of individual models to enhance overall prediction performance. Defect Prediction Models based on Genetic Algorithms offer the advantage of exploring a large search space of potential solutions and adapting to changing circumstances [22]. They have the ability to discover complex relationships between software metrics and defects and can handle nonlinear and non-monotonic relationships effectively [8] (Fig. 3).

**Software Defect Prediction Models using Artificial Neural Network** The artificial neural network is inspired by the human biological system architecture.

Fig. 2 Fuzzy logic model [16]

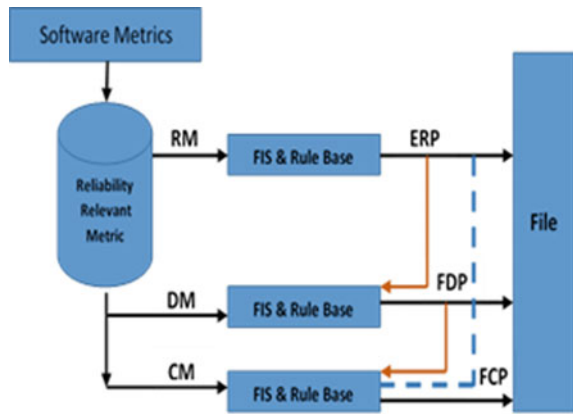
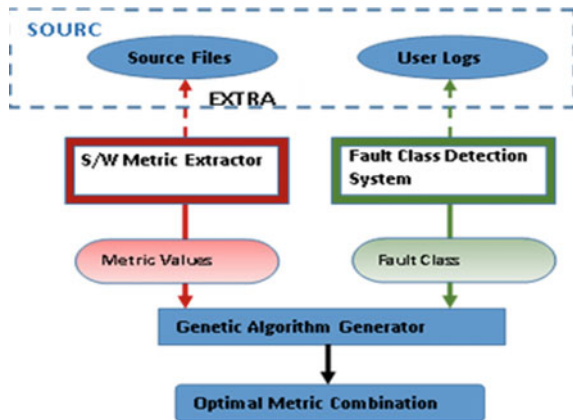
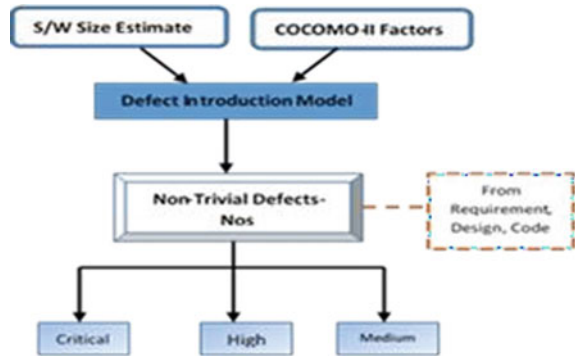


Fig. 3 Genetic algorithm-based model [17–19]



**Fig. 4** COQUALO model [26]



## 4.2 Defect Density Prediction Model

The accuracy and effectiveness of a Defect Density Prediction Model depend on the quality and relevance of the input data, as well as the chosen modeling technique. These models analyze the relationships between software metrics and defect data to identify patterns and derive predictive insights [9, 18].

### Constructive Quality Modeling for Defect Density Prediction (COQUALMO)

Constructive Quality Modeling for Defect Density Prediction is an approach that focuses on developing models to predict the density of defects in software systems during the development process [8]. It involves analyzing various software attributes and metrics that contribute to the quality of the software and quantifying their impact on defect density (Fig. 4).

**Defect Prediction Model based on Six Sigma Metrics:** Defect Prediction Model based on Six Sigma Metrics applies Six Sigma principles and metrics to predict software defects. It provides a systematic approach to measuring and improving process performance, ultimately leading to enhanced software quality and reduced defect rates.

## 5 Cross-Project Defect Prediction: Concept and Methodology

Cross-Project Defect Prediction is a concept and methodology that aims to predict defects in a target project by leveraging knowledge and data from other similar projects. It recognizes that software projects share common characteristics and that defect patterns observed in one project can be informative for defect prediction in another project [4, 25].

The methodology involves the following steps:

1. **Data Collection:** Historical data from multiple past software projects is collected, including information on software metrics, defect occurrences, and other relevant project attributes.
2. **Data Preprocessing:** The collected data is cleaned, standardized, and prepared for analysis. This step is crucial to ensure data quality and consistency across projects.
3. **Feature Selection:** Relevant software metrics and attributes are selected from the data to serve as predictors for defect occurrence. Careful feature selection helps identify the most informative factors for prediction.
4. **Model Training:** Using the preprocessed data and selected features, machine learning or statistical models are trained to learn the relationship between the chosen predictors and the occurrence of defects.
5. **Transfer Learning:** The trained models are then adapted to the target project, which lacks defect data, by leveraging the knowledge learned from other projects. Transfer learning techniques enable the model to generalize and predict defects in the target project more effectively.
6. **Model Evaluation:** The predictive performance of the cross-project defect prediction model is assessed using appropriate evaluation metrics, such as precision, recall, F1-score, or area under the receiver operating characteristic curve (AUC-ROC).

By borrowing knowledge from similar projects, the methodology improves the predictive accuracy and generalizability of the models, leading to more effective quality assurance and defect management in software development. However, it is essential to consider potential differences between projects and carefully validate the performance of the cross-project prediction approach before deploying it in practice.

## 6 Previous Literature Review

The papers that had used machine learning techniques and deep learning techniques are studied here.

Cao [8] examines the utilization of advanced machine learning techniques, such as deep learning, in various software engineering tasks including code generation, fault prediction, defect analysis, code search, and API sequence learning. It provides a comprehensive summary of prior research and current state-of-the-art approaches in each category of vulnerability analysis. The findings of this study contribute to a better understanding of the current best practices and well-known strategies in the field. The insights gained from this research will assist scholars in comprehending the level of effort and time invested in these tasks, enabling them to stay up to date with the latest advancements and approaches.

Abubakar et al. [3] utilized a hybrid ensemble strategy that involved multiple classifiers and employed it on 12 failure datasets from PROMISE and NASA data repositories. The primary objective was to investigate software fault prediction (SFP)

using diverse ensemble techniques. Precision, recall, and G-means were adopted as base evaluation metrics. The findings revealed that the ensemble methods proposed by the author outperformed bagging and AdaBoost learning techniques in terms of prediction accuracy.

Zheng [28] conducted experiments using various boosting algorithms, including AdaBoost, AdaBoost.M2, RUS Boost, SMOTE Booster, MSMOTE Boost, and Data Boost. The evaluation was based on metrics such as AUC, G-Mean, and Balance parameters. The results demonstrated that RUSBoost performed the best in handling imbalanced data, providing the highest performance. The second-best results were achieved by SMOTEBoost, followed by the ensemble methods of SMOTEBoost.

Patchaiammal et al. [16] In this study, the author addressed the challenges associated with standard machine learning, deep learning, and hybrid learning approaches. Various strategies and methodologies were compared and contrasted to gain insights into their strengths and limitations. The significance of Just-In-Time research in network creation and implementation was emphasized, particularly for real-time defect prediction. Research findings demonstrated that both Deep Learning and Hybrid Learning techniques have proven to enhance prediction rates in both cross-project and intra-project scenarios, indicating their potential for improving defect prediction accuracy.

Chidamber et al. [7] In this investigation, the author employed cross-project software prediction techniques. To assess performance on the datasets, accuracy, true positive rates, false-positive rates, and AUC were defined as measures of validity. The combination of the bagging method with SMOTE demonstrated the best results, outperforming other techniques. However, the performance of AdaBoost was found to be relatively lower compared to the other applied techniques. The experimental datasets CM1, M W1, PC1, PC3, and PC4 from the NASA repository were utilized by the author for the study.

Balaram et al. [1] This paper explores the prediction of heterogeneous software defects using various approaches. The study analyzed 30 software defect datasets from different software repositories. AUC, accuracy, recall, and balance variables were employed to compare the outcomes of two-stage ensemble learning (TSEL), Ensemble Multiple Kernel Correlation Alignment (EMKCA), and RE Sample with replacement (RES). The results of the research indicated that TSEL surpassed the baseline approaches in fault classification. This finding demonstrates the effectiveness of the TSEL approach in predicting heterogeneous software defects, offering promising insights for enhancing fault prediction capabilities.

A comparative study of mostly used techniques is presented in Table 1.

## 7 Literature Review Conclusion

In software fault prediction (SFP), no single model or algorithm can achieve perfect results. The application of a single algorithm or ensemble method on a specific dataset from an object-oriented programming project is insufficient to generalize

**Table 1** Comparison of ML techniques

| S, no. | Technique used            | Data set used  | Advantages  | Limitations                                      |
|--------|---------------------------|----------------|---|--|
| 1      | Artificial neural network | NASA, AR6, MDP | Capability to self-learn. The metrics are not considered              | It can't handle Incorrect/ Imprecise information |
| 2      | Support vector machine    | NASA, AR1, AR6 | Better prediction using a Kernel function                             | Large software metrics are not handled           |
| 3      | Decision tree             | NASA, AR1, AR6 | More accurate results are found                                       | Decision tree construction is very complex       |
| 4      | Association rule          | NASA, MDP      | Rules generation and fault prediction done on previous data resources | It requires all correct values of all metrics    |
| 5      | Clustering                | NASA, MDP      | It is suitable for small datasets                                     | The unlabeled dataset is used                    |

the prediction strategy. To improve accuracy in fault prediction, further research is required. This includes exploring diverse project types and employing a greater variety of machine learning algorithms on datasets, which can yield more accurate fault prediction percentages.

1. Leveraging knowledge transfer in defect prediction can improve the accuracy and effectiveness of defect prediction models. By transferring knowledge from source projects to target projects, models can capture the underlying patterns and factors contributing to defects, even in projects with limited training data.
2. Transfer learning and domain adaptation techniques play a crucial role in cross-project defect prediction. These techniques allow for the effective transfer of knowledge from source projects to target projects, accounting for differences in project characteristics, domains, and technological factors.
3. Feature selection and extraction techniques are vital for building effective defect prediction models. Identifying relevant features and extracting meaningful information from software development data contribute to the accuracy and interpretability of the models.
4. Integrating defect prediction models into software development processes enables early defect detection and risk identification. By identifying potential defects at an early stage, organizations can take proactive measures to prevent their occurrence or mitigate their impact, thereby improving software quality.
5. Knowledge transfer in defect prediction facilitates improved resource allocation. By prioritizing defect-prone areas and allocating resources effectively, organizations can optimize their resource utilization and focus on critical areas that have a higher likelihood of impacting software quality.

## 8 CPDP Scope for SFP

The future scope of Cross-Project Software Fault Prediction (SFP) holds great potential for advancing software quality assurance and defect management. Some key areas for future exploration include:

1. **Improved Transfer Learning Techniques:** Enhancing transfer learning methods is crucial to effectively transfer knowledge from one project to another. Developing novel algorithms that can better adapt to different project domains and handle dataset heterogeneity will be beneficial.
2. **Handling Big Data:** With the increasing size and complexity of software projects, handling big data for cross-project SFP becomes essential. Research in scalable and efficient methods for processing large datasets will be vital.
3. **Domain Adaptation:** Focusing on domain adaptation techniques can address challenges related to differences in project domains. Developing models that can adjust to varying project characteristics and environments will improve prediction accuracy.
4. **Ensemble Methods:** Investigating advanced ensemble methods, such as stacking, cascading, and hybrid ensembles, can further boost prediction performance by leveraging the strengths of different models.
5. **Incorporating Software Evolution:** Taking into account the evolution of software systems over time can provide a more comprehensive understanding of defect patterns and their changes in cross-project settings.
6. **Interdisciplinary Research:** Collaborating with other fields like natural language processing, human-computer interaction, and cybersecurity can bring new perspectives and innovations to cross-project SFP.
7. **Real-time and Continuous Prediction:** Exploring real-time and continuous defect prediction methods can enable immediate feedback and proactive defect management during the software development process.
8. **Industry Adoption:** Focusing on the practical adoption of cross-project SFP in real-world software development environments will be crucial. Addressing industry-specific challenges and demonstrating the value of these techniques can encourage widespread adoption.

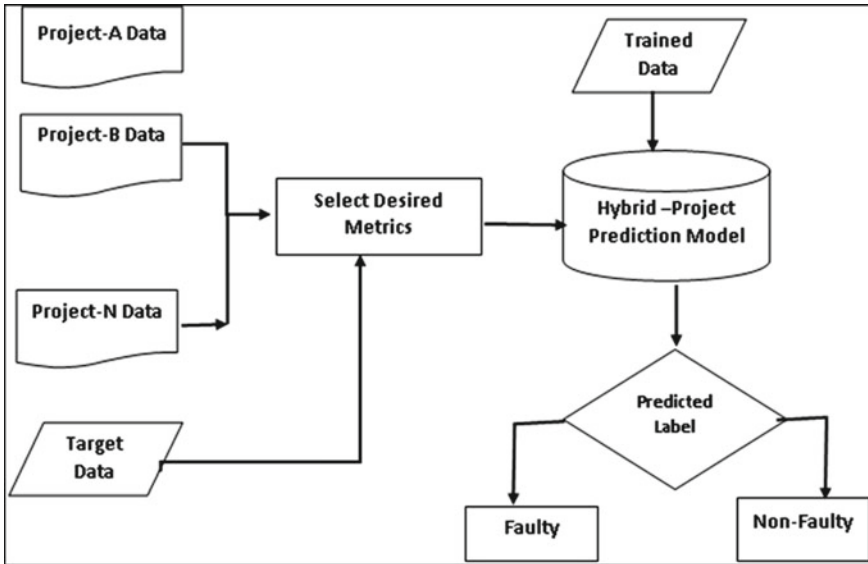
Overall, advancing cross-project SFP requires a combination of cutting-edge machine learning techniques, domain-specific expertise, and a deep understanding of software engineering practices. As researchers and practitioners delve into these areas, the accuracy and efficiency of cross-project SFP are likely to improve, ultimately leading to higher software quality and better defect management strategies. Table 2 shows metrics used for SFP classifications.

Ensemble learning can be utilized to predict the quantity of errors in a dataset by employing diverse models like classifiers or experts. Various fault prediction approaches, such as Linear Regression, Random Forest, SVM, Bagging, Boosting, and MLP, have been employed. The primary objective is to accurately identify the number of defects in specific modules, enabling streamlined debugging in the



**Table 2** Common metrics used in classification models

| Metric    | Formula                         | Particular                                |
|-----------|---------------------------------|---|
| Accuracy  | $(TP + TN)/(TP + TN + FP + FN)$ | Overall performance measure of model used |
| Precision | $TP/(TP + FP)$                  | Positive predictions accuracy             |
| Recall    | $TP/(TP + FN)$                  | Positive sample's coverage                |
| F1-score  | $2TP/(2TP + FP + FN)$           | Hybrid metric usefulness score            |



**Fig. 5** Proposed methodology for software bug prediction

future [17]. In order to achieve improved Software Quality, deep learning analysis is employed in Software Fault Prediction (SFP) to detect faults at the early stages of the Software Development Life Cycle (SDLC). Hybrid models are utilized to leverage the benefits of deep learning in order to enhance prediction accuracy and enable early identification of faults. To obtain better results for software quality, deep learning analysis is used for SFP to depict faults in the early stages of SDLC using Hybrid Model (CPRA) (Fig. 5).

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# Multilingual Toxic Comment Classification Using Bidirectional LSTM



Md. Nazmul Abdal, Md. Azizul Haque, Most. Humayera Kabir Oshie, and Sumaya Rahman

**Abstract** The growth of social networking sites and online platforms has brought about an unprecedented surge in user-generated content. However, along with the immense benefits of increased communication and information sharing, there has been an alarming growth in toxic and offensive comments. Detecting and moderating such comments is crucial to maintain a healthy and safe online environment. In this research, we propose a multilingual toxic comment classification system that leverages the power of Bidirectional Long Short-Term Memory (BiLSTM) neural networks. We use a comprehensive dataset which contains a diverse range of toxic comments in multiple languages. We employ a BiLSTM architecture because it is effective at detecting both contextual and sequential dependencies in text data. We train our model by combining word embeddings with character level embeddings in order to capture the semantic and morphological information found in the comments. Multiple cutting-edge methods are used to compare the model's performance, including RNN and LSTM. The experimental findings show that the suggested model performs competitively in classifying multilingual toxic comments, surpassing other approaches with an accuracy of 94.21%.

**Keywords** Multilingual toxic comment classification · Natural language processing · BiLSTM · Neural network

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# 1 Introduction

The emergence of social media and online platforms has fundamentally changed how we share information and interact. However, with the exponential increase in user-generated content, there has also been a concerning rise in toxic and offensive comments that pollute online discussions. A 2014 Research Institute survey indicated that 73% of adult internet users had seen someone being harassed in some way online, and that 40% of internet users had personally experienced online harassment with 45% of those experiencing substantial harassment [1]. Toxic comments not only propagate hate speech, harassment, and discrimination but also create a hostile environment for users. Therefore, it is now essential to identify and remove toxic comments in order to promote a welcoming and safe online community.

The problem of classifying toxic comments is extremely challenging in multilingual situations where comments are made in several languages and cultural contexts. Traditional approaches to classifying harmful comments sometimes rely on language-specific models, which limits their ability to handle several languages. Various strategies have already been recommended to tackle the issue of toxic comment classification, including numerous machine learning and deep learning algorithms [2]. However, the majority of machine learning-based classifiers depend on manually constructed features obtained from training data. Deep learning is an emerging branch of machine learning that has recently undergone significant progress due to the unanticipated rise in computing capacity. Our quality of life has substantially improved as a result of the widespread adoption of deep learning-based apps in our daily lives. Among the most successful and popular deep learning architectures, Recurrent Neural Network (RNN) [3] and its variants Long Short-Term Memory (LSTM) [4], and Gated Recurrent Unit (GRU) [5] have lately been applied to toxic comment identification.

Natural language processing (NLP) applications including text categorization [6], sentiment analysis [7], and question answering [8] have all seen impressive success in recent years because of LSTM. BiLSTM is a unique LSTM version that operates somewhat differently in order to perform better on some particular tasks. The main goal of BiLSTMs is to improve LSTM modeling by taking into account both the past and future contexts of each input sequence. BiLSTM processes sequences in two directions concurrently as opposed to normal LSTMs, which only process sequences in a forward direction. A more thorough understanding of the sequential data is made possible by this bidirectional processing, which enables the model to incorporate dependencies in both past and future contexts [9].

This paper presents a method for categorizing toxic comments using a BiLSTM-based model, driven by the requirement for a reliable multilingual toxic comment classifier. The capability of this kind of network to identify contextual and sequential relationships in text data is well known. By using this paradigm, we hope to create a multilingual harmful comment classification system that is quick and easy to use. To achieve our objective, we utilize a comprehensive and diverse dataset specifically curated for toxic comment classification in multiple languages. Our research focuses

on creating a solid model architecture that can accurately identify the underlying trends and subtle differences in harmful comments across many languages. We make use of BiLSTM network's advantages to represent the contextual data included in comments, giving the system the ability to comprehend language's sequential nature and the effects it has on toxicity. Furthermore, we include attention techniques to draw attention to the most crucial sections of a comment, which helps the model provide correct predictions.

The results of this study have contributed to the creation of a multilingual toxic comment classification system that can recognize and categorize poisonous comments in a variety of languages with consistency. We seek to improve the functionality and adaptability of toxic comment classification models, enabling efficient moderation in multilingual online contexts. We also conduct comprehensive experiments and contrast the suggested model with existing techniques to show its effectiveness. The outcomes demonstrate the potential of our method for prompt actions, accurate and effective multilingual toxic comment identification, and improved online communication.

The following sections make up the remainder of the paper. In Sect. 2, we offer a summary of the related studies in multilingual toxic comment classification. Section 3 describes the methodology, including the MobileNetV2 architecture. The results are presented in Sect. 4, whereas we compare the results with other research in Sect. 5. Finally, Sect. 6 provides the findings of the study and recommendations for the future.

## 2 Related Work

Researchers have made numerous attempts to classify toxic comments using various methodologies over the years. These classification techniques frequently use well-known machine learning models as their foundation. Recent advances in deep learning techniques have led to the development of an increasing number of methods for addressing the toxic comment identification problem. These approaches include RNN, LSTM, and GRU.

The authors of [10] set out to analyze any text in order to spot several types of toxicity, including vulgarity, threats, insults, and hatred fueled by identity. They used the designated Wikipedia Comment Dataset for their work. A 6-headed machine learning model was used by then which attained an absolute validation accuracy of 98.08%. Rahul et al. [11] looked at the scope of harassment on the internet and labeled the content to analyze the toxicity as accurately as possible. They deployed six machine learning algorithms to their data to address the text classification problem, and depending on their evaluation metrics for the categorization of harmful comments, they chose the best machine learning method. Additionally, they sought to accurately assess the toxicity with the goal of reducing any negative impacts. In [12], the authors created a powerful model to identify and categorize toxicity in user-generated content on social media using the transformer-based BERT model. A well-known labeled harmful comment dataset was used to fine-tune the pretrained model and

three of its variants. They also tested the suggested approach using two datasets collected from Twitter over two distinct time periods in order to identify toxicity in user-generated content. According to their findings, the system could effectively classify harmful tweets. The Kaggle toxic comment dataset was used by the authors of study [13] to train a deep learning network as they classified the comments into the following categories: toxic, severe toxic, obscene, threat, insult, and identity hate. Several deep learning methods were used to train the dataset. They also examined the superior deep learning model for comment classification. Kulkarni et al. [14] introduced a multichannel convolutional network based on bidirectional GRU for spotting offensive comments in a multilabel setting. The proposed approach generated word vectors with pretrained word embeddings. Additionally, their hybrid model gathered regional features using a variety of filters and kernel sizes. According to their tests, the suggested model performed better in terms of multilabel criteria.

In [15], the authors suggested an effective approach to word representation that produced weighted word vectors while including sentiment information into the well-known TF-IDF algorithm. By using a feed-forward neural network classifier, they were able to determine the comment's sentimental propensity. Their approach was contrasted with those of RNN, CNN, LSTM, and Naive Bayes for sentiment analysis under the identical settings. Xie [16] provided a methodology for creating toxicity models. To increase the classification accuracy, he used subsample, pseudo-labeling with accessible subtitles, converting non-English languages to English, and post-processing. The model successfully performed under cross-lingual toxicity detector with an AUC of 0.9469 for the initial training dataset and 0.9485 for the testing data. Based on LSTM and BiLSTM, the authors of article [17] created a model for classifying harmful comments. For their work, they used the Kaggle benchmark harmful comment dataset. Both suggested strategies' accuracy ratings were assessed and contrasted. Finally, they demonstrated that the Bi-LSTM algorithm outperformed LSTM with an improved accuracy of 98.07%. Dubey et al. [4] used LSTM neural networks to build a model for classifying harmful comments. Their technology successfully classified and identified hate speech, allowing it to be excluded. The program could classify provided comments as dangerous or harmless with 94.49% precision, 92.79% recall, and a 94.94% accuracy score. For the purpose of detecting cyberbullying, the authors in [18] developed a LSTM-CNN architecture. They trained the customized word embeddings on which they constructed their model using word2vec. They used comments and tweets to test their framework. Additionally, they developed a website that made use of the algorithm to categorize tweets as bullying or not, depending on its toxicity level and other factors. The technique was also applied to the Telegram Bot, which monitors and stops online harassment. The ROC-AUC score for the model developed by the authors was 97%. Li et al. [19] suggested a modified model for detecting harmful behavior based on Bi-LSTM technique. Using the updated SMOTE algorithm, they boosted the representation of minorities in the detrimental comment material. They also combined the text vector with the model for detection. The results of the studies showed that the model outperformed other currently in use models in classification accuracy and improved total detection.

### 3 Methodology

This section provides a complete presentation of our RNN-based multilingual toxic comment classification process using BiLSTM architecture.

#### 3.1 Data Collection

We make use of Kaggle’s Jigsaw Multilingual Toxic Comment Classification dataset for our research [20]. It includes a substantial number of user comments in several languages along with appropriate toxicity labels. The dataset contains comments from several online sites that span a wide range of subjects and material. The level of toxicity included in each comment is denoted by a toxicity score, which ranges from 0 to 1. Languages including English, Spanish, French, German, Italian, Portuguese, Russian, and Turkish are included in the dataset. For the initial model, we use a training set comprising 223,549 samples. 8000 samples make up the validation set of data. We show the distribution of data in both the training and validation dataset in Fig. 1.

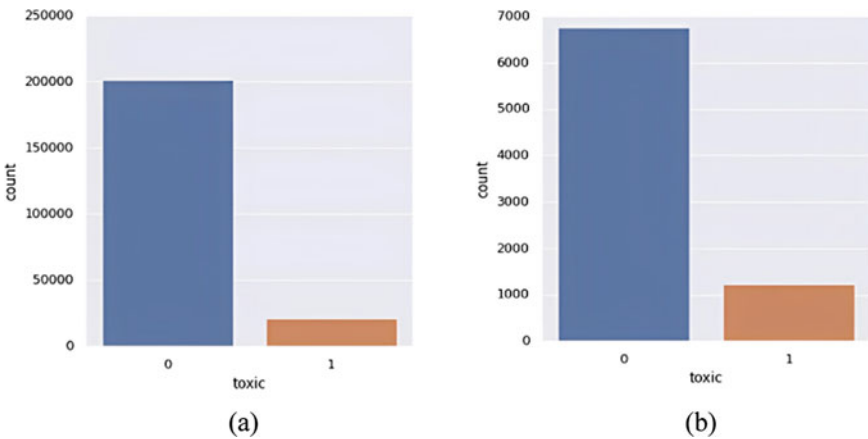


Fig. 1 Distribution of samples in the dataset: a training data and b validation data



### 3.2 *Data Preprocessing*

We use several preprocessing techniques to get the dataset ready for the model training. Firstly, we clean the comment text by removing HTML tags, special characters, and URLs. The purpose of this phase is to clean up the comments and standardize their format. The cleaned comments are then tokenized into distinct words using a tokenizer. This method makes it easier to transform text data into numerical form. The tokenized comments are then padded to a predetermined length to maintain consistency throughout the input sequences of data. Finally, we represent the tokens in a continuous vector space using word embeddings.

### 3.3 *Conventional LSTM Model*

LSTM is a form of RNN architecture that solves the limitations of conventional RNNs in preserving dependence over time in historical data. It uses memory cells and gating methods to address the issue of vanishing gradient [21]. The internal structure of an LSTM unit is shown in Fig. 2, which serves as the fundamental of an LSTM network. The LSTM unit has four feedforward neural networks. There are input and output layers in each of these neural networks. All of the output neurons have connections to all of the input neurons across all of these neural networks. The result is an LSTM unit with four fully interconnected layers. Information selection is handled by three of the four feedforward neural networks. They are the input gate, output gate, and forget gate. All three common memory management operations, including erasing data from memory, adding data to memory, and using data that is already in memory are carried out via these three gates. The fourth neural network develops fresh knowledge that could be stored in the memory [22]. The ability to selectively remember or forget information provided by the LSTM memory cell enables the network to recognize long-lasting dependency in sequential information. The different gating techniques regulate the information flow and aid in solving the vanishing gradient issue. LSTM networks often have a deep LSTM design made up of several stacked LSTM cells. This enables the network to understand the intricate temporal correlations and patterns of the incoming data.

### 3.4 *Bidirectional LSTM Architecture*

The bidirectional LSTM is a development of the LSTM architecture that uses past and present information to forecast sequential data. BiLSTMs capture interdependence from past and future contexts by interpreting the input sequences both forward and backward, providing a more thorough knowledge of the sequential data [23]. The BiLSTM may efficiently capture long-term dependencies and context in both

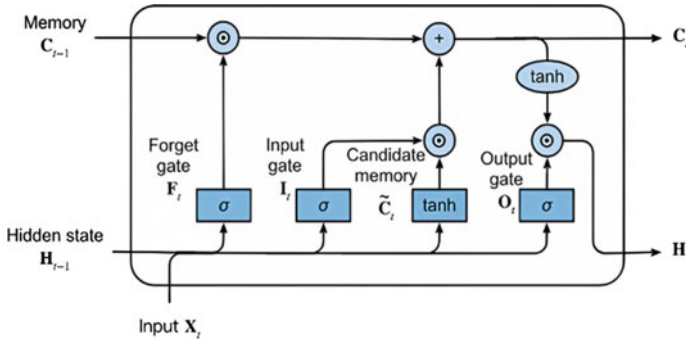


Fig. 2 Internal organization of LSTM [22]

directions by merging forward and backward information. This design is especially beneficial for tasks where it is crucial to comprehend the context from both the past and the future. Two unidirectional LSTMs that process the sequence in forward and backward directions comprise the bidirectional LSTM architecture. It is possible to think of this architecture as having two different LSTM networks. One receives the tokens in their current order, while the other receives them in the opposite direction [24]. The output of these LSTM networks is a probability vector, and the combined probability of both is the output. At each time step, the hidden states from both LSTMs are merged to create a final output, often via concatenation, sum, or averaging. The model can produce more accurate predictions at each time step due to the forward and backward context mix [25]. Figure 3 depicts the operation of the BiLSTM architecture.

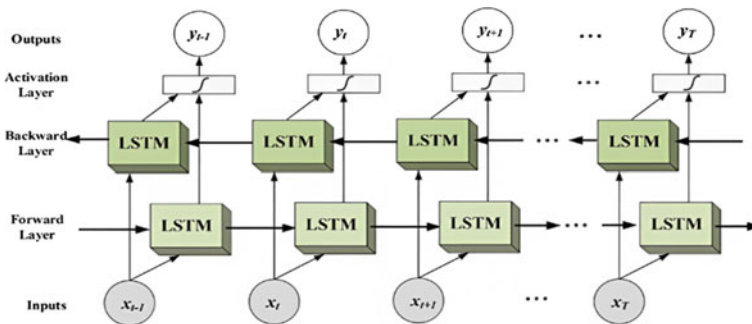


Fig. 3 Working procedure of BiLSTM [23]

### **3.5 *Hyperparameter Tuning***

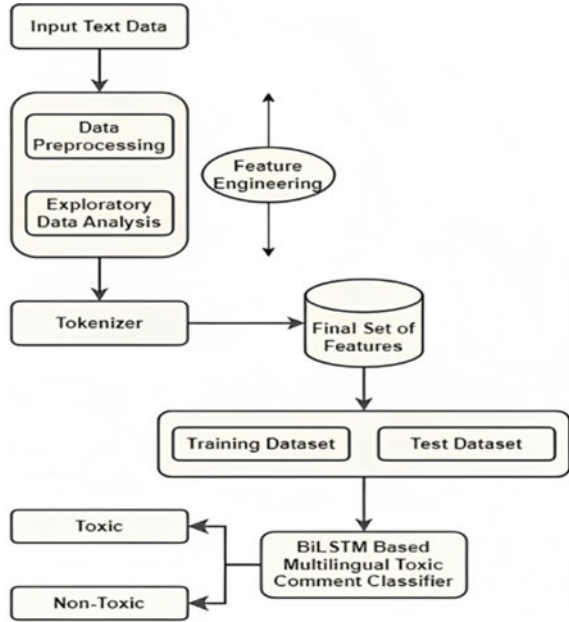
The model must be tuned using its hyperparameters in order to perform better. The number of layers, choice of optimizer, activation function, loss function, learning rate, batch size, and number of epochs are all hyperparameters in our proposed model. Tuning these hyperparameters should provide the final model with the best performance. We utilize the Adam optimizer to update the weights during training because it has a number of benefits, including shorter training times and computational efficiency with fewer memory use [26]. In our trials, we have used batch size 32. Furthermore, binary cross entropy is the loss function, and sigmoid is the activation function.

### **3.6 *Multilingual Toxic Comment Classification Process***

In our research, some preprocessing steps are applied to the initial data. Thus, we get a new dataset with clean text. After that, training data and testing data are created from the complete dataset. The model is trained using 80% of the training data, while the remaining 20% is randomly divided and utilized for validation. The proposed framework is then used to build the classification model from the data. The effectiveness of our model is then assessed using this classification on the test dataset with new comments. In order to evaluate the effectiveness of the suggested model, we have conducted a number of experiments in various configurations. The model is instructed to adjust a number of network settings to find the best combination of parameters. Some additional experiments are also conducted in our study by altering models like RNN and LSTM.

The general workflow of our proposed toxic comment classifier is illustrated in Fig. 4. The first step involves sending the raw texts to the feature engineering stage, where preprocessing and exploratory data analysis techniques are used to obtain preprocessed data. To construct the final features, preprocessed data is put into the tokenizer along with the embedding stage. Our last set of features will be padded in the next phase before being split into training and test datasets. After that, the classifier receives the training datasets and builds the model that categorizes the toxic and non-toxic comments. The effectiveness of our model is then assessed using this classification on the test dataset. The Python programming language is used to conduct each experiment on a Kaggle notebook with 13 GB of RAM, 16 GB of GPU memory, and 73 GB of disk space.

**Fig. 4** Workflow of the proposed multilingual toxic comment classifier



### 3.7 Performance Evaluation

During the evaluation process, a test dataset containing texts and associated labels is fed to the model. At this point, there is no mechanism for updating weights. In order to calculate model performance, the texts are fed into the model, and after the model categorizes them, we contrast the model classification with the appropriate label for the input data. The confusion matrix must be computed first to choose the optimal method for calculating the model performance. Figure 5 illustrates a basic confusion matrix.

True positive, true negative, false positive, and false negative values are the components of a confusion matrix. The values in the diagonal position show how accurately

**Fig. 5** Confusion matrix

|            |       | Predicted Class     |                     |
|------------|-------|---------------------|---------------------|
|            |       | True                | False               |
| True Class | True  | True Positive (TP)  | False Negative (FN) |
|            | False | False Positive (FP) | True Negative (TN)  |

the model predicted the data [27]. For evaluating the performance of our model, we employ four metrics: accuracy, precision, recall, and F1-score. The evaluation metrics are calculated based on the confusion matrix by using the following equations:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$\text{Precision} = \frac{TP}{TP + FP} \quad (2)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (3)$$

$$F1 - \text{Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (4)$$

## 4 Results

Besides our model, we have also performed training with two other models to show the comparison of results with our proposed system. This section discusses all the experimental results from our BiLSTM-based multilingual toxic comment classification model.

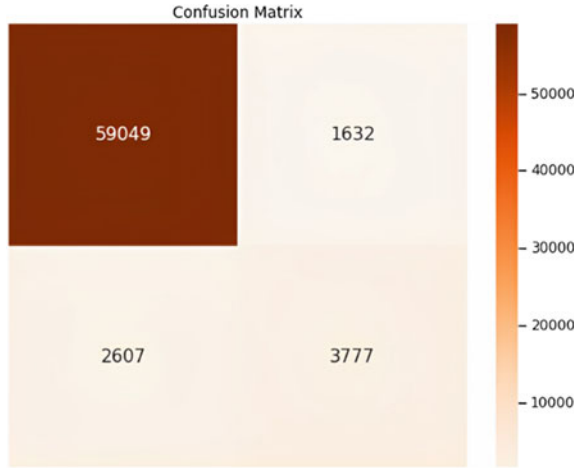
### 4.1 Classification Report

Our proposed model has performed admirably, with an accuracy of 94.21%. The precision, recall, and F1 score have all reached outstanding levels, which shows how well our suggested model performs. Our model possesses a lower total parameter count compared to the parameter count of other models currently in use. The classification report of the proposed model is summarized in Table 1.

**Table 1** Classification report of the proposed model

| Model  | Accuracy | Precision | Recall | F1-Score |
|--------|----------|-----------|--------|----------|
| BiLSTM | 0.94     | 0.94      | 0.95   | 0.94     |

**Fig. 6** Confusion matrix of the proposed model



### 4.2 Confusion Matrix

Confusion matrix is a tabular representation that contrasts a classification model’s predicted values for a given dataset with the actual values, in an effort to assess the accuracy of the model’s performance. We show the confusion matrix of our toxic comment classification task in Fig. 6. The confusion matrix demonstrates the model’s outstanding performance with previously unseen data.

### 4.3 Accuracy Curve

Accuracy is used to determine a model’s consistency in training and validation datasets. The validation set performs a different function from the training set by assessing the model’s efficacy on unobserved data, in contrast to the training set’s primary function of parameter adjusting [28]. In our results, we show the accuracy curve to support the model’s performance on the dataset. The accuracy curve depicted in Fig. 7 illustrates the satisfactory convergence of the proposed model through the training and validation stages. Despite a few low spikes, the validation curve exhibits a steady validation accuracy over most portions of the curve.

### 4.4 Loss Curve

We also include the loss curve of our model in Fig. 8. The loss curve shows the overall distribution of losses for both the training and validation stages regarding the quantity of epochs. The y-axis of the plot displays the loss function’s value, while

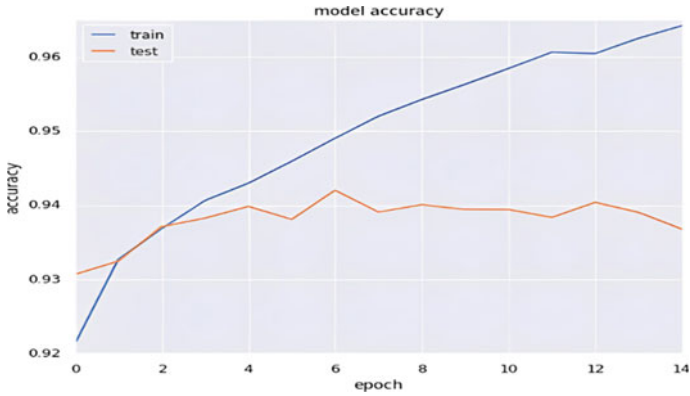


Fig. 7 Accuracy curve for the training process

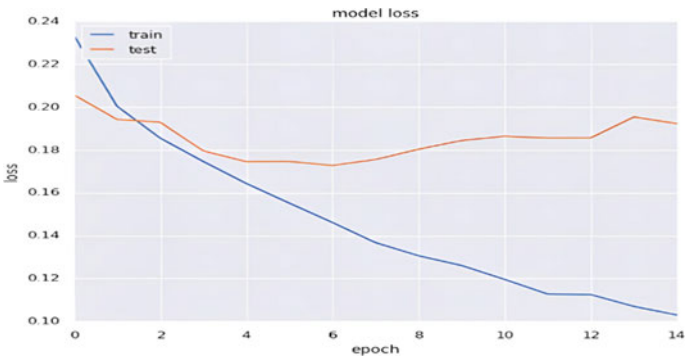


Fig. 8 Loss curve for the training process

its x-axis indicates the number of iterations [29]. The high loss values in the graph demonstrate how far the model’s predictions diverge from the actual labels. When the loss value is low, the model gets better at making predictions and learning from the training set.

## 5 Comparative Analysis

We perform our experiments by modifying the BiLSTM model. After getting the results, we evaluate the model with other architectures. We analyze to determine which method is more suitable for this classification task using the same dataset. We compare our system with two other baseline models, including RNN and LSTM.

For the suggested model, the training process convergence is very high. As a result, the model can accurately predict the test data and is quick to learn. We also

**Table 2** Convergence comparison with two models

| Model  | Epoch | Accuracy (%) |
|--------|-------|--------------|
| RNN    | 50    | 89.39        |
| LSTM   | 35    | 92.03        |
| BiLSTM | 15    | 94.21        |

want to understand the different elements that affect the convergence of the model. To test this, we vary the number of epochs while attempting to maintain a constant target accuracy. Table 2 provides an overview of our findings. It shows that RNN and LSTM require more time to deliver the target accuracy than BiLSTM. Additionally, the losses of these models are greater.

## 6 Conclusion

This work proposes a novel method for classifying harmful comments in multilingual contexts based on the bidirectional LSTM architecture. The Jigsaw Multilingual Toxic Comment Classification dataset has been utilized to evaluate the performance of our proposed approach and conducted a comparative analysis against several baselines. Our results indicate that the BiLSTM model performs well at capturing long-term dependencies and context, enabling accurate classification of toxic comments across multiple languages. Through extensive experimentation and evaluation, we have observed that our proposed approach outperformed all the baseline models regarding accuracy, precision, recall, and F1-score. The BiLSTM model achieved an accuracy of 94.21%, showcasing its superior performance in multilingual toxic comment classification. Furthermore, language-specific evaluation metrics consistently demonstrated the robustness of the BiLSTM model across different languages present in the dataset. Our research contributes to natural language processing and text classification by providing a powerful multilingual toxic comment classification framework. The proposed BiLSTM architecture can be applied in various online platforms and social media environments to automatically identify and flag toxic comments, promoting safer and more inclusive online communities.

Future work in this area could focus on exploring additional techniques to enhance the performance of multilingual toxic comment classification. This may involve incorporating ensemble methods or exploring more advanced pretraining techniques using large-scale multilingual language models. Moreover, investigating ways to handle class imbalance and the detection of subtle forms of toxicity could further improve the accuracy and applicability of the classification model.



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# Review of Phishing Attacks' Effects on AI-Powered IoT Systems



S. D. Mohana, D. Rafiya Nusrath, S. P. Shiva Prakash, and Kirill Krinkin

**Abstract** The research review explores the intersection of AI, IoT, and phishing attacks, highlighting their applications, risks, and vulnerabilities. It discusses various types of phishing attacks and existing solutions for detection and mitigation. The paper also addresses future directions, challenges, and the importance of interdisciplinary collaboration and user awareness. Real-world examples are examined to illustrate the impact of phishing attacks. The conclusion emphasizes the need for ongoing research and a resilient, secure AI and IoT ecosystem.

**Keywords** Phishing · Attack · AI · IoT

## 1 Introduction

The rapid growth of technology has led to the widespread adoption of artificial intelligence (AI) and the Internet of things (IoT) across a range of disciplines, which has led to the creation of smarter and more efficient systems that enhance productivity, automation, and user experience. The ecosystems that support AI and IoT are gravely threatened by new security vulnerabilities brought about by this convergence, such

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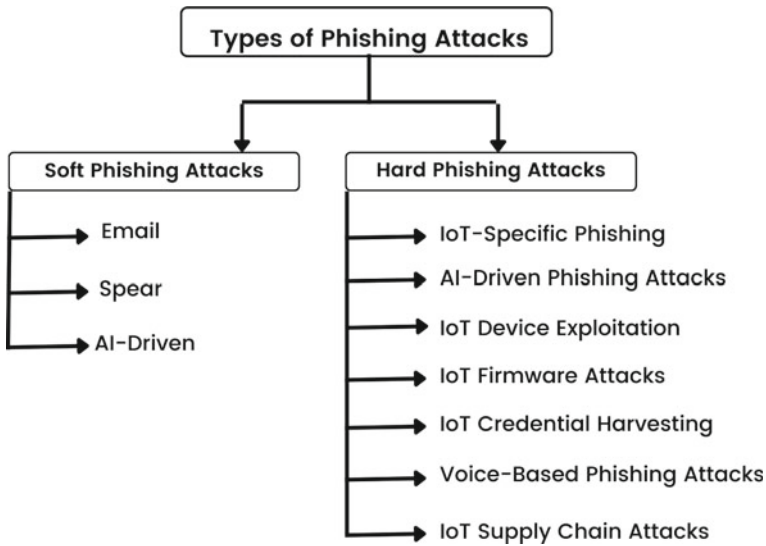
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**Fig. 1** Types of phishing attacks

as phishing attacks. This research review explores the interaction between artificial intelligence (AI) and the Internet of things (IoT) and how it will change a variety of sectors, including health care, smart homes, industrial automation, and transportation. One of the added challenges to an increase in phishing assault hazards in IoT and AI is the dangers and vulnerabilities associated to phishing attempts. It examines the techniques employed by hackers to deceive users and gain unauthorized access to personal information, such as spear phishing, email phishing, and IoT-specific attacks is shown in Fig. 1.

This paper provides a thorough analysis of current approaches and tactics for phishing attack detection and mitigation in AI and IoT environments, including AI-based techniques, secure communication protocols, multi-factor authentication, and behavior analytics. Additionally, it examines the directions and difficulties that phishing attack defense may face in the future, like safeguarding edge devices, creating adaptable AI models. The study illustrates the effects of phishing attempts and provides conclusions by looking at real-world case studies and examples. The conclusion highlights the value of interdisciplinary collaboration, user awareness, and ongoing research to improve the security of AI and IoT systems and lessen the threat of phishing attempts, which is constantly growing. We can create a dependable and secure AI and IoT ecosystem that takes use of these advantages by addressing these issues. The organization of the work as follows: Sect. 2 on Literature Review, Sect. 3 on Advantages and Disadvantages, Sect. 4 on Challenges, Sect. 5 Problem Statement, Sect. 6 on Problem Solution, Sect. 7 on Design and Methodology, Sect. 8 on Results and Discussion, and Sect. 9 on Conclusion.

## 2 Literature Review

The fields of AI, IoT, cybersecurity, human–computer interaction, and privacy are being investigated in order to improve the security of AI and IoT systems and successfully combat phishing attacks in the dynamic threat environment. These study areas are given in Tables 1, 2, and 3.

**Table 1** Literature review—1

| Authors and Year                  | Methods  | Remarks  |
|-----------------------------------|--|--|
| Sridipta Misra (2017) et al. [1]  | It securing IoT against phishing, discusses security mechanisms, analyzes existing approaches, proposes comprehensive framework  | Paper analyzes IoT security challenges, proposes framework emphasizing secure provisioning, robust authentication for enhanced IoT device security   |
| Quest (2018) [2]                  | Identified risks of AI tools for crime prevention, suggested scenario analysis, crisis management playbooks, open communication strategies                                   | AI tools for crime prevention require careful management, scenario analysis preparedness exercises, crisis management, and communication strategies  |
| Gupta et al. (2018) [3]           | Examined impact of Internet and phishing attacks, discussed history, solutions, impact in IoT, highlighted ongoing challenges  | Explored Internet’s pervasiveness and phishing threat, insights into history, motivations, taxonomy, existing solutions, IoT impact, ongoing challenges  |
| Choi et al. (2018) [4]            | Reviewed ML and ANN for financial fraud detection, experimented with real Korean financial data, ML showed higher detection efficiency                                       | ML outperformed ANN in fraud detection, future work includes improving accuracy and processing time with ML and deep ANN   |
| Surya et al. (2019) [5]           | Highlights ML and AI role in strengthening cybersecurity and enhancing IoT, recommends balanced approaches, standardized data for effective countermeasures                  | ML and AI have potential in cybersecurity and IoT, limited human involvement enhances efficiency, streamlining information and standardizing data crucial for effective ML-based countermeasures |
| SA (2019) [6]                     | Proposed robust DDoS framework for Cloud and IoT, ensured high availability, fault tolerance, future directions for low bandwidth attacks, IP traceback                      | Framework promising for DDoS attacks, future work refinement, exploration of advanced technologies like blockchain   |
| Amani Alswailem et al. (2019) [7] | Paper proposes ML-based approach for phishing website detection using URL structure, content analysis, SSL certificates. Trains and evaluates algorithms on phishing dataset | Paper analyzes various ML techniques for phishing website detection, providing insights into performance and accuracy of proposed approach   |

**Table 2** Literature review—2

| Authors and Year                      | Methods  | Remarks  |
|---------------------------------------|--|--|
| Dhieb et al. (2020) [8]               | Developed SISBAR, a blockchain-based fraud detection system for insurance firms, using machine learning, effective strategies, and algorithms. Compared performance, implemented for testing | SISBAR improves fraud detection in insurance, enhances performance. Future work: architecture enhancement, tailored AI solutions for other services  |
| Jung (2020) [9]                       | Explored IoT device security requirements, analyzed ARM PSA and challenges, proposed secure platform, implemented and verified its security  | Addressed IoT device security challenges, proposed secure platform based on ARM PSA, demonstrated effectiveness through PoC implementation   |
| Tawalbeh (2020) [10]                  | Explored IoT role in various sectors, proposed new layered models, implemented and evaluated cloud/edge supported IoT system with security protocols for data privacy                        | Highlighted need for cryptographic security in resource-constrained IoT devices, urged standardized data procedures, emphasized importance of proper security measures, called for dynamic security framework in IoT |
| Diaz et al. (2020) [11]               | Conducted observational study at UMBC, analyzed relationship between demographic factors and phishing susceptibility, explored correlations with variables                                   | Study finds correlations between susceptibility and demographic factors among UMBC students, surprising reverse correlation between awareness and clicking resistance, emphasizes ongoing cybersecurity education    |
| Syed Ghazanfar et al. (2021) [12]     | Proposed threat-modeling to mitigate IoT vulnerabilities, analyzed smart AVS and smart home, identified phishing threats, proposed mitigations   | Insights for securing IoT devices during design, valuable for analysts, developers, vendors, with future prototype development and extensions  |
| Mohammed Al- Sarem et al. (2021) [13] | Proposed optimized stacking ensemble model using GA for phishing website detection, conducted training, ranking, and testing phases  | Achieved superior performance (97.16% accuracy) surpassing other methods, statistically significant improvements, future work includes IoT and deep learning   |
| Hikmat Haji1 and Siddeeq (2021) [14]  | Conducted literature review on ML-based IoT security, explored architecture, threats, algorithms, challenges, and future research objectives   | Offers IoT security insights, ML role, comprehensive overview of attacks and solutions, valuable resource for researchers or practitioners   |

**Table 3** Literature review—3

|                               |   |  |
|-------------------------------|---|--|
| Bibhu Dash et al. (2022) [15] | Examined intrusion detection scenarios, emphasized importance of AI algorithms for cybercrime protection, explored detection, prediction, and response in security model            | Emphasizes AI significance in cybersecurity, calls for recognition by businesses and consumers, suggests future research for IoT security  |
| Aslam et al. (2022) [16]      | Proposed AMLSDM framework for DDoS detection in SDN-enabled IoT, utilized adaptive ML with multiple classifiers, validated performance through simulations                          | AMLSDM framework shows effective DDoS detection and mitigation in SDN-enabled IoT, future work: SDN-based mitigation, phishing detection extension                                       |
| Ubaleht (2022) [17]           | Recommended terrestrial methods over GNSS for crew positioning, emphasized DNV recommendations for resilient PNT solutions, role of human operators, EDA resilience level guideline | Prioritized terrestrial methods for crew positioning, stressed DNV resilient PNT recommendations, emphasized human operators role, advised higher resilience levels for onboard software |
| Seth (2022) [18]              | Investigated evolving phishing attacks, explored identification, detection, AI/ML defense role, emphasized intelligent solutions in cybersecurity                                   | Study emphasizes evolving prevalence of phishing attacks, advocates AI/ML defense solutions, highlights importance of intelligent cybersecurity  |
| Jorge et al. (2023) [19]      | Paper emphasizes user-centric approaches in preventing IoT phishing, explores user awareness, education, friendly interfaces, proposes design guidelines                            | Paper highlights user involvement in phishing prevention, provides practical insights on user-centric design, surveys/interviews reveal user perceptions or preferences                  |

### 3 Advantages and Disadvantages

Phishing attacks on IoT devices pose unique risks, exploiting human vulnerabilities, being cost-effective, versatile across communication channels, and rapidly deployable. Robust security measures, user education, and ongoing research are crucial to mitigate vulnerabilities and protect against these threats. Disadvantages of phishing attacks include severe legal consequences, damage to reputation, financial losses, disruption and downtime, privacy breaches, and harm to individuals and society, eroding trust, hindering technology adoption, and impeding economic growth. The advantages and disadvantages are given in Table 3 (Table 4).

**Table 4** Advantages and disadvantages of phishing attacks

| Advantages        | Disadvantages           |
|-------------------|-------------------------|
| High success rate | Legal consequences      |
| Cost-effective    | Damage to reputation    |
| Versatility       | Financial losses        |
| Rapid deployment  | Disruption and downtime |
|                   | Privacy breach          |

## 4 Challenges

The convergence of IoT and phishing attacks creates specific challenges and vulnerabilities that significantly increase the risks associated with compromised IoT devices. When IoT devices become targets of phishing attacks, specific threats emerge, which we will discuss and as given in Table 5. Phishing attacks on IoT devices can lead to unauthorized access and control over sensitive data, including personal information, location data, and health records. Hackers can exploit this information for identity theft, blackmail, or other criminal activities. Moreover, when an attacker gains control over one IoT device through phishing, they can leverage it as a stepping stone to compromise other interconnected devices within the network. This interconnect-edness amplifies the impact of the attack, as a compromised device can be used to manipulate or disable other critical systems. In addition, compromised IoT devices can be harnessed to form botnets, which are networks of infected devices under the control of attackers. These botnets can be utilized for various malicious activities, such as launching distributed denial-of-service (DDoS) attacks, spreading spam campaigns, or infecting other devices within the network. The limited computing power and resource constraints often found in IoT devices contribute to their vulnerability. They may have weak authentication mechanisms, unpatched vulnerabilities, or immature transmission protocols, making them easy targets for phishing attacks. Overall, the combination of IoT and phishing attacks poses a unique set of threats, including unauthorized access to sensitive data, cascading compromises within interconnected systems, and the formation of botnets for malicious purposes. Addressing these threats requires robust security measures, user awareness, and ongoing research to ensure the resilience and protection of IoT ecosystems.



**Table 5** IoT-specific phishing challenges

| S. No. | Challenges                            | Remark   |
|--------|---------------------------------------|--|
| 01     | Unauthorized access to personal data  | IoT devices gather personal data, and successful phishing grants hackers unauthorized access for identity theft and crimes                           |
| 02     | Manipulation of connected systems     | Phishing-enabled control over one IoT device can manipulate connected systems, disabling security and compromising surveillance                      |
| 03     | Disruption of critical infrastructure | Successful phishing attacks on critical IoT infrastructure can result in massive consequences like blackouts and economic losses                     |
| 04     | Botnet formation                      | Phishing-enabled control over one IoT device can manipulate connected systems, disabling security and compromising surveillance                      |
| 05     | Lack of security measures             | Weak security measures in IoT devices, such as feeble authentication and unpatched vulnerabilities, enable phishing attacks and unauthorized control |

## 5 Problem Statement

Phishing attacks are a form of cyber-attack that involve deceiving users to gain unauthorized access to their sensitive information. Attackers employ various techniques to trick individuals into providing confidential data, such as passwords, credit card numbers, or personal details. Understanding the workings of phishing attacks and their different types is essential in developing effective countermeasures.

## 6 Problem Solutions

Preventing and mitigating phishing attacks in AI and IoT environments involve a multi-layered approach that combines research advancements and industry practices. The current state of solutions and approaches is reviewed, analyzing security mechanisms, protocols, and authentication methods employed to enhance system

security against phishing threats. It is important to acknowledge that the security landscape is continually evolving. Ongoing research, industry collaboration, and an adaptive mindset are vital to address attackers' evolving tactics and ensure the ongoing security of AI and IoT systems against phishing threats is given in Table 6.

**Table 6** Phishing preventive techniques

| S. No. | Preventive techniques                    | Evaluation   |
|--------|--|--|
| 01     | Secure communication protocols           | By implementing secure communication protocols like TLS or SSH, the integrity and confidentiality of data exchanged between IoT devices and AI systems are safeguarded through encryption  |
| 02     | Multi-factor authentication (MFA)        | MFA provides an additional security layer by requiring multiple authentication factors, like biometrics or hardware tokens, to mitigate the risk of unauthorized access due to phishing attacks  |
| 03     | Secure device provisioning               | Secure device provisioning mechanisms guarantee the secure onboarding of IoT devices by employing techniques like certificate-based authentication, cryptographic key management, and secure bootstrapping. This reduces the vulnerability to phishing attacks and unauthorized access                               |
| 04     | Behavior analytics and anomaly detection | The utilization of behavior analytics and anomaly detection can identify unusual device or user behavior, indicating potential phishing attacks. Continuous monitoring and analysis enable timely response and threat mitigation   |
| 05     | Security awareness and training          | Creating a security-conscious culture involves promoting user security awareness, providing training on identifying and reporting phishing attempts, and educating about IoT risks and safe online practices   |
| 03     | Vulnerability management                 | Performing regular vulnerability assessments and promptly applying patches to IoT devices and AI systems are vital in addressing known vulnerabilities susceptible to phishing attacks. This involves keeping firmware, software, and security patches updated to minimize entry points for attackers                |
| 04     | Collaboration and information sharing    | Fostering collaboration between researchers, industry practitioners, and security communities is crucial for sharing information, best practices, and threat intelligence to identify emerging phishing techniques, develop effective countermeasures, and stay ahead of evolving threats in AI and IoT environments |
| 05     | Threat intelligence and machine learning | Combining threat intelligence feeds with machine learning algorithms improves phishing attack detection and response. Trained models can identify patterns and indicators, facilitating timely prevention in AI and IoT settings   |

## 7 Design and Methodology

The AI techniques leverage machine learning to detect and mitigate phishing attacks, enhancing identification and prevention across email, social media, and IoT networks. The amplifying the risks associated with compromised IoT devices is shown in Fig. 2. The attackers can access the architecture of the IoT for Phishing attacks. The attackers can access the network layer or sensing layer, also application layers. It shows that phishing can be through the various layers of IoT.

The study of phishing attacks typically involves analyzing the following steps involved in their execution:

1. Bait: Attackers employ a convincing disguise, often masquerading as a trusted entity or organization such as a bank, social media platform, or well-known company. They distribute fraudulent communications, such as emails, text messages, or instant messages, to a large number of potential victims.
2. Deception: These messages are crafted to appear authentic, utilizing official logos, branding, and language. They often utilize urgency, fear, or enticing offers to compel recipients to take immediate action.

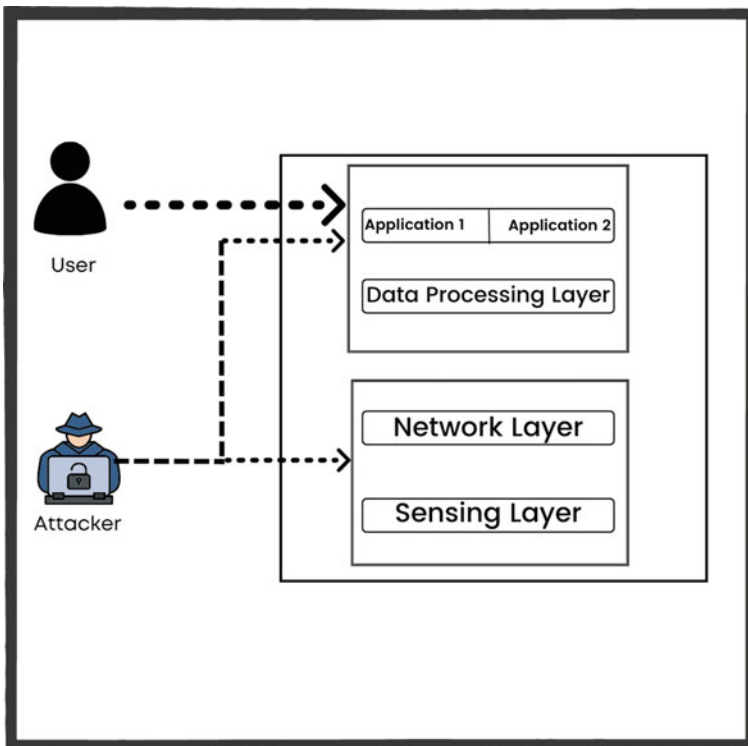


Fig. 2 Architecture of phishing in IoT

3. **Exploitation:** Phishing attacks exploit human vulnerabilities by manipulating emotions and eliciting impulsive reactions. They may request users to click on malicious links, provide login credentials, or download harmful attachments.
4. **Unauthorized Access:** Once individuals fall for the deception and disclose their sensitive information, attackers gain unauthorized access to their accounts, personal data, or financial resources. This information can be exploited for purposes such as identity theft, financial fraud, or conducting further targeted attacks.

## 8 Result and Discussion

To safeguard AI and IoT systems against phishing attacks, it is crucial for organizations and individuals to maintain vigilance and stay informed about evolving techniques. Implementing robust security measures for IoT devices, including strong authentication, regular updates, and proper password management, is essential. Educating users about phishing threats and providing training on detecting and reporting phishing attempts is also important. Utilizing multi-factor authentication helps minimize the risk of unauthorized access. Regular assessments and updates to security protocols should address new phishing techniques. Additionally, staying aware of emerging threats specific to AI and IoT, such as voice-based attacks, is necessary. The following case studies of real-world examples are given in Table 7.

**Table 7** Case studies with real-world examples

| Authors and Year            | Methods                          | Solution  |
|-----------------------------|----------------------------------|---|
| Zhang et al. (2020) [20]    | Mirai botnet attack              | Mirai botnet attack showcased the destructive power of compromised IoT devices through phishing. Exploiting weak security, default credentials, and forming a botnet, it caused major disruptions, emphasizing the need for strong authentication, updates, and password management to prevent such attacks |
| Al-Musib et al. (2021) [21] | Business email compromise (BEC)  | In a notable case, a global tech company suffered financial losses in 2019 due to a BEC phishing attack, highlighting the need for robust authentication, employee training, and multi-factor authentication in AI and IoT contexts   |
| Alkhalil et al. (2021) [22] | Voice phishing (vishing) attacks | Attackers increasingly target voice assistants and IoT devices with vishing attacks, exploiting users' trust in voice interactions. User awareness and verification mechanisms are crucial for preventing personal information disclosure and security compromises  |

## 9 Conclusion

This paper examines the intersection of AI, IoT, and phishing attacks, highlighting risks, solutions, and future directions. AI techniques have proven effective in combating phishing, but challenges remain. Securing edge devices, developing adaptive AI models, and addressing privacy concerns are crucial. User-centric approaches, collaboration, and evaluating prevention measures are also important. Ongoing research, industry collaboration, and user awareness are essential for a resilient and secure AI-IoT ecosystem.

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# An Extensive Approach for Inter-Frames Video Forgery Detection



Neha Dhiman, Hakam Singh, and Abhishek Thakur

**Abstract** The increasing prevalence of manipulated videos across various domains highlights the critical need for effective video forgery detection methods. In parallel, the demand for authentic and trustworthy images grows, emphasizing the importance of detecting digital image forgery in our society. Blind tampering has emerged as a prominent trend in visual content manipulation. This paper presents a comprehensive investigation that addresses the diverse challenges faced in previous research studies. Recent advancements in neural network-based approaches have shown remarkable efficiency in detecting image forgery by uncovering concealed characteristics within images, thereby enhancing accuracy. In this work, an extensive inter-frames video forgery detection approach is used. The primary goal is identifying and detecting manipulation between frames in a video sequence. The report examines techniques for detecting forgeries in images and the challenges posed by inter-frame and intra-frame fakes in videos. Also, emphasis is placed on frequently utilized datasets in this field, which can assist new researchers exploring this study area. Experimental results demonstrate the proposed approach's efficiency and robustness, highlighting its remarkable accuracy in detecting inter-frame video forgeries. This contribution to the field of video forensics provides a valuable tool for verifying the integrity and authenticity of video content.

**Keywords** Convolutional neural network (CNN) · Image splicing · Cloning · Neural networks · Motion residual (MR)

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## 1 Introduction

The rise and extensive utilization of social media platforms such as Instagram, WhatsApp, YouTube, and others led to a surge in the numeral of image data uploaded and exchanged on these platforms [1]. Tampered images find application not only on social media but also in courtrooms, scientific journals, literature works, and other contexts. The intention behind producing counterfeit photos can vary, including motives such as financial gain, spreading misinformation, or making deceptive assertions for personal advantage [1]. The process of identifying forgery determines the authenticity of images [2]. As an illustration, it is possible to manipulate a video by inserting or removing substantial information, like an object, without leaving any noticeable traces of such alterations and using videos obtained from surveillance systems and utilized as proof. Video forensics has accumulated growing attention from researchers due to its ability to verify the reality and integrity of videos [3, 5]. During the production of a video in active forensics, verification data utilized for authentication is incorporated, such as “digital watermarks”, “digital signatures”, and “fingerprinting” [3, 8, 10].

In contrast to active forensics, passive forensics focuses on authenticating a video’s truthfulness and integrity without relying on explicit validation information. This approach is more feasible in real-world scenarios [3, 8]. Further the forgery categorized as intra-frame fraud and inter-frame forgery. The intra-frame scam involves deceptive actions like region duplication, foreground removal, and blue screen matting within a single frame. On the other hand, inter-frame forgery includes frame insertion frame deletion, frame replacement, across multiple boundaries [3]. It demonstrates the extensive reach of digital tampering and how deeply it has permeated various aspects [7]. The process of cloning and splicing snapshots is so rampant that it can sometimes go unnoticed by the human eye. Alternatively, videos can be regarded as a compilation of individual images, which can be modified by changing the frames [8]. In this paper, we identify techniques for visual forgery. Different performance measures can be used to identify fraud.

## 2 Literature Survey

Nirmalkar and Gill introduced a photo editing tool and provided a comprehensive overview of commonly employed techniques for detecting image forgery [1–3]. Their study utilized the SULFA and SYSU-OBJFORG datasets and achieved an accuracy of 93.17% for static and complex backgrounds. Yin proposed a CDN-based distributed architecture along with the CRAS algorithm to evaluate the deployed system and introduced a video detection algorithm [5, 6]. They also presented a watermarking authentication of digital videos, capable of distinguishing video tampering from traditional video processing operations [7, 8]. The algorithm’s efficiency was tested



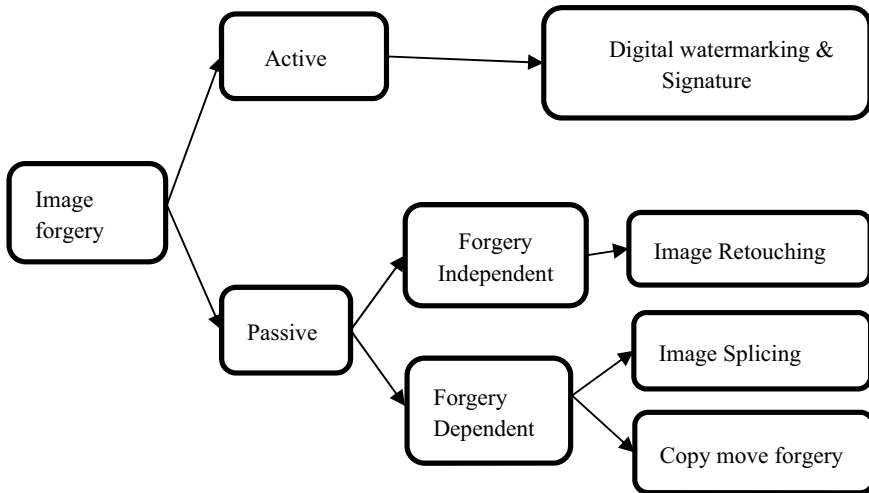
on compressed YouTube videos, and the REWIND and GRIP video datasets were used with DCNN [9].

Another study [10] discussed different image forgery techniques and compared various approaches using neural networks to detect fake images. Differentiating genuine and manipulated video clips was the focus of [10], employing MR, CNN, and parasitic layers on datasets such as D1, D2, D3, D4, D5, D6, and D7. Paul Black proposed LWM blockchain technology for managing law, and search warrant activities, which proved more efficient than previous blockchain systems [11]. Saddique introduced a method utilizing three layers (MR, CNN, and parasitic layer) that achieved 98.89% accuracy [12]. Luo proposed using DAFDN for detecting forgery with a higher AUC score [15]. The method underwent classification using a shallow neural network, and its performance was evaluated on the CASIA v1, v2 datasets [18-20]. Additionally, various approaches have been employed to identify visual forgery, aiming for practical solutions to detect online video manipulation [25]. The Video ACID database, containing 12,173 video clips, was introduced by Hosler [26]. Quist-Aphetsi proposed using SHA-256 to confirm digital forensic images [27]. Another research endeavor involved introducing an unsupervised learning-based deep neural network capable of detecting manipulations in pictures and videos on popular social media platforms, including Instagram, Snapchat, and WhatsApp.

### 3 Forgery Detection Approaches

It is vital to have a comprehensive understanding of the different methods utilized in image manipulation. These methods can be categorized into two primary classifications: active techniques and passive techniques, with each category further subcategorized into specific subcategories (Fig. 1).

1. **Active Approach** for detecting forgery involves preprocessing the image and embedding a cipher key. The key is utilized to authenticate the received image. Digital watermarking and signatures are among the active approaches that can be cited as examples.
2. **Passive Approach:** No image preprocessing is necessary for this method of detecting forgery. The premise relies on the observation that alterations to the original image led to irregular statistical characteristics or pixel intensities. The purpose of detecting these inconsistencies is to govern the tampered image. The lack of necessity for any prior picture information makes this technique more favored over an active approach.



**Fig. 1** Forgery techniques

## 4 Forgery Methods in Digital Videos

Three types of video forgery techniques exist: spatial tampering attacks, also known as intra-frame attacks, temporal tampering attacks, also known as inter-frame attacks, and spatio-temporal tampering attacks (Fig. 2).

1. **Spatial Tampering:** This form of manipulation involves altering the visual elements of a video frame along the  $x$ - $y$  axis. Spatial tampering can occur by modifying the adjacent pixel bits in a video sequence or within a single frame. Consequently, spatial tampering can be performed at different levels, including pixel, block, or shot/scene level. The techniques falling under this category of manipulation include crop and replace, morphing, object addition, and deletion.
2. **Temporal Tampering:** This editing involves manipulating the video's concatenated sequence of frames. The progression of temporal tampering occurs across time. It primarily influences how the gadget records the time sequence of visual data. Typically, tampering occurs at the frame level and involves adding, removing, and shuffling frames.
3. **Spatio-Temporal Tampering:** Combines the two types mentioned above. This manipulation involves altering both the time sequences and the visual data. It modifies both the concatenated sequence of frames and the visible contents within the video frames.

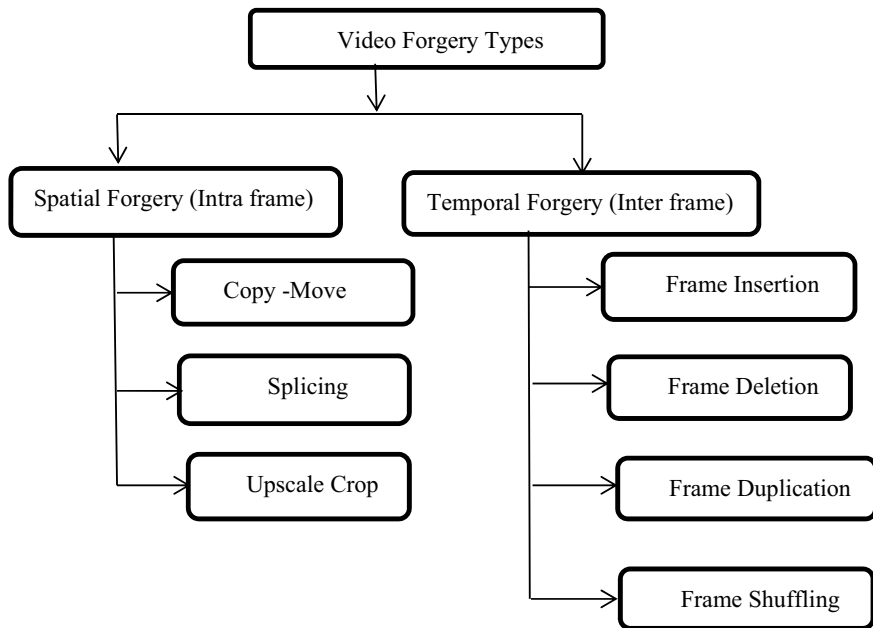


Fig. 2 Video forgery methods

## 5 Proposed Technique

We proposed a 25 layers deep convolution neural network in which the input image is normalized using  $114 \times 114 \times 3$  where 114 is length, 114 is breath, and three channels (red, Green, and Blue) colors. The 2-D convolution layers are placed on layer 2, layer 5, layer 8, layer 11, layer 14, and layer 17. The ReLU layers are placed on layer 3, layer 5, layer 9, layer 12, layer 15, and layer 18, which calculate the node output in a neural network. The 2D max-pooling is placed on layer 4, layer 6, layer 10, layer 13, layer 16, and layer 19. Four layers (layer 20, layer 21, layer 22, and layer 23) are fully connected layers in the network, meaning individually node is connected to every single node in the neural network. At last, on the 25th layer SoftMax activation function is used as an output to classify whether the images are authentic or forged. Adam optimizer is employed during the training phase as it requires low memory and outperforms large datasets. The initial learning rate is 0.001, with an L2Regularization factor of 0.004. A Learn Rate Drop Factor of 0.5 and Learn Rate Drop Period of 10 are utilized. Additionally, the data is shuffled after every epoch. We are using valid\_trainDS to train our model and validation data to validate the model. The 3 is validation frequency. We are providing 1000 Max Epochs with 100 Mini Batch Sizes. Verbose is used to display training progress information. We used the hardware for our experiment: Intel (R) Core (TM) i5-6500 CPU @ 3.20 GHz 3.20 GHz 16.0 GB, 8 GB NVIDIA GeForce GTX 1070 GPU.

Initially, we had to clean the disk. We have to set the flag properly for the training network and then load the data for training the CNN. After that, we have to add a path. Then, for training, we have to include subfolders, set the flag true, use the file extension like .jpg, label the source, and have to add the folder name. We have used image Datastore to load the images of two categories. Then we must read the image and its color information and label the category. Then we generate the training and validation set. The data was split into two sets, with 80% used for training the model and the remaining 20% utilized for validation purposes. Then we had to load the labeled information, and print was generated showing how many images we had for each category. For training, we have to set up the CNN and convolutional parameters; no data augmentation should be in the input layer. The first convolutional layer was added with numFilter of filters and 4 pixels of symmetric padding. After the convolutional layer next layer we have to add is ReLU. ReLU was followed by a max-pooling layer containing 5\*5 spatial pooling, and a 2-pixel stride we have to do from which data dimension was down-sampled. To complete the middle of the network, we have to repeat the three core layers. Then a fully connected layer with two output neurons was added.

To improve the training convergence, we used typically distributed random numbers, and then we initialized the first convolution layer weights with a standard deviation of 0.0001. We used 10,64 for Quardo to set the network training option. MiniBatchSize was minimized to 64 from 128 as GPU ran out of the memory, and for Quardo G, MiniBatchSize was more significant than 512 from 128. From this, many images were required. At last, to train the network, we saved and loaded the photos. We also loaded the validations too. Afterward, performance was tested on the validation set. If the plot is, accurate means classification is done.

We have a total of 3221 authentic and 873 forged images. The accuracy for the validation set is 90.87, and 90.33% is for the training set, as shown in Fig. 3. The 1116 images out of 1228 are classified accurately for the validation dataset, as shown in Fig. 4, whereas 112 images out of 1228 are false classifications for the validation dataset. The accurate classification percentage is 90.87% for the validation dataset. At the same time, the incorrect prediction percentage is 9.12% for the validation dataset, as shown in Fig. 5.

We have to set the transfer learning approach for the training network and then load the data for training the CNN. After that, we have to add a path. We used 80% of the data for training the model and 20% for validation. The dataset for training is imported using the import image classification Matlab application, as shown in Fig. 6. We have set random rotation from 1 to 10 degrees, random rescaling from 1 to 1.1, random horizontal translation from 0 to 0.1 pixels, and random vertical translation from 0 to 0.1 pixels. We have to set up the CNN and convolutional parameters; the training parameters used were Adam optimizer with an initial learning rate of 0.001, mini-batch size of 128, maximum epochs set to 1000, and validation frequency of 50. The gradient decay factor was 0.9, while the squared gradient decay factor was 0.999. The learning rate schedule was set to piecewise, with a learn rate drop factor of 0.1 and a learn rate drop period of 10. L2 regularization was applied with a value of 0.0001. The training was performed on multi-GPU hardware.

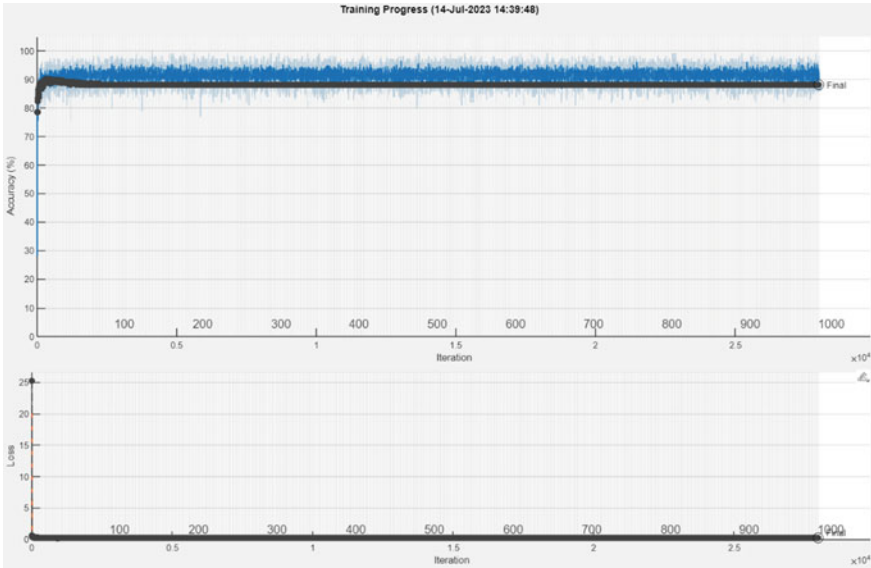


Fig. 3 Deep neural network training process for video forgery detection



Fig. 4 Video forgery dataset

Finally, the trained network was saved and the photos were loaded for testing and evaluation, as depicted in Fig. 7. We also loaded the validations. Afterward, performance was tested on the validation set. If the plot is, accurate means classification is done. The training accuracy plot is shown in Fig. 8, and the loss plot is shown in Fig. 9.

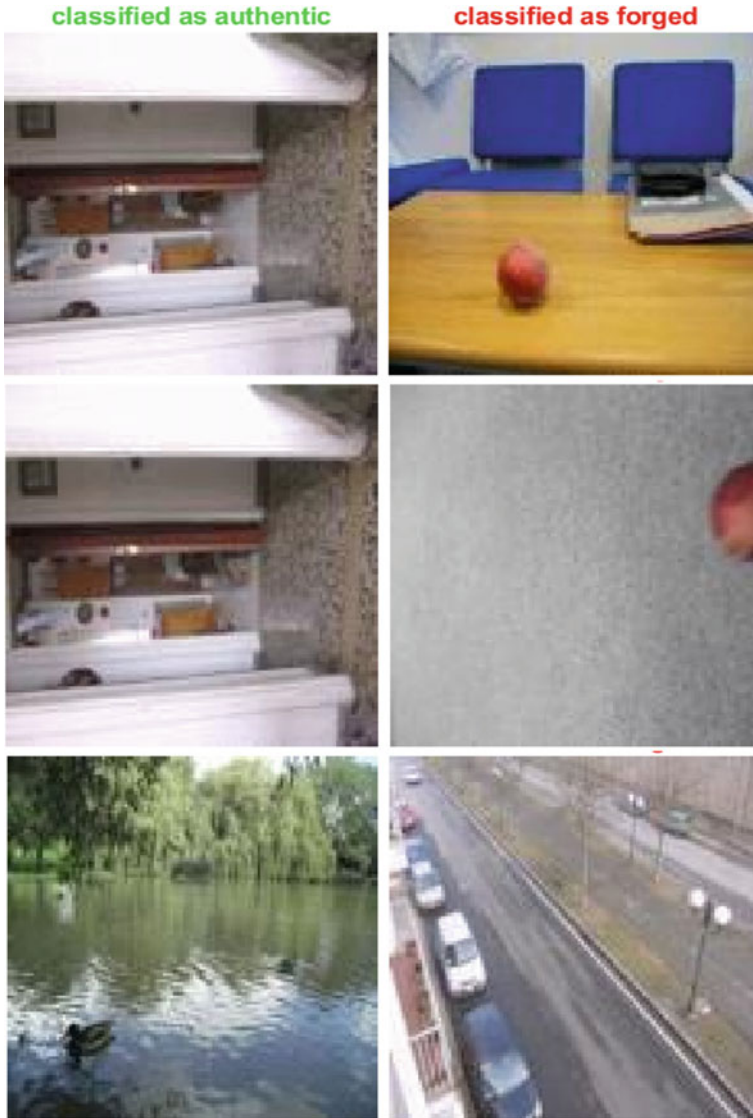


Fig. 5 Video forgery classification

## 6 Results and Comparison

In the Results and Comparison session, accuracy and loss graphs are presented to analyze the performance of different techniques. The accuracy graph illustrates the changes in accuracy over mini-batch iterations and validation steps, providing insights into the model’s ability to classify data correctly. On the other hand, the loss

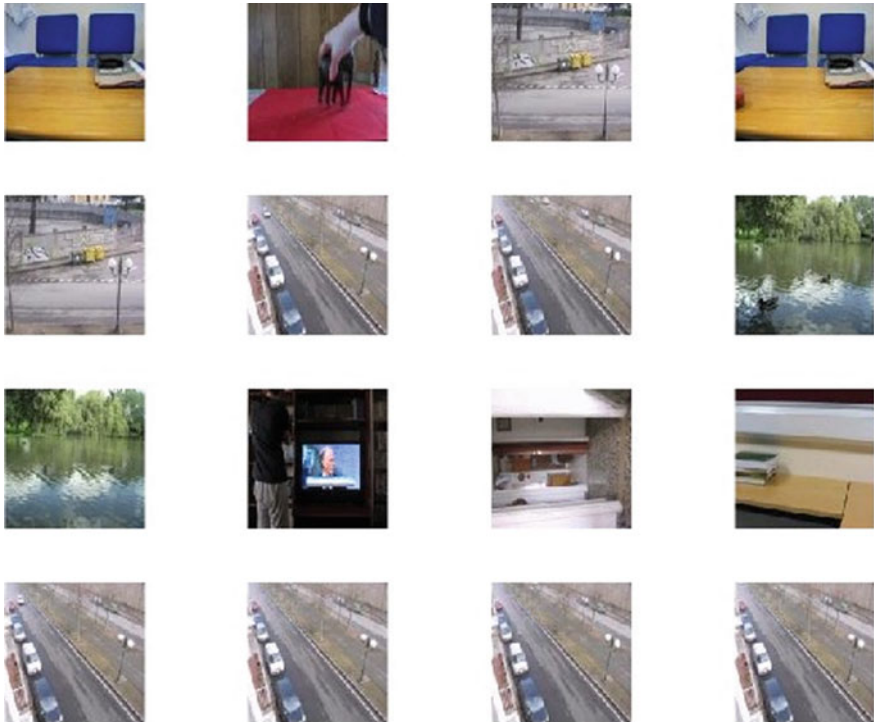


Fig. 6 Deep neural network transfer training videos frames for video forgery detection

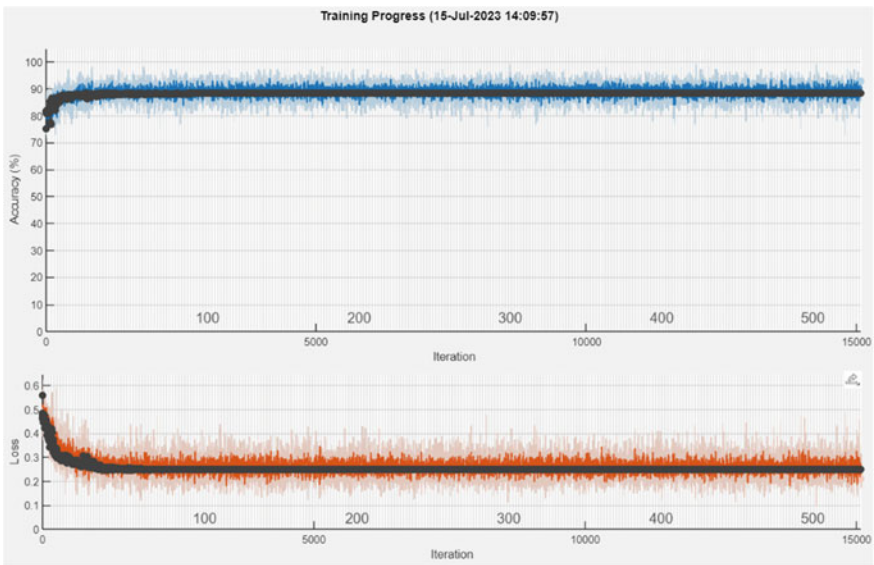


Fig. 7 Deep neural network transfer training process for video forgery detection

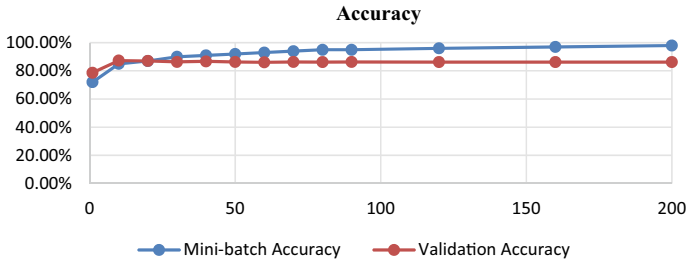


Fig. 8 Accuracy graph between Mini-batch and validation



Fig. 9 Loss graph between Mini-batch and validation

graph depicts the variation in loss values during mini-batch iterations and validation, indicating how well the model minimizes errors. By examining these graphs, researchers and practitioners can assess the convergence behavior, stability, and effectiveness of different techniques. It allows for a comparative analysis of the model’s accuracy and loss trends, aiding in selecting the most suitable strategy for specific tasks or objectives.

Figure 8 depicts relation between Mini batch accuracy and Validation accuracy. It shows that more is Mini-batch accuracy and greater is validation accuracy.

Figure 9 depicts relation between Mini batch loss and validation loss. It shows that greater is Mini-batch loss validation loss is also higher, this graph is linear in high-order Mini batch loss.

Table 1 presents a comprehensive analysis of each step, ranging from traditional to advanced algorithms. It highlights the intricate details and provides a comparison between them comprehensively.



**Table 1** Comparative study

| References           | Technique and dataset   | Accuracy   |
|----------------------|---|--|
| Su et al. [3]        | AVIBE) The algorithm is used on the SULFA and SYSU-OBJFORG dataset      | The average accuracy of 88.12% and 90.64%  |
| Van-Nhan et al. [19] | MDD algorithm is used and blocks the snuffling transformation approach  | AUC is 0.931, ACC is 0.861 The loss decreases from 0.84 to 0.78                              |
| Boato et al. [22]    | A morphological filter detector is used on UCID, DRESDEN RAISE datasets | Accuracy is equal to or above 76.8% on all datasets  |
| Vega et al. [23]     | The CASIA v1.0 dataset is used  | 73.3% of accuracy was obtained   |
| Quan et al. [27]     | SPN (selective perception network) forensics dataset                    | The F1 scores for ISO speeds 100, 800, and 3200 are 84.33%, 82.86%, and 80.13%, respectively |
| Proposed             | Deep convolution neural network with transfer learning                  | The accuracy for the validation set is 90.87%, 90.33% is for the training set                |

## 7 Conclusion

The increasing prevalence of manipulated videos across various domains highlights the critical need for effective video forgery detection methods. This paper presents a comprehensive investigation that addresses the diverse challenges faced in previous research studies. Recent advancements in neural network-based approaches have shown remarkable efficiency in detecting image forgery by uncovering concealed characteristics within images, thereby enhancing accuracy. This paper proposes an extensive inter-frames video forgery detection approach. The primary goal is identifying and detecting manipulation between frames in a video sequence. The report examines techniques for detecting forgeries in images and the challenges posed by inter-frame and intra-frame fakes in videos. Furthermore, emphasis is placed on frequently utilized datasets in this field, which can assist new researchers exploring this study area. The simulation results effectively showcase the efficiency and robustness of the anticipated approach, emphasizing its impressive accuracy in detecting inter-frame video forgeries. This contribution to the field of visual forensics introduces a valuable method for validating the authenticity and integrity of video content.

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# Blockchain Empowered IVF: Revolutionizing Efficiency and Trust Through Smart Contracts



Kamal Upreti, Mustafizul Haque, S. S. Patil, Samiksha Shukla,  
Ashish Kumar Rai, and Prashant Vats

**Abstract** Couples who are having trouble becoming pregnant now have hope thanks to in vitro fertilization (IVF), a revolutionary medical advancement. However, the IVF procedure calls for a large number of stakeholders, intricate paperwork, and highly confidential management of information that frequently results in inaccuracies, mistakes, and worries about data confidentiality and confidence. In this study, the revolutionary potential of the blockchain and smart contracts enabling the treatment of IVF is investigated. The IVF procedure may be accelerated by utilizing smart contracts, resulting in improved effectiveness, openness, and confidence among everybody involved. The paper explores the primary advantages of using smart agreements in IVF, including automation, implementing obligations under contracts, doing away with middlemen, assuring confidentiality and anonymity, and enabling safe and auditable operations. The implementation of electronic agreements and blockchain-based technologies in the discipline of IVF is also investigated, along with the problems it may face and possible alternatives. This study offers insightful information about the use of intelligent agreements and blockchain technology in the field of IVF, accompanied by conducting an in-depth evaluation of the literature on the topic, research papers, and interviews with professionals. The results demonstrate the possibility of lower prices, more accessibility, higher success rates, and better

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patient experiences in the IVF field. In general, this study intends to illuminate how blockchain and smart contracts have revolutionized IVF technological advances, opening the door for a more effective, transparent, and reliable IVF procedure.

**Keywords** IVF · Blockchain technology · Smart contracts · Data privacy · Healthcare · Ethereum · Hyperledger

## 1 Introduction

When it comes to the reproductive health field, in vitro fertilization (IVF) has completely changed the field and given infertile couples fresh hope. The IVF procedure, however, is challenging because it involves several participants, precise record-keeping, and sophisticated coordination. These complications may result in inconsistencies, possible mistakes, and worries about openness and confidence in the IVF process. The advent of smart contract technology in recent years has created intriguing opportunities for improving the IVF procedure. Built on the technology known as blockchain, artificially intelligent agreements are self-executing arrangements that administer the implementation of established rules eliminating the use of middlemen. IVF operations may be made more efficient, transparent, and trustworthy by utilizing smart contracts, which can be used to leverage their potential. The present research attempts to investigate how electronic agreements may revolutionize IVF treatment. We want to provide insights regarding how intelligent contracts might revolutionize the process of IVF and enhance results for couples considering reproductive therapy by examining the available research, case reports, and authoritative views. The following is how this paper will be divided into its subsequent sections: The associated work of the IVF procedure is summarized in Sect. 2, emphasizing its complexity and difficulties. The notion of electronic agreements is further explored, with an explanation of how they operate along with how they relate to the field of in vitro fertilization. It looks at the possible advantages of using smart contract technology in IVF, such as higher productivity, increased accountability, lower costs, and better patient experiences. We attempted to deal with the difficulties and factors to be considered while developing smart contract technology in the context thereof IVF. In this case study, we tried to investigate the difficulties and factors involved in applying smart contract technology in the setting of in vitro fertilization, which include the potential for regulatory and governmental repercussions, concerns regarding data privacy, and manageability. This study aims to add to the collection of understanding regarding the use of blockchain-based technologies in reproductive healthcare by examining the use of smart contract agreements in IVF. In the final analysis, the goal is to open the door to an IVF procedure that becomes more effective, open, and patient-centered while also giving families greater control over how they progress toward parenting.

## 2 Related Work

Using examples that include health information systems (EHRs), pharmaceutical administration of supply chains, and authorization from patients' administration, Barrera et al. [1] investigate how the use of blockchain technology and intelligent agreements are being used in the healthcare industry. The benefits and drawbacks of using these innovations in medical facilities are highlighted.

In their investigation of the implementation of blockchain-based technologies for healthcare purposes, Ismagilova et al. [2] investigate a range of programs, encompassing security of information and privacy, seamless integration, and patient-focused solutions. While not specifically focused on IVF treatment, the research offers perspectives on the advantages and difficulties of applying blockchain-based technologies in healthcare organizations.

The prospective uses of blockchain-based technology in the medical industry are examined by Baldwin et al. [3]. Regarding IVF therapy and pharmaceutical management, it tackles topics like medication accountability, distribution chain administration, and safeguarding patients.

Electronic health records, also known as EHRs, for IVF therapy are explicitly examined in Mintziori et al.'s [4] analysis of the application of blockchain technology to EHR management. It investigates the prospective advantages of utilizing blockchain technology for safe and open data exchange between IVF medical centers, clients, and various other participants.

In order to streamline clinical study administration processes, Kushnir et al. [5] investigate the use of both blockchain-based technologies and smart contracts to improve efficiency. It talks about the possible advantages of better openness, decentralized data administration, and elevated confidence in clinical investigation procedures.

A plan of action powered by a blockchain database of information in healthcare organizations is suggested by Donnez et al. [6]. In relation to reproductive technological advances, it explores the usage of smart contracts in order to guarantee the accuracy of information, accountability, and safeguards while protecting health care information.

The potential of blockchain-based technologies, particularly smart contracts, in order to improve the security and confidentiality of information within the healthcare sector is explored by Flink et al. [7] in their study published in *Science Advances*. It goes through how using blockchain-based technologies can allow for private and personal information to be protected simultaneously enabling safe and transparent information preservation and distribution.

The application of the technology of blockchain for transferring information systems across different fields, particularly medical treatment, is examined by Gunnala et al. [8] in their article from 2008. In order to enable safe and decentralized information preservation and communication, it is discussed how smart agreements might be used. This may be important for protecting information associated with IVF technologies.

A system built on blockchain technology for sharing information and retention in collaborative investigation contexts is presented by Baldwin et al. [3] within their work. It talks about using intelligent agreements to make it easier for different parties to share and preserve data in a safe and accessible manner. This has ramifications for handling information and IVF development.

IVF and other assisted reproductive methods, incorporating the application of blockchain technology, are covered by Mintziori et al. [9] in their article. In topics including the security of information, authorization administration, and product traceability, it examines the advantages of block-chaining architecture.

In their investigation of possible blockchain uses in IVF and other forms of reproductive treatment, Couture et al. [10] investigate this topic. In addition to preserving the reliability and provenance of the gametes and fertilized eggs, it explores the potential applications of the distributed ledger for secure preservation and exchange of information about patients as well as intelligent contract-based permission administration.

The potential advantages and difficulties of implementing blockchain-based technology into assisted reproductive technology (ART), with an emphasis on IVF, have been investigated by Curchoe et al. [11]. The application of distributed ledger technology for the security of information, safe health information sharing, authorization management, and the prospective role of smart contract agreements in expediting operations are all covered in this article.

The ethical issues and possible uses of blockchain-based technology in reproductive healthcare, particularly IVF, are covered by Kaufmann et al. [12] in their article published in 2013. Significant issues about the confidentiality of information, consent that is informed, and the effects of using blockchain technology in the setting of the field of assisted reproduction are raised by this.

In their study on the distributed ledger use cases in medical treatment, Wang et al. [13] look at the ways it may be used for patient authorization administration, management of supply chains, and the administration of healthcare records. It emphasizes the potential advantages of using the use of blockchain technology in healthcare, including enhanced safety, openness, and connectivity.

A thorough review paper on blockchain's capacity for possible uses in healthcare, encompassing sharing of data, the empowerment of patients, and research studies, was provided by Krittanawong et al. [14]. It analyses the difficulties of using blockchain technology for medical applications and offers suggestions for further study.

In their study of blockchain's distributed led possible uses for healthcare purposes, Rieke et al. [15] look at applications such as managing data from clinical trials, maintaining the medication distribution chain, and managing health information. It explores the difficulties in applying blockchain technology to the healthcare sector and offers suggestions regarding how to overcome them.

The management team of IVF can benefit from the blockchain relying on solutions for the safe transmission of images from medical imaging proposed by Fauser et al. [16]. It talks about the possible advantages of adopting blockchain technology to

handle healthcare image information, such as enhanced safety, confidentiality, and transparency.

IVF administration can benefit from using the distributed ledger, which is the reason why Tagde et al. [17, 18] explored its prospective uses in clinical investigation visibility. It talks about the difficulties in integrating blockchain technology into research studies and offers suggestions to overcome them.

### 3 Proposed Work and Research Methodology

In the following paragraphs, we put forth an approach for using distributed ledger technology as well as automated agreements to increase effectiveness and confidence in IVF technological advances. Yet, we've also covered some of the more widespread uses of distributed ledgers in handling information and medical care that can help with the development and execution of relying on blockchain IVF techniques management products and services.

1. **Baseline evaluation: Determine the major problems and inefficiency with the present IVF technique.**
  - (1) Identify the precise contexts in which blockchain technology and smart contracts might address these issues.
2. **Building a distributed ledger construction:**
  - (1) Depending on the needs of IVF technological advances, pick the suitable distributed ledger (such as Ethereum or Hyperledger).
  - (2) Describe the components that make up the decentralized ledger network's organization, such as the nodes themselves, the systems for consensus, as well as information storage.
3. **Creation of Smart Contracts:**
  - (1) Determine the many steps in the procedure for IVF and create intelligent agreements for each one (such as registration of patients, test findings, permission leadership, and therapeutic planning).
  - (2) Specify the reasoning, guidelines, and requirements that will be written into electronic agreements that regulate and streamline IVF procedures.
4. **Integrating and storing data:**
  - (1) Select the sorts of data (such as patient information, test results, and medical records) that will be kept on the blockchain.
  - (2) Connecting current IVF data systems to the blockchain network would enable smooth data storage and transmission.
5. **Ensuring Security and Privacy:**



- (1) Use privacy safeguards to secure sensitive patient data, such as encryption methods and private key management.
  - (2) Create access control methods to make sure that only those with permission may access and modify data stored on the blockchain.
6. Integrating with Alternative Platforms:
- (1) Connect a blockchain-based IVF platform with third-party systems, including EHR systems, which are electronic health record systems, and medical laboratory equipment, to facilitate efficient exchange of information and compatibility.
7. User Experience and Interface: Create an intuitive user interface that allows IVF doctors, patients, and other stakeholders to communicate with the blockchain-based system:
- (1) Make sure that the consumer's interface supports the smooth carrying out of assisted reproduction procedures and simple navigation through the necessary data.
8. Evaluation and Implementation:
- (1) To assure the functionality, dependability, and security of the smart contracts and the broader blockchain infrastructure, conduct in-depth testing.
  - (2) Install the blockchain-based IVF system in a controlled setting and keep an eye on its efficiency.
9. Education and adoption:
- (1) Educate and teach IVF professionals and staff members on how to use the blockchain-based system.
  - (2) Encourage the adoption of technology by raising awareness of and understanding of its advantages.
10. Assessment and ongoing improvement:
- (1) Regularly evaluate the effectiveness, usability, and performance of the blockchain-based IVF system.
  - (2) Gather user and stakeholder input to pinpoint problem areas and execute the necessary improvements.

By using this recommended structure, the fertility treatment industry could be able to oversee IVF treatments while boosting effectiveness, accountability, and confidence, which is divided which could result more effectively in improved outcomes and better experiences for patients. Concerning the Design of the Blockchain Technology Architecture Although Ethereum and Hyperledger, two well-known blockchain-based systems, are present their feasibility for fertility treatments depends on [19]. Regarding the construction of the blockchain system's architecture even though Hyperledger and Ethereum have both become well-known platforms for

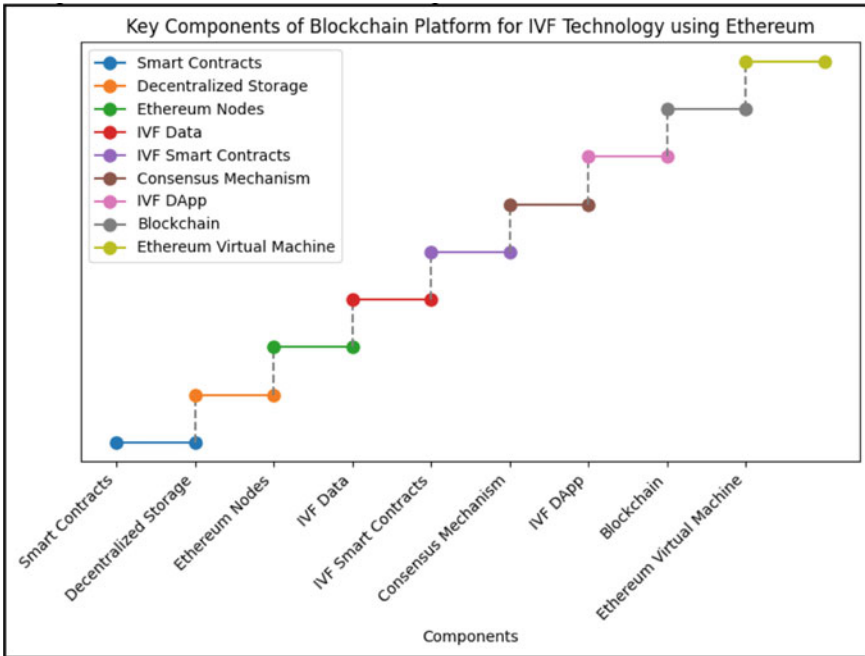
blockchain technologies, only specific conditions will decide if either of them is suitable for IVF technologies. Whether each of the platforms complies with IVF technology standards is described in the section that follows:

### Case Study 1. Ethereum

1. **Smart Contracts:** Using Ethereum, you may produce and employ smart contractual arrangements, known as autonomous agreements that may streamline procedures. Coordinating forms for consent, preserving biological material ownership, and streamlining payment and monetary transactions are all potential applications of intelligent agreements in fertilization technologies.
2. **Decentralization:** As an open source blockchain platform, Ethereum relies on a distributed network of peers to function. This quality guarantees openness and permanence, which might help preserve the accuracy of individual patient information as well as medical documentation throughout IVF.
3. **Tokenization:** Tokens may be created using Ether (ETH), the native coin of Ethereum. The issuance of tokens might be used in assisted reproduction to monitor and transmit control over the embryo's genome, enabling the collaborative use of reproductive belongings in a secure and publicly accessible manner.
4. **Ability to adapt:** Ethereum offers a complete according to turing programming framework, enabling programmers to create intricate decentralized applications (dApps), and modify smart contract agreements to meet the particular needs of infertility technological advancements [20].

The following are the main elements of the distributed ledger system employing Ethereum according to the needs of IVF technological advances, as shown in Fig. 1:

1. **The Ethereum Distributed Computing Platform:** This is an illustration of the fundamental Ethereum blockchain computing architecture that serves as the basis for developing decentralized software applications (dApps) including carrying out smart contract activities.
2. **Smart Contracts:** Running on the distributed ledger Ethereum constitutes autonomous agreements or programs. The procedure known as IVF uses them to manage permission development, identify who owns what genetic information, facilitate safe transactions as well as automate processes while adhering to standards.
3. **Evidence of work agreement methodology:** Ethereum presently makes use of this type of collective decision-making method. The system's miner solves difficult mathematical difficulties to protect and authenticate transactions. Due to this, transactions made on the blockchain are guaranteed to be in accordance and unchangeable.
4. **Security and Privatization (Permissioned Networking):** In accordance with the confidentiality and safety needs of IVF technological advances, a permissioned infrastructure may be built on top of the blockchain used by Ethereum. This ensures the security of confidential information by limiting accessibility to



**Fig. 1** To show the block diagram for the use of the key components of the blockchain platform using Ethereum based on the requirements of IVF technology

blockchain technology to authorized users, including medical professionals and patients [21, 22].

5. **Decentralized Storage of Information and Availability:** The blockchain of Ethereum offers decentralized preservation of information connected to in vitro fertilization (IVF), guaranteeing data permanence and accountability. Medical knowledge about genetic blueprints, along with additional IVF-related data may all be safely preserved and accessed by authorized individuals.
6. **Incorporation and Compatibility:** To promote compatibility in the IVF environment, the Ethereum blockchain technology may be associated with present systems, records, and medical infrastructure. This makes it possible for data to be seamlessly exchanged and integrated using additional healthcare processes and software.
7. **Customer Interface:** To make the platform used by Ethereum blockchain applications and dApps more approachable, graphical user interfaces (UI) may be created. Customers, such as individuals, healthcare providers, and executives, can effortlessly communicate regarding the Ethereum-based artificial reproductive system using the aforementioned interfaces, which may be implemented in a web-based or application-based on mobile devices as shown in Fig. 2.

```

class IVFBlockchain:
    def __init__(self):
        self.blocks = []

    def add_block(self, data):
        if self.blocks:
            prev_block = self.blocks[-1]
            new_block = IVFBlock(data, prev_block.hash)
        else:
            new_block = IVFBlock(data)
        self.blocks.append(new_block)

    def display(self):
        for block in self.blocks:
            print(block)
            print('-' * 40)

class IVFBlock:
    def __init__(self, data, prev_hash=None):
        self.data = data
        self.prev_hash = prev_hash
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        # In a real blockchain, hash calculation involves various cryptographic functions
        # For simplicity, we'll use a basic hash function here
        return hash(str(self.data) + str(self.prev_hash))

    def __str__(self):
        return f"Block Hash: {self.hash}\nPrevious Hash: {self.prev_hash}\nData: {self.data}"

# Usage
if __name__ == "__main__":
    ivf_chain = IVFBlockchain()
    ivf_chain.add_block("IVF Patient Data 1")
    ivf_chain.add_block("IVF Patient Data 2")
    ivf_chain.add_block("IVF Patient Data 3")
    
```

Fig. 2 To show the Ethereum-based artificial reproductive system using the aforementioned interfaces, which may be implemented in a web-based or application-based on mobile devices

### Case Study 2. Hyperledger

1. **Permissioned Networking and confidentiality:** Hyperledger Networking is made toward permissioned relationships, offering users greater authority regarding who can view and partake in data. This quality fits well with the requirement for

confidentiality and anonymity in fertility treatments, as important patient data must be transmitted securely among authorized participants.

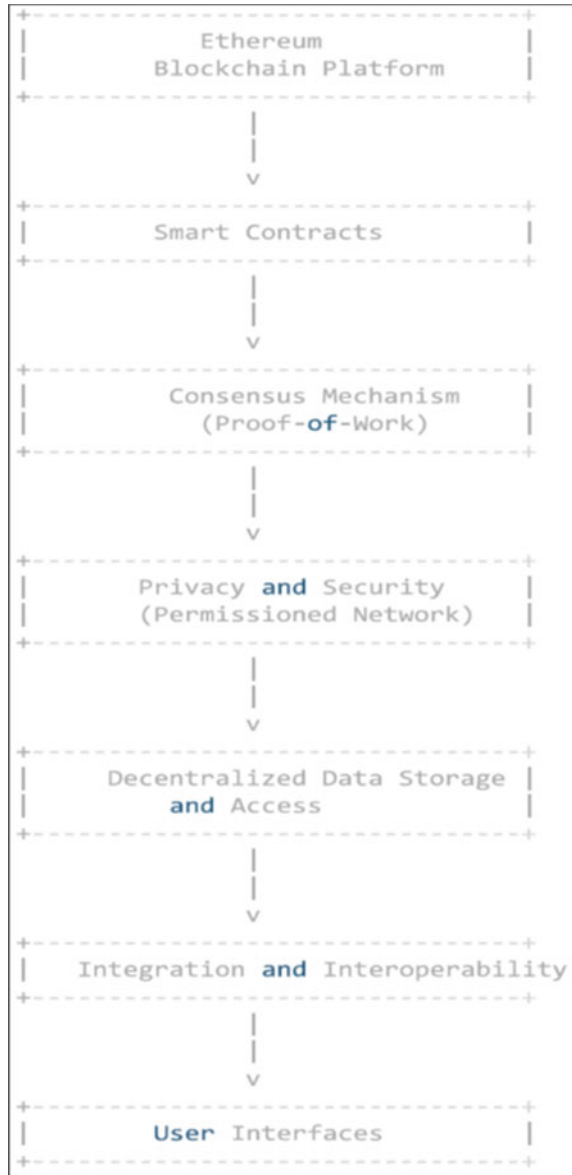
2. **Scalability and Modularity:** Hyperledger Networking has a modular design that allows organizations to select and include specific elements that are pertinent to their intended application case. This adaptability can handle the many demands of reproductive technological advances, where different parties and technologies are required to communicate and share information in an efficient manner.
3. **Agreement Mechanisms:** Hyperledger Networking offers connected consensus algorithms that are extensible, permitting customization according to the specific requirements of the fertility treatment environment. This makes it possible for organizations to choose consensus-building processes that give priority to achievement, environmental sustainability, or additional desirable characteristics.
4. **Commercial emphasis:** The Linux Foundation, on the other hand, is responsible for the creation and upkeep of Hyperledger, it places an emphasis on high-quality blockchain technologies for businesses. This fits with how technology for IVF must be strong, scalable, and compatible with regulations.

In the end, the selection of Ethereum or Hyperledger will depend on specific needs, key players, and application instances inside the embryo fertilization environment. In order to develop safe, open, and effective IVF procedures solutions using technology, it is possible to take advantage of the distinguishing characteristics & traits that each ecosystem provides.

According to the specifications of reproductive technological advances, the major elements of the distributed ledger platform employing Hyperledger Networking are shown in the representation in Fig. 2 as follows:

1. **Hyperledger Networking Blockchain Framework:** This constitutes the fundamental architecture of the Hyperledger Networking blockchain technology, from which enterprise-grade blockchain-based applications may be built.
2. **Intelligent Agreements:** Hyperledger Networking intelligent agreements enables mechanization and the enforcement of norms in IVF technological advances. They may be created with coding languages like Solidity, also known as Chain code (depending on Python or other supporting technologies), enabling modification that accommodates the particular demands in IVF-related operations.
3. **The Agreement Mechanism (Pluggable Resolution Algorithm):** Hyperledger Networking provides adaptable consensus algorithms that are extensible, permitting customization according to the demands of the IVF network. Organizations might choose consensus procedures that prioritize achievement, energy conservation, or additional desirable features.
4. **Security and Privatization (Permissioned System):** To suit the security and confidentiality needs of reproductive technological advances, Hyperledger Networking can be built as a network with permissions as shown in Fig. 3.
5. **By protecting the private nature of confidential information,** this makes certain only those who are authorized users, including patients and medical professionals, are granted permission to the network.

**Fig. 3** Depicts a block diagram for the vital elements of the blockchain infrastructure utilizing Hyperledger Networking based on the demands of reproductive technologies



6. Decentralized Storage of Information and Accessibility: The Hyperledger Networking blockchain technology offers decentralized preservation for data pertaining to in vitro reproduction (IVF). Health information, biological information, and any other pertinent data may be securely kept and consulted by authorized parties on the distributed ledger.

7. Compatibility and Collaboration: The Hyperledger Networking blockchain platform could be connected with current platforms, the form of databases, and medical facilities to facilitate compatibility throughout the intrauterine fertilization (IVF) environment. As a result, it is possible to integrate and communicate information with additional healthcare services as well as apps without any issues.
8. User Interfaces: User interfaces (UI) that perform the Hyperledger blockchain technology and its associated applications accessible to users may be created. These user interfaces may be found in smartphone or online communication apps.

## 4 Experimental Results

With a general overview of how smart contracts and blockchain technology can revolutionize IVF technology, enhancing efficiency, and trust we can have the following results as shown in Fig. 4.

**1. Better Data Integrity and Protection:** Blockchain-based technology makes certain that the information of treatments for IVF remains secure in an irrevocable and impermeable way. The privacy and confidentiality of information about patients may be substantially enhanced by employing decentralized agreement processes, contract technology, and encryption. This promotes confidence between patients and medical professionals by preventing unauthorized retrieval, alteration, or displacement of sensitive data. The outcomes are displayed in Table 1.

**2. Simplified authorization Administration:** For the purpose of managing and upholding permission guidelines during fertilization procedures, intelligent contracts

```
# Usage
if __name__ == "__main__":
    ivf_chain = IVFBlockchain()
    ivf_chain.add_block("IVF Patient Data 1")
    ivf_chain.add_block("IVF Patient Data 2")
    ivf_chain.add_block("IVF Patient Data 3")
    ...
    ivf_chain.display()

Block Hash: 7692533423797059392
Previous Hash: None
Data: IVF Patient Data 1
-----
Block Hash: -5039367167201602668
Previous Hash: 7692533423797059392
Data: IVF Patient Data 2
-----
Block Hash: -9211068371099562432
Previous Hash: -5039367167201602668
Data: IVF Patient Data 3
-----
```

**Fig. 4** To show how smart contracts and blockchain technology can revolutionize IVF technology, enhancing efficiency and trust

**Table 1** Improved data integrity and security in IVF technology

| Aspect                      | Description   |
|-----------------------------|---|
| Blockchain technology       | Utilize blockchain to create an immutable and tamper-proof record of IVF-related data and transactions              |
| Encryption and privacy      | Implement strong encryption protocols to safeguard sensitive patient information and medical records                |
| Access control              | Apply strict access controls and authentication mechanisms to ensure that only authorized personnel can access data |
| Decentralized storage       | Store data across a decentralized network to reduce the risk of data loss and improve resilience                    |
| Biometric authentication    | Implement biometric authentication methods (fingerprint, facial recognition) to enhance user identity verification  |
| Audit trails                | Maintain detailed audit trails of data access and modifications for accountability and traceability                 |
| Multi-factor authentication | Require multiple forms of authentication (e.g., password, token, biometrics) to access critical systems             |
| Data encryption in transit  | Encrypt data while it's being transmitted over networks to prevent unauthorized interception                        |

might be used as shown in Fig. 5. To ensure that only individuals or organizations with the appropriate authorizations may access their information, individuals can set particular authorizations and gain rights regarding their health information. As a result, patients have greater independence and confidentiality, which means it additionally makes it easier to share data having appropriate organizations having patient approval, such as investigators or insurance businesses. Table 2 is provided to show the data values for quantitative metrics or Streamlined Consent Management using smart contracts for IVF technology.

**3. Effective management of the supply chain:** Blockchain-based technology has the potential to optimize and restructure the procedures that comprise the manufacturing process for the treatment of IVF as shown in Fig. 6. Smart contracts make it simpler to trace and confirm the provenance of important supplies, like lab equipment, donor eggs or sperm, and medicines. By doing so, the possibility of receiving fake or inferior goods is decreased, and the materials utilized in IVF operations are of high quality and can be traced. Table 3 is provided to show the data values for quantitative metrics efficient supply chain management using smart contracts for IVF technology.

The prospective benefits outlined above show how the application of intelligent agreements and the distributed ledger can improve efficiency, security of information, confidence, and cooperation across the spectrum of IVF treatments, despite the fact that there aren't many particular findings from experiments and research studies within relation to the technology behind IVF as well as the distributed ledger. The beneficial impact of these advancements on IVF results has to be validated and quantified through more study and practical use.



```

if __name__ == "__main__":
    consent_system = ConsentManagementSystem()

    patient1 = Patient(patient_id="P001", name="Alice", age=30)
    patient2 = Patient(patient_id="P002", name="Bob", age=35)

    consent1 = Consent(consent_type="Treatment", date="2023-08-04", description="Consent for IVF treatment.")
    consent2 = Consent(consent_type="Data Sharing", date="2023-08-05", description="Consent for sharing medical data.")

    consent_system.add_patient(patient1)
    consent_system.add_patient(patient2)

    consent_system.add_consent_to_patient("P001", consent1)
    consent_system.add_consent_to_patient("P002", consent2)

    consent_system.display_patient_consents("P001")
    consent_system.display_patient_consents("P002")

Consent added successfully.
Consent added successfully.
Consents for Patient Alice (ID: P001):
1. Consent Type: Treatment
   Date: 2023-08-04
   Description: Consent for IVF treatment.
Consents for Patient Bob (ID: P002):
1. Consent Type: Data Sharing
   Date: 2023-08-05
   Description: Consent for sharing medical data.
    
```

**Fig. 5** To show how to manage and uphold permission guidelines during fertilization procedures

**Table 2** Data values for quantitative metrics or streamlined consent management using smart contracts for IVF technology

| Metric  | Data values (hypothetical)        |
|---|-----------------------------------|
| Consent Processing Time (seconds)             | 25, 30, 22, 40, 28                |
| Number of Consents Processed per Hour         | 50, 62, 45, 53, 57                |
| Accuracy of Consent Execution (%)             | 98.5, 99.2, 97.8, 99.8, 98.9      |
| Patient Satisfaction Score (out of 10)        | 8.7, 9.2, 8.5, 9.0, 8.9           |
| Reduction in Administrative Costs (%)         | 15.2, 12.8, 18.6, 14.5, 16.3      |
| Avg. Time to Resolve Consent Disputes (hours) | 4.5, 3.8, 5.2, 4.0, 4.7           |
| Blockchain Transaction Fees (ETH)             | 0.023, 0.018, 0.027, 0.021, 0.025 |
| % Increase in Data Security                   | 24.7, 28.5, 22.1, 26.0, 25.6      |
| Number of Consent Audits Conducted            | 5, 4, 6, 5, 5                     |
| Smart Contract Uptime (%)                     | 99.8, 99.5, 99.9, 99.7, 99.6      |

```

class IVFProduct:
    def __init__(self, product_id, name, quantity):
        self.product_id = product_id
        self.name = name
        self.quantity = quantity

class SmartContract:
    def __init__(self):
        self.products = {}

    def add_product(self, product):
        self.products[product.product_id] = product

    def update_quantity(self, product_id, new_quantity):
        if product_id in self.products:
            self.products[product_id].quantity = new_quantity
            print(f"Updated quantity of {self.products[product_id].name} to {new_quantity}")
        else:
            print("Product not found.")

    def display_products(self):
        print("Current Products in Supply Chain:")
        for product in self.products.values():
            print(f"Product ID: {product.product_id}, Name: {product.name}, Quantity: {product.quantity}")

if __name__ == "__main__":
    smart_contract = SmartContract()

    product1 = IVFProduct(product_id="P001", name="Fertility Drugs", quantity=100)
    product2 = IVFProduct(product_id="P002", name="IVF Consumables", quantity=200)

    smart_contract.add_product(product1)
    smart_contract.add_product(product2)

    smart_contract.display_products()

    smart_contract.update_quantity("P001", 80)
    smart_contract.update_quantity("P003", 150)

Current Products in Supply Chain:
Product ID: P001, Name: Fertility Drugs, Quantity: 100
Product ID: P002, Name: IVF Consumables, Quantity: 200
Updated quantity of Fertility Drugs to 80
Product not found.

```

**Fig. 6** To show how to optimize and restructure the procedures that comprise the manufacturing process for the treatment of IVF

**Table 3** Data values for quantitative metrics efficient supply chain management using smart contracts for IVF technology

| Metric  | Data values (hypothetical)   |
|---|------------------------------|
| Order fulfilment time (hours)                 | 8.2, 7.5, 9.0, 8.8, 7.9      |
| Inventory turnover ratio                      | 4.2, 4.8, 3.9, 4.5, 4.1      |
| Percentage reduction in stockouts             | 15.2, 12.8, 18.6, 14.5, 16.3 |
| Supplier lead time (days)                     | 4, 5, 4, 6, 5                |
| Smart contract transparency score (out of 10) | 9.5, 9.8, 9.2, 9.7, 9.6      |
| Percentage decrease in overhead costs         | 7.6, 6.2, 8.4, 7.9, 7.3      |
| Average product traceability time (hours)     | 3.5, 4.0, 3.2, 4.5, 3.7      |
| Number of discrepancies detected              | 2, 1, 3, 2, 2                |
| Contract execution time (seconds)             | 12, 15, 10, 14, 13           |
| Supplier on-time delivery rate (%)            | 92.3, 94.8, 90.5, 93.7, 91.6 |

## 5 Conclusion

In conclusion, using the autonomy of intelligent agreements and the use of blockchain technology offers the possibility to revolutionize in vitro fertilization (IVF) technologies by improving effectiveness and trustworthiness. Several advantages can be realized by utilizing these technologies: Blockchain guarantees that treatment with IVF documents is irrevocable and impenetrable hindering contrary to unauthorized access and guaranteeing information integrity. Smart contractual arrangements facilitate the creation of authorization procedures, permitting individuals to set particular authorizations regarding their IVF information while guaranteeing that solely authorized persons or organizations have permission to utilize it. Blockchain technology increases accountability and reliability in the IVF procurement process, validating the validity and sourcing of essential materials and lowering the danger of fraudulent or substandard merchandise. Blockchain platforms support communication and teamwork between medical professionals, IVF healthcare facilities, as well as research organizations, enabling safeguarded data exchange, and advancing the science of IVF through collaborative research. By allowing patients to see how their fertility treatment is progressing, encouraging openness, and enabling them to arrive at informed choices, the application of blockchain technology's openness fosters confidence among people. Although particular findings from experiments can differ based on execution and its context, the utilization of smart contracting and blockchain-based systems in artificial reproduction (IVF) has the possibility of helping improve effectiveness while the safety of information, confidence, and collaboration, eventually enhancing overall satisfaction and positive results for patients as well as physicians in the practice of IVF treatment.

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# IoT-Based Smart Door Lock System with Face Recognition Using ESP32 CAM and Android App



Pramod Kumar Goyal, Moksh Giri, and Saurabh Verma

**Abstract** Door lock security is an important consideration for any homeowner or renter. There are various options available for door locks, including deadbolts, keyless entry systems, and smart locks. It is important to choose a lock that fits your specific needs and budget. Most of the current IOT-based smart door lock systems are based on third part apps like Blynk which are works using Wi-Fi within a limited area of home or office premises. The proposed system removes these both limitations. This paper presents an IoT-based smart door lock system with four core functionalities. An Android app is developed by the authors which offers a secure login and registration mechanism, facilitates capturing photos of individuals positioned in front of the door and remote locking/unlocking using the app. The Android app also displays captured photos and videos for easy accessibility and monitoring. The system incorporates face recognition technology utilizing the ESP32 CAM module to allow the door automatically unlocks upon recognition. Most importantly, in case of non-recognition, it incorporated an alert message functionality into the system. If an individual stood in front of the ESP32 CAM for a duration exceeding 30 s, an alert notification would be dispatched to the Android app, notifying that “Someone is at the door for more than 30 s”. The functional prototype of the system is fully developed, implemented, and tested in real time environment which proves successful.

**Keywords** IoT · Smart door lock system · ESP32 CAM · Android app · Node MCU · Arduino · Face recognition

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# 1 Introduction

A door is a crucial element in maintaining the physical security of a house. If the door is easily opened, it becomes an invitation for thieves to enter and steal the valuables. Traditionally, doors were secured with physical keys, but with technological advancements, digital doors have been introduced. These modern doors can be locked and unlocked without a physical key, providing convenience and ease of access. However, they are also vulnerable to damage or hacking. To ensure the security of the house, it is essential to keep the doors locked at all times, whether leaving the house or relaxing inside. This practice will help prevent unauthorized access and provide peace of mind to the occupants. Despite the importance of keeping doors locked, occupants may sometimes forget to do so when in a hurry or become uncertain about whether they locked the door. This forgetfulness or uncertainty can be a significant threat to the security of the house. Thus, the need for a smart door lock system arises to enhance and bolster security measures.

This paper presents an IoT-based smart door lock system with four core functionalities.

1. Firstly, the Android app is developed by our own and it offers a secure login and registration mechanism exclusively for authorized users. Individuals can register themselves by using a designated passcode.
2. Secondly, the app facilitates capturing photos of individuals positioned in front of the door, providing a convenient means to identify visitors. Furthermore, users can unlock the door remotely using the app.
3. Thirdly, the system incorporates face recognition technology utilizing the ESP32 CAM module. If a user's face is enrolled in the system, the door automatically unlocks upon recognition. The Android app also displays captured photos and videos for easy accessibility and monitoring.
4. Lastly, we incorporated an alert message functionality into our system. If an individual stood in front of the ESP32 CAM for a duration exceeding 30 s, an alert notification would be dispatched to the Android app, notifying that "Someone is at the door for more than 30 s".

The novelty of this works is that:

- It has implemented the login and registration features in Android app and these features are implemented in such a way that only the authorized people can be able to register in the Android app.
- This IoT-based system allows users to remotely control the door lock system from anywhere via the Internet. It provides features such as unlocking the door, viewing photos of visitors, and receiving notifications. Users are not restricted to the same network and can conveniently manage the system from any location.
- **The team has developed the entire system for controlling and accessing the smart door lock, including the Android app, without relying on any third-party applications such as Blynk.** It means that we have built the system from

scratch, without using any pre-existing software or tools developed by other companies.

## 2 Related Work

A smart Wi-Fi Door Lock [1] utilized the ESP32 CAM and the Blynk App. In this working model, whenever a person pressed the doorbell, the owner would receive a notification on their phone containing a photo of the individual. After reviewing the photo, the owner had the option to unlock the door using their mobile phone. The Door Security System application, proposed in the paper, employed the Wi-Fi Door Lock with ESP32 CAM and leveraged Internet of Things (IoT) technology to monitor the door's status, manage its operation, and enhance home security. Blynk, a communication protocol, served as the bridge between a smartphone and the door lock system, effectively augmenting the security measures of a home.

A remote lock system based on a microprocessor [2], utilized Wi-Fi connectivity to establish a connection with the Blynk app, providing convenient access to the door. This implementation serves as a basic example of an Internet of Things (IoT) application. IoT is an evolving field of computing that facilitates the interconnection of diverse objects that were not traditionally linked. The paper enabled to remotely control access to door using a straightforward microcontroller and a companion app. For system control, they also used Blynk, a third-party IoT app.

Paper [3], presented a smart Wi-Fi Door Lock that utilized the ESP32 CAM and the Blynk App. In this simplified working model, when a person pressed the doorbell, the owner received a notification on their phone containing a photo of that person. Even in paper [4] also, the door lock was controlled using the Blynk app.

In paper [5], the system proposed consisted of a camera sensor, commonly known as esp32-cam, which was used for capturing and storing pictures of individuals as well as for live streaming. The system utilized AI-Thinker technology integrated into the esp32-cam to recognize the faces of individuals standing in front of the door. The captured face image was then compared with the faces of authorized individuals stored in the SD card of the esp32-cam. In the case of a match with an authorized person, the door was unlocked using a solenoid lock as a hardware component. In paper [6], this paper shares a simple yet effective idea for safeguarding smart homes, especially through door key locks. It caters to Android phone users, making security accessible to everyone. The use of the Android platform, which is free and open-source, ensures a cost-effective solution suitable for the average person. By incorporating wireless Wi-Fi connectivity, the system becomes easy to set up using an Android phone with Wi-Fi capabilities. While the paper showcases a basic model, it sparks possibilities for broader exploration in smart home security. The project's affordability and simplicity make it suitable for widespread use, and there's potential for further advancements beyond the discussed prototype.



### 3 Proposed Work

While reviewing the related work mentioned above, it is evident that numerous researchers have employed the Blynk IoT as a third-party application for managing door lock systems. However, our approach differs significantly as we opted not to utilize any third-party apps such as Blynk. Instead, we developed our own dedicated Android application to fulfill multiple functions. This custom application enables us to monitor photos and videos captured by the ESP32 CAM, while also providing control over the smart door lock system. By developing our own Android application, we were able to tailor the user experience and functionality according to our specific requirements, ensuring a more seamless and integrated solution.

This paper aims to incorporate the ESP32 CAM module, which is a camera module with Wi-Fi capabilities. This module is equipped with an OV2640 camera and features an SD card slot, allowing for increased storage capacity. This camera module will be mounted over the door lock. This project involves the integration of the Internet of Things (IoT) and ESP module for monitoring purposes. Additionally, it utilizes the Node MCU and relay module for the door lock/unlock mechanism.

This project can be operated using the Android application which is developed by our own, providing users with increased convenience and flexibility.

We will be using the ESP32 CAM module for the purpose of Face Detection, Face Recognition, and Photo Capture.

In addition, the project will integrate a Node MCU board, which is a microcontroller with Wi-Fi capabilities. It will be programmed to enable locking and unlocking of the door via buttons on a custom-built Android application. This Android application will be developed in-house to ensure compatibility with the Node MCU board and ESP32 CAM module. Moreover, the ESP32 CAM module will facilitate the capturing of photographs, which will be displayed on the Android application, allowing users to monitor their premises remotely.

#### We have implemented these functionalities in this paper

- **Register and Login to the Android App:** We have implemented the login and registration features in Android app and these features are implemented in such a way that only the authorized people can be able to register in the Android app, as we will provide a secret passcode to the authorized users, so that while registering to the Android app if they enter the exact passcode then only they will be able to register and get the access to control the door lock. That means no third person or any unauthorized person can be able to register. And after registering, the users can simply login to android app by their own entering their email and password that they have created at the time of registration.
- **Capturing photo and unlocking the door:** After successfully logging in to the Android app, the users will be redirected to the Dashboard Activity page. There will be three buttons available on this—"Click Photo", "Lock Door", and "Unlock

Door”. By tapping on “Click Photo” button, the user can simply click the photo of that person who is ringing the doorbell. This can be done by using ESP32 CAM module which is mounted over the door lock. After that the photo will be displayed on the Android app itself. If the person on 3 the photo is known to the user, then he can simply unlock the door by tapping on the button “Unlock Door” and the door will be unlocked. We can also lock it back by tapping on “Lock Door” button.

- **Door Unlock with Face Recognition using ESP32 CAM:** We can simply enroll the faces of the authorized users to the ESP32 CAM, so that there is no need to unlock the door for these users manually or by using the Android app also. If any of them appears in front of the camera module, the module will detect and recognizes the face and if the face is recognized then the door will be automatically unlocked for them and they can easily enter in the house/office.
- **Duration-based Alert Notification:** We incorporated an alert message functionality into our system. If an individual stood in front of the ESP32 CAM for a duration exceeding 30 s, an alert notification would be dispatched to the Android app, notifying that “Someone is at the door for more than 30 s”. To achieve this functionality, we leveraged the Alarm Manager features of the Android platform, effectively monitoring the duration and triggering the appropriate notification. This additional feature ensured that timely alerts were provided to the user in case of prolonged presence at the door, enhancing the overall security, and responsiveness of the system.

**In order to implement the above functionalities, the hardware and software requirements are as follows**

- **Software Requirements:**
  - Android Studio
  - ARDUINO Integrated Development Environment (IDE)
  - Firebase
- **Hardware Requirements:**
  - ESP32 CAM
  - Node MCU
  - Electronic Solenoid Lock (12 V)
  - Breadboard
  - Jumper Wires
  - 2-Channel Relay Module
  - 12 V DC Adaptor

## 4 Methodology/Implementation

### 4.1 Programming ESP32 CAM

1. First, we must program the ESP32 camera using Arduino IDE [7].
2. To program the ESP32 camera, we will use FTDI232 USB to Serial interface board and we will connect the FTDI232 with ESP32CAM as per the above circuit.
3. Also connect the ESP32 CAM with relay module. So that whenever the face is recognized by camera, the relay will turn on and the solenoid lock will be unlocked.
4. Before uploading the code to ESP32CAM, we have to update some settings in Arduino IDE like:
  - (1) Update the Preferences –> Additional boards Manager URLs.
  - (2) Install ESP32 Library.
  - (3) Update Board Settings (Change to ESP32 Wrover Module).
  - (4) Setting up SSID and password.
  - (5) Set COM Port.
  - (6) GPIO 0 must be connected to GND pin while uploading the code.
  - (7) To initiate the flashing mode, connect GPIO 0 to the GND pin on the ESP32 CAM board. Then, press the RESET button of the ESP32 CAM.
5. As soon as the program is uploaded to ESP32 CAM, open Serial Monitor in Arduino IDE and press reset button on ESP32 CAM. Now, ESP32 CAM will be connected to the Wi-Fi.
6. When the ESP32 CAM is successfully connected to the Wi-Fi, it will provide the IP address of camera which is visible on the Serial Monitor.
7. Copy the IP address and paste it on any web browser and now you can access the camera. One can live stream and can also click photos and display it on the web server.

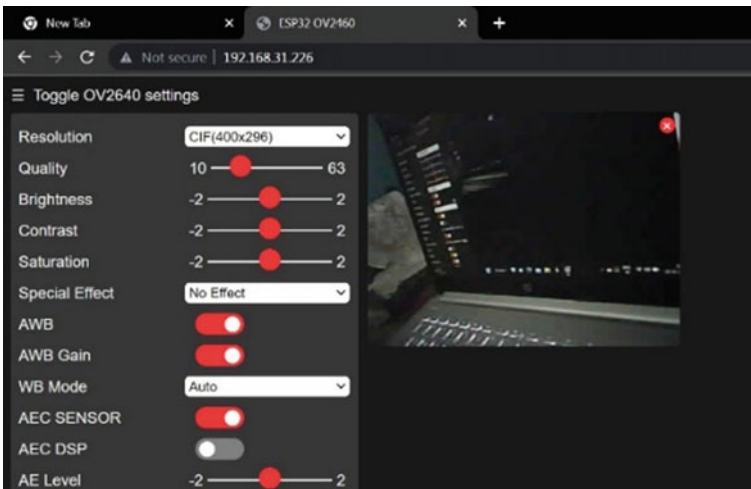
There are many more features like we can also change the resolution of the images captured by ESP32 CAM.

### 4.2 Programming Node MCU Board

1. First, we must program the Node MCU using Arduino IDE [8].
2. To program the Node MCU, we will simply connect the board with our laptop using USB cable.
3. Also connect the Node MCU with relay module. So that whenever the unlock or lock button is clicked by the user, the relay will turn on and the solenoid lock will be unlocked or locked.

4. Before uploading the code to Node MCU, we have to update some settings in Arduino IDE like:
  - (1) Update the Preferences –> Additional boards Manager URLs.
  - (2) Install ESP8266 (Node MCU) Library.
  - (3) Update Board Settings (Change to Node MCU Board).
  - (4) Setting up SSID and password.
  - (5) Set COM Port.
  - (6) To initiate the flashing mode, connect GPIO 0 to the GND pin on the ESP32 CAM board. Then, press the RESET button of the Node MCU.
5. As soon as the program is uploaded to Node MCU, open Serial Monitor in Arduino IDE and press reset button on Node MCU. Now, Node MCU Board will be connected to the Wi-Fi.
6. When the Node MCU is successfully connected to the Wi-Fi, it will provide the IP address of Board which is visible on the Serial Monitor.
7. Copy the IP address and paste it on any web browser and now you can access the board. Door unlock and door lock buttons will be displayed on the web server along with the live streaming functionality (Fig. 1).

Now we will integrate all the devices that is ESP32 CAM, Node MCU and relay module, and connect them to Solenoid door lock and 12 V DC adaptor.



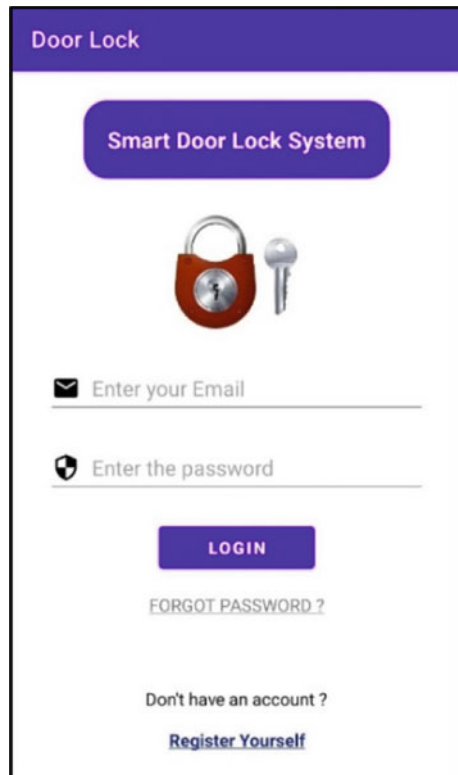
**Fig. 1** Live streaming on web server (screenshot)

## 5 Results and Functionality Analysis


Now we have developed the Android app. So that we can control the devices by using the Android app itself. For that we have created four activities in Android Studio that is Login Activity, Register Activity, Forgot Password Activity, and Dashboard Activity.

1. **Login Activity:** As soon as the user launches the Android application, the Main Activity will appear. This Activity will serve as the primary interface for the application.
2. **Register Activity:** If the user is not registered then he can register himself by clicking on “Register Yourself” button. And then he can fill the details by entering the secret passcode which will be only shared to the authorized users. When the user is registered successfully, their details will be stored in our Firebase database.
3. **Forgot Password Activity:** In case the registered user forgets the password, then he can reset the password by using this Activity and the password recovery mail will be sent to them.
4. **Dashboard Activity:** This is the final Activity page that will appear if the user is successfully logged in to the application. In this Activity, there are two buttons that is “Turn on Camera” to turn on the camera which is mounted over the door lock and user can simply click the photo and start live streaming by tapping on this button, and another button is “Unlock/Lock Door” to simply unlock or lock the door by tapping on this button (Fig. 2, 3, 4, 5 and Fig. 6).

**Fig. 2** Login activity



**Fig. 3** Register activity



Door Lock

Smart Door Lock System



User Name

Email

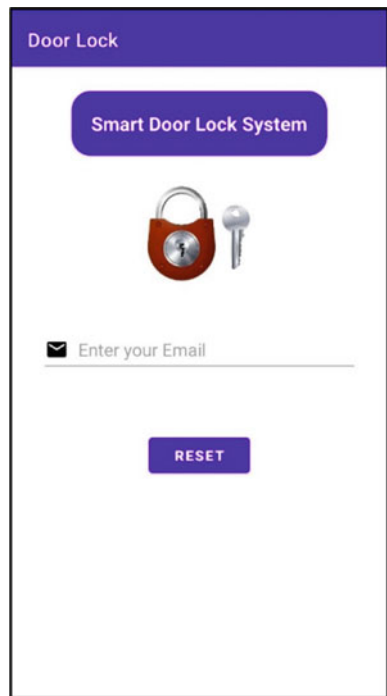
Password

Confirm Password

Lock Passcode


REGISTER

**Fig. 4** Forgot password activity



Door Lock

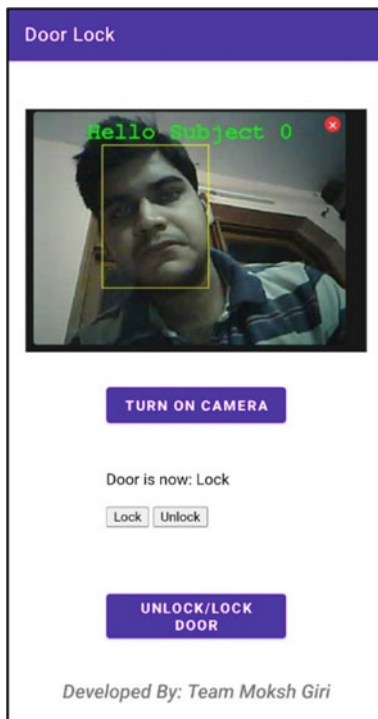
Smart Door Lock System



Enter your Email

RESET

**Fig. 5** Dashboard activity



**Fig. 6** Hardware setup (prototype)





## 6 Conclusions

The authors have successfully developed a smart door lock system that uses the Internet of Things (IoT) technology, which allows devices to communicate with each other over the Internet. Our system is designed to work with an ESP32 CAM module and an Android app. The ESP32 CAM module captures photos of the person standing in front of the door, and the Android app displays these photos. We have also implemented a face recognition feature that allows authorized people to unlock the door automatically by recognizing their faces. Additionally, the Android app includes buttons that allow users to lock and unlock the door manually.

## 7 Future Scope

In the future, the time-based features like scheduling the door lock for unlocking/locking at a specific time can also be incorporated. With this, users no longer need to manually lock or unlock the door at specific times. The system handles this automatically, offering convenience, and ensuring peace of mind. Users can trust that the door will always be locked when required, such as during nighttime or when they are away from home.

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# IoT-Based Smart Home Automation



Ishu Gaur, Srishti Rai, Utkarsh Tiwari, and Anil Kumar Sagar

**Abstract** Smart home automation refers to the use of advanced technology to control, monitor, and automate differences in a home, such as temperature, security, and lighting, remotely through a centralized interface. The Internet of Things (IoT) has transformed the way the authors interact with technology and our environment. Home automation systems are a very rapidly growing interest among the people of this generation, and it has gotten a considerable amount of attention after the introduction of communication technologies. In the field of smart homes, IoT has played a very significant role in helping it grow. IoT in its most basic terms is connecting things like software and sensors to the Internet, enabling them to collect and exchange data without human intervention. IoT deals with AI sensors, cloud messaging, networking, etc., and aims to deliver complete information at the right time. IoT-based systems have greater transparency, control, performance as well as efficiency. The two primary concerns with home automation are security and energy utilization. This paper highlights different methods of achieving smart home automation via several different technologies such as Bluetooth, Global System for Mobile (GSM), Zigbee, and Dual-Tone Multi-Frequency (DTMF). In this paper, the authors will delve into the details of IoT-based smart home automation and its various components, benefits, and challenges as well as its impact on society.

**Keywords** Energy conservation · Wireless sensor network · Zigbee · Phone · Bluetooth · Global System for Mobile · Microcontroller · Arduino · Peripheral Interface Controller · Internet of Things · And home automation

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## 1 Introduction

Technology and human mentality are both evolving daily throughout the world. People in today's modern generation prefer to rely solely on technology for their work as well as daily lives. Human-machine interaction has become very popular, plausible, and realistic. Smart home technology is any collection of devices and systems that are linked to a network and have remote control and independent operation capabilities. Using your smartphone or a mobile touch-sensitive device, you may control the temperature, lights, music players, TVs, door locks, gadgets, and more that are all connected to one system in your house. The Internet on the other hand has helped this human interaction to move one step ahead. In the past, the Internet was predominantly used for communication, but today it is utilized for a wide range of purposes. The advancement of technology has brought about a new era of interconnected devices, collectively referred to as the Internet of Things (IoT). This technology has revolutionized various industries and has had a significant impact on the way the authors live our lives. The Internet of Things (IoT) can be summed up as the linking of common objects to the Internet, that have sensors, electronics, and software incorporated in them. It helps in gathering and communicating data without the need for human involvement. Smart home automation is connecting and controlling devices via a central smart home hub. Devices like smartphones, TVs, washing machines, sensors, refrigerators, and lights have been a part of our day-to-day life, which can be interconnected in a network via sensors, actuators, and controllers to form a system that helps not only increase the comfort of people but also their safety, and increase their efficiency in everyday work. The market is filled with a huge number of smart home appliances. An example of such a smart home appliance is a smart bulb that can be operated directly through an app. Almost all home appliances used by people can be categorized as IoT devices and can be used in home automation to make the life of a common person a lot easier. Smart home automation has made high-tech utility and luxury accessible to everyone in ways that weren't before possible. As technology develops, home automation will have a greater potential to enhance the quality of life. Also in this paper, the authors have proposed a very simple model of home automation which anyone would be able to implement easily to control their home smartly.

## 2 Literature Survey

R. Teymourzadeh, Salah Addin Ahmed, Kok Wai Chan, and Mok Vee Hoong, "Smart Global System for Mobile (GSM)-based Home Automation System," 2017. This paper aims at the usage of the Global System for Mobile Communication (Global System for Mobile (GSM)) modem to control all the devices that are a part of any automated home. In support of this statement, the paper proposes the various features of the Global System for Mobile (GSM) protocol. Also, it suggests the use of a

Peripheral Interface Controller (PIC)16F887 microcontroller with Global System for Mobile (GSM) enhances the technology. Somani, P. Solunke, S. Oke, P. Medhi, and P. P. Laturkar, "IoT-Based Smart Security and Home Automation," 2018. This research is all about how appliances are installed with sensors and actuators that allow data transfer over a network. Also, this suggests how the installation of these smart IoT-based devices in our houses can enhance the automation process in our houses. This paper also suggests the security features of this technology. L. Li, H. Xiaoguang, C. Ke, and H. Ketai, "The applications of Wi-Fi-based Wireless Sensor Network in Internet of Things and Smart Grid," 2016 suggest that Wi-Fi-based wireless sensor networks offer unique features that other Internet of Things (IoT)-based devices do not. A few of these features include high bandwidth, a high transmission rate, non-line transmission, and a feature that is very different from other IoT devices: video sharing. This Wireless Sensor Network (WSN) is a very economical approach. The study also makes recommendations on how IoT technology might advance as a result of this technology. The use of Wireless Sensor Network (WSN) in IoT in smart grids, smart agriculture, and intelligent environmental protection serves as the paper's ultimate conclusion. R. Piyare and M. Tazil, "Bluetooth-based home automation system using cell phone," 2016 suggest how smart home automation can be achieved by Arduino BT board. This suggested system in this is cost-effective and feasible. It also provides password protection so that only authorized persons can access the appliances. M. J. Iqbal et al., "Smart Home Automation Using Intelligent Electricity Dispatch," 2021, advocate using this technology in an energy-efficient way so the financial and ecological concerns are maintained as a solution to one of the primary issues with smart home automation. This paper offers a solution by recommending manual, app-based, or web-based device switching based on the requirements of the user. In their 2017 paper, "Smart House Automation Using Internet of Things," M. Goyal and N. Kumar present an IoT-based smart home automation system that enables remote control of home appliances using a smartphone application. In order to automate the home environment according to the user's preferences, the system contains sensors that can detect the presence of people, temperature, and humidity levels. The report emphasizes the advantages of IoT-based smart home automation, such as energy savings, heightened security, and enhanced convenience. An overview of the many home automation systems on the market, including wired, wireless, and hybrid systems, is given in R. Das and M. Ghosal's 2018 article, "A Complete Analysis of Home Automation Systems." The report examines the benefits, drawbacks, and features of each system and offers views about how home automation technology will grow in the future. In their article "Smart House Automation: A Review," S. Gupta, S. K. Singh, and S. Khurana undertake a thorough analysis of several smart home automation systems, including IoT-based, voice-controlled, and gesture-controlled systems. The research assesses each system's functionality, usability, and security and offers insights into the prospects and problems facing the sector of smart home automation. The authors of "Smart Home Automation System Using Deep Learning Techniques," published in 2021, N. A. Malik, A. B. A. Rahman, and M. F. A. Rasid, propose a smart home automation system that makes use of deep learning to offer personalized home automation services based on

the user's behavior and preferences. The system has sensors that can recognize the user's actions and change the atmosphere of the house accordingly. The study emphasizes how deep learning has the potential to enhance the precision and efficiency of smart home automation systems. A thorough analysis of the many technologies, platforms, and standards utilized in smart home automation systems is provided in M. H. Alsuwailem's 2022 article, "Towards Smart House Automation: A Review of Technologies, Platforms, and Standards." The study offers insights into the future growth of smart home automation by analyzing the characteristics, advantages, and limits of each technology. A review of smart home automation systems and technologies is given in S. Karakus and O. Uykan's 2019 article, "A Review of Smart Home Automation Systems and Technologies." The research discusses a range of topics related to smart home automation, such as energy management, user interfaces, communication protocols, and sensors. The writers also discuss the difficulties and possibilities associated with smart home automation. S. Sharma and S. Dhawan, "A Review on Smart House Automation Technologies," 2020, examine the IoT, cloud computing, and AI technologies utilized in smart home automation systems. The study assesses the merits and drawbacks of each technology and offers insights into how smart home automation will grow in the future. A complete assessment of smart home energy management systems is provided by M. H. Alnaser, M. T. Rahman, and S. A. Mahmud in "A Comprehensive Review of Smart Home Energy Management System," published in 2021. Demand response, energy monitoring, and energy conservation are only a few of the several facets of energy management that are covered in the research. The writers also discuss the difficulties and possibilities associated with smart home energy management. A comprehensive review of smart home automation is provided by N. K. Gupta, A. Jain, and V. Tyagi in their article from 2021, "A Comprehensive Review on Smart Home Automation: Opportunities and Challenges," which covers a variety of topics including security, privacy, energy efficiency, and interoperability. The writers examine the possibilities and difficulties in the area of smart home automation and offer views on how the technology will advance in the future. Smart home automation: A Study of Security and Privacy Problems, S. Patil and A. Sharma, 2022, offers a thorough analysis of the security and privacy concerns with these systems. Data protection, authentication, and access control are just a few of the security and privacy-related topics that are covered in the research. The authors offer insights into the upcoming development of safe and privacy-preserving smart home automation systems by analyzing the prospects and problems in the field of security and privacy in smart home automation.

### 3 IoT in Smart Homes

See Fig. 1.

Internet of Things (IoT) has fundamentally changed how the authors live, and one area where it has done so is in the field of smart houses. A smart home is a building with fixtures and equipment that can be operated remotely or automatically to carry out certain duties following set guidelines or parameters. Smart houses have become even more intelligent and effective as a result of IoT integration [1].

Lighting, heating, ventilation, air-conditioning, security, and entertainment are just a few of the systems and appliances that may be highly automated and controlled in smart homes thanks to IoT. The smart home can monitor and modify the environment based on resident preferences with the use of sensors, cameras, and other connected devices.

The following are some of the main advantages of IoT in smart homes:

A. Energy Efficiency:

By automatically changing heating, cooling, and lighting based on occupancy and weather conditions, IoT-enabled smart homes can save energy use [2].

B. Convenience:

Smart home devices may be remotely managed with the use of a smartphone or tablet, making it simple to check on settings from any location.

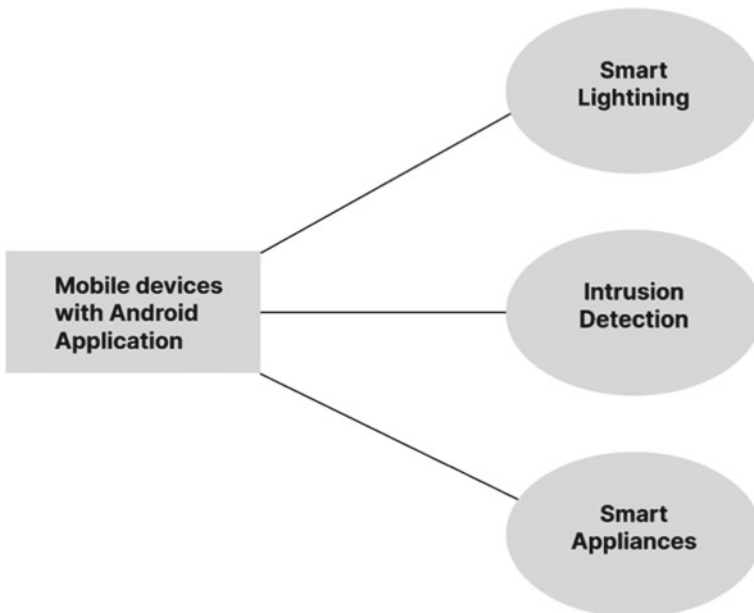


Fig. 1 A diagram of smart home automation

C. Security:

IoT-enabled security systems can send real-time alerts and monitor the home with video to make sure it is always safe and secure.

D. Customization:

Smart home appliances can be set up to react to particular triggers and circumstances, enabling one-of-a-kind and personalized experiences.

Smart appliances, voice assistants, smart security systems, smart lighting, and smart thermostats are a few of the prominent IoT gadgets used in smart homes. More gadgets and systems will likely be integrated into houses to make them smarter, safer, and more effective as the IoT in smart homes continues to rise.

### 4 Different Methods of Home Automation

Home automation is the use of technology and gadgets to automate and control various home systems and appliances. The choice of a home automation approach is influenced by a variety of variables, including a budget, the number of devices that need to be managed, and the required level of automation. To achieve the required amount of automation in their houses, homeowners might use one way or a mix of technologies.

There are many ways to automate your home, however, a few of the more well-liked ones include: automating your home, however a few of the more well-liked ones include (Fig. 2).

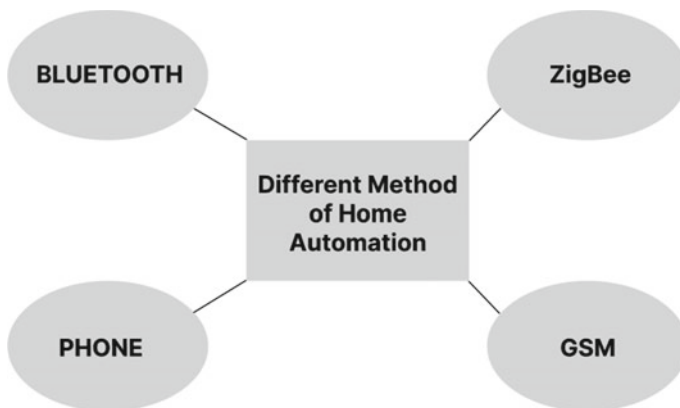


Fig. 2 Flowchart for a different method of smart home automation

### 4.1 Bluetooth

See Fig. 3.

Bluetooth is a wireless technology that enables proximity (about 10 m) communication between devices. Because of its low-power consumption, simplicity of usage, and ubiquitous availability in many electronic products, it has grown in popularity as a solution for home automation [3]. A smartphone, tablet, or computer can be used to control and connect with Bluetooth-enabled devices. This makes it the perfect technology for uses in the home that automate things like lighting, heating, security, and entertainment.

A user interface for a mobile phone running an interactive Application is provided via an Arduino Bluetooth board. The I/O ports on the Bluetooth board are used to communicate with and control the devices. It also aids in preventing unauthorized access from abusing the system. Password protection on Bluetooth makes it safer to use. The range of Bluetooth is 10–100 m. The Bluetooth standard protocols state that it operates at a speed of 3 Mbps while using 2.4 GHz bandwidth [4]. The app is transferable and is as fast as well as an efficient system that can send and receive timely diagnostic reports through a feedback system. Bluetooth technology can only be accessed within its range.

The lack of an Internet connection, which might be a security concern for some homeowners, is one advantage of adopting Bluetooth for home automation. Also, because of its limited range, remote system access by hackers is more challenging. Another benefit of adopting Bluetooth for home automation is that it has a big user base and is an established technology. This indicates that a Bluetooth-based home automation system can incorporate a wide variety of devices with ease. Bluetooth can be used for home automation; however, there are some restrictions. One of its key drawbacks is its low range, which necessitates that devices are close to one another to communicate [3]. Larger residences may have an issue, as well as those with walls or other obstructions in the path. Moreover, Bluetooth cannot be used

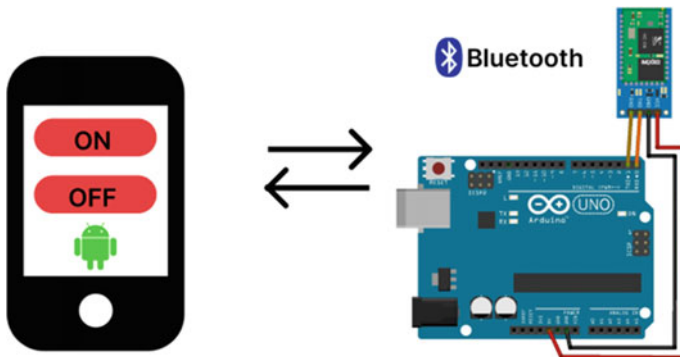


Fig. 3 App-based controlling using Arduino BT



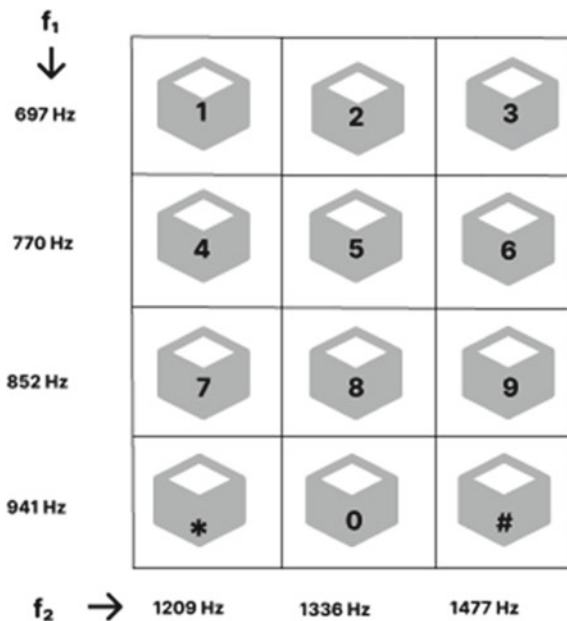
to control equipment that is located outside the home, which may limit its applicability in some situations. In conclusion, Bluetooth can be a useful tool for home automation, especially for directing devices that are close to the device. For larger or more complicated home automation systems, it might not be appropriate for all applications and could need to be coupled with other technologies.

### 4.2 Phone-Based

See Fig. 4.

A method called Dual-Tone Multi-Frequency (DTMF) is used to transmit and receive signals over a phone connection. When a key is pressed on a phone keypad, Dual-Tone Multi-Frequency (DTMF) signals are produced, and these signals can be utilized to operate numerous devices. Telephone line control is used by Dual-Tone Multi-Frequency (DTMF)-based smart home automation systems to operate various home appliances. To operate various home appliances, the user can dial a number and enter a series of Dual-Tone Multi-Frequency (DTMF) signals. For instance, the user might dial a number and enter a specified string of Dual-Tone Multi-Frequency (DTMF) signals to modify the thermostat, turn on or off the lights, or unlock a door. Additionally, this technology can be utilized to operate other home automation systems, including security and audio systems.

Fig. 4 Dual-Tone Multi-Frequency (DTMF) phone frequencies



The entire system is divided into three functional components. The first unit has a Dual-Tone Multi-Frequency (DTMF) that picks up signals and also consists of a ring detector that is connected to it. The unit that will manage the system’s input and output follows this. Finally, it contains a PC/hardware device that will carry out the user’s requested commands.

The ease of use and lack of need for specialized tools or training are two benefits of Dual-Tone Multi-Frequency (DTMF)-based smart home automation. The majority of individuals are already accustomed to using telephones and entering Dual-Tone Multi-Frequency (DTMF) signals. Not only is it reasonably priced, but the system also operates quickly. This technology does have certain limits, though. The system’s ability to link to so many different devices is one of its drawbacks. Since conventional phones have just 12 keys worldwide, a user can only connect 12 devices. In some cases, noise or interference on the phone line can also interfere with Dual-Tone Multi-Frequency (DTMF) signals, resulting in errors or incorrect commands being transmitted to the home automation system. In conclusion, Dual-Tone Multi-Frequency (DTMF)-based smart home automation can be a useful method for managing multiple home appliances through a phone line [4]. More sophisticated home automation systems might need to be integrated with other technologies as it might not be appropriate in all circumstances.

### 4.3 Zigbee

See Fig. 5.

A wireless communication protocol called Zigbee was created especially for low-power, low-bandwidth, and inexpensive applications. This wireless protocol is used by Zigbee-based smart home automation to operate and communicate with various home appliances, including heating, cooling, and security systems. IEEE 802.15 is the operating system. The smart home is a great application for this wireless communication technology [5]. It makes use of a Peripheral Interface Controller (PIC) microcontroller and voice recognition for this procedure. Input devices like microphones are used to capture spoken commands. Devices can connect using

Fig. 5 Zigbee-based home automation system



Zigbee technology without needing to be within range of a central hub since it enables devices to interact with each other using a mesh network. This may aid in extending the system's range and reliability.

A hub or gateway, sensors, controllers, and actuators are typical components of a Zigbee-based smart home automation system. The hub serves as a central control point and uses Zigbee wireless technology to connect with the sensors and controllers. The controllers respond to changes in the environment caused by the sensors, such as motion, temperature, or light.

Zigbee is very simple to implement as well as to understand. The voice instructions are used as input, and a recorded and processed voice is used as a comparison. Following this, a Peripheral Interface Controller (PIC) microcontroller is used to carry out the task. One Peripheral Interface Controller (PIC) controller communicates the orders through Zigbee to the receiver, while a second Peripheral Interface Controller (PIC) microcontroller carries out all the processing. Relays are used by this microcontroller to operate the relevant appliances.

The range of Zigbee is just approximately 291 m, which is relatively short and hinders the transmission of commands [6]. The speech recognition module becomes difficult to utilize as a result. But in contrast to the limited coverage area, Zigbee is the most cost-effective and power-efficient smart home automation tool.

Low-power consumption is one of the key benefits of Zigbee-based smart home automation, which can assist to increase device battery life and cut down on energy expenditures. Zigbee technology is also ideal for usage in bigger houses or commercial structures because it is incredibly dependable and supports a huge number of devices.

The ability of Zigbee-based smart home automation to work with other home automation platforms like Google Home and Amazon Alexa is another benefit. This gives the system more adaptability and control.

Zigbee-based smart home automation does have certain limits, though. The limited range of Zigbee wireless technology is one of its key drawbacks, which can be an issue in larger households or if there are walls or other obstructions in the way [7]. Moreover, Zigbee cannot be used to operate equipment that is located outside the home, which may limit its applicability in some situations.

In conclusion, Zigbee-based smart home automation can be a reliable and efficient approach to operating different appliances in the house over a wireless network. More sophisticated home automation systems might need to be integrated with other technologies as they might not be appropriate in all circumstances.

### 4.4 Global System for Mobile

See Fig. 6.

The system proposed in the following method has three key elements for managing the home appliances, namely the Internet, Global System for Mobile (GSM), network, and voice control [8]. Real-time control and communication with household appliances are one of the primary aspects of home automation. The three key elements you mentioned are:

1. **The Internet:** This technology allows devices to connect to the Internet and communicate with each other. In a smart home, Internet connectivity is crucial for managing and controlling various appliances and systems remotely, using a smartphone, tablet, or computer.
2. **Global System for Mobile (GSM) network:** Global System for Mobile (GSM) stands for Global System for Mobile Communications, and it is a standard for cellular networks used by many mobile phones and other devices [8]. In a smart home, Global System for Mobile (GSM) can be used to communicate with devices and appliances via text messages or notifications.
3. **Voice control:** Voice control technology allows users to control their smart home devices and appliances using voice commands. This is typically accomplished through smart speakers or virtual assistants like Amazon Alexa, Google Home, or Apple HomeKit.

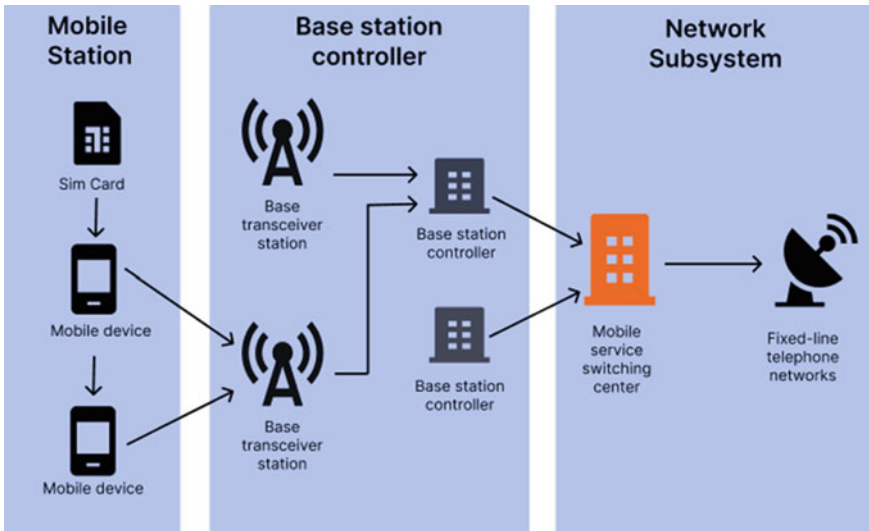


Fig. 6 Working of a Global System for Mobile (GSM) model

By combining these technologies, a smart home automation system can provide users with a convenient and seamless way to manage their home appliances and systems. Through a PC, the user sends instructions to the server [9]. The server transmits these instructions to the appropriate units for implementation after processing every command given by the user. Establishing a reliable Internet connection is made easier by Global System for Mobile (GSM). To establish a connection or communicate with a Global System for Mobile (GSM) modem, the server uses attention (abbreviated as AT) commands. For example, a user could use their smartphone to turn off the lights or adjust the thermostat, receive a text message notification if the security system detects an intruder, or use voice commands to play music or check the weather forecast.

Some advantages of using a Global System for Mobile (GSM)-based smart home automation system are:

1. **Remote access:** The user can control the devices from anywhere in the world using their mobile phone.
2. **Real-time monitoring:** The user can monitor the environment and devices in real time.
3. **Energy savings:** The system can be programmed to turn off the devices when not in use, leading to energy savings.
4. **Enhanced security:** The system can be used to monitor the security of the house by detecting motion and sending alerts to the user.

There is a chance that SMS delivery will be delayed [10]. Its drawbacks include the need to deploy repeaters to expand coverage and the possibility of electrical interference [8]. Overall, a Global System for Mobile (GSM)-based smart home automation system is a convenient and efficient way to control and monitor your home appliances and devices.

## 4.5 *Mixed Type*

The process for deploying home automation through the fusion of all previously covered technologies is covered in this section. The user will manage the appliances using an intuitive and easy-to-use Android application. The user can effortlessly command a desired action to be performed just by using their voice [5]. These orders are subsequently delivered by SMS to another device, where they can conveniently be forwarded over Bluetooth to a Peripheral Interface Controller (PIC) controller [3]. These instructions are sent to a Zigbee transceiver via a Peripheral Interface Controller (PIC) controller. To complete the necessary operation, the Zigbee ultimately employs the same method that was discussed in Sect. 5.3 of this research paper.

Since it makes use of several controllers and numerous distinct technologies, this approach of merging and utilizing all of the technologies is not commonly employed.

Additionally, the ideal option for home automation isn't to rely solely on SMS for quick and reliable data delivery.

## 5 Discussion

See Fig. 7.

The authors must thoroughly compare each one to determine the best approach to take when integrating home automation in any region. The key elements that all approaches have in common are their reliance on the same core communication technology and their use of control circuitry as an interface with electrical equipment. All of these approaches receive their advantages and disadvantages from their underlying technology.

The user interface is the next most crucial component of home automation. It provides the required amount of control of the user over the system and builds the user system understanding. It also affects how broadly the system may be used [1].

A crucial component that all users demand from home automation systems is security, which makes sure that only authorized users have access to their appliances. Some of the most prevalent approaches used in home automation systems are Global System for Mobile (GSM), Bluetooth, Wireless Sensor Network (WSN), and combinations of these technologies.

You can operate appliances using home automation from anywhere on the globe. However, depending on the locality, the cost may differ. This system's unreliability—where there is no assurance that the message will be delivered—is a serious drawback. This drawback of home automation makes it challenging to connect with and regulate appliances in real time.

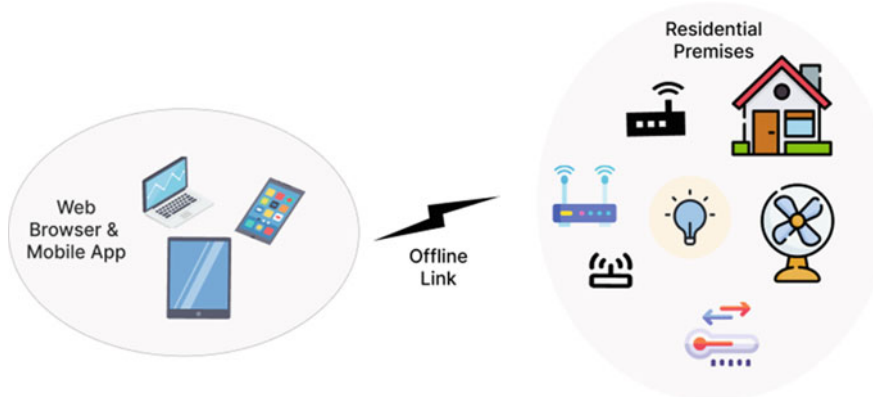


Fig. 7 App-based controlling of home appliances

Global System for Mobile (GSM) may communicate with users through software and network connectivity. As long as the user is near the gadget Bluetooth can provide the user with a strong connection using a smartphone or computer. It is capable of operating as a system design. Communication happens quickly and frequently. It indicates that the user can get notifications of events as necessary. It cannot offer its services to the individual if they are outside their home. The range provided by Bluetooth is its main demerit which is only about 10 m [8].

To transmit instructions with handset functions one can, use those double frequency values. The phone-based automation system is dependent on the transfer of commands via a phone call from any remote area. The disadvantage here is Dual-Tone Multi-Frequency (DTMF) tones which are in limited amounts.

Zigbee is a Bluetooth-compatible alternative technology. It has the same benefits and drawbacks as GPS. It is a new technology that uses wireless systems for messaging. These could be radio frequency or electromagnetic rays. It is also capable of powering a system's behavior. The only drawback here is the spectrum's variation and accessibility [11]. Radio waves have a much greater range and are ideal for remote access. However, the existence of the spectral region must be considered. Certain spectrum products are in high demand, while unlicensed bands are used in many other implementations [1]. There is a chance of invasion. It jeopardizes the program's security. Many systems use a fusion of the research methods to reimburse for the shortcomings of each. Such a hybrid execution can result in sound systems. The only factors that may impact such systems are the cost of the frameworks and the prospect of duplication of effort. Some other component in which structures differ greatly is the user interface. Early systems had marginal or no user interface and relied on keys for the user to enter commands to the controllers. On the other hand, modern systems have intuitive user interfaces that have been meticulously designed. New phones seem to be used mostly these days [12]. Smartphones are a useful method for managing home automation systems overall. Another option is to use web applications, which can run on browsers. It is also a popular option, but it is not as convenient. Table 1 provides a comprehensive correlation of all systems and applications.

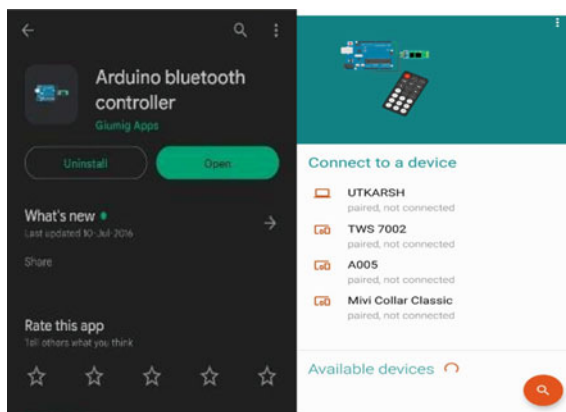
**Table 1** Comparison report of all system

| System type | Mode of communication     | Range of access         | Number of devices | Cost of installation                               | Speed of delivery      |
|-------------|---------------------------|-------------------------|-------------------|--|------------------------|
| GSM         | SMS messages              | Unlimited access        | Unlimited         | High cost because of SMS charges                   | Slow                   |
| Bluetooth   | Bluetooth and AT commands | Standard 10 m           | Unlimited         | Protocol is free and installation is low cost      | Fast                   |
| Zigbee      | Zigbee and AT command     | Expected range is 291 m | Unlimited         | Protocol is free to use but installation is costly | Maximum speed 250 kbps |
| Phone-based | Telephone lines           | Anywhere with phone     | 12                | Quick  | Quick                  |

## 6 Bluetooth-Based Home Automation Model

### 6.1 Apparatus Required

The apparatus or components required for building a Bluetooth-Based Home Automation Using Arduino are as follows: Arduino NANO REV3, HC-05 Bluetooth module, 5-V 1-channel Arduino relay module, a few male-to-male jumper wires, and a breadboard (Figs. 8, 9, 10, 11, and 12).



**Fig. 8** Illustrations of the app





Fig. 9 5-V 1 channel Arduino relay module

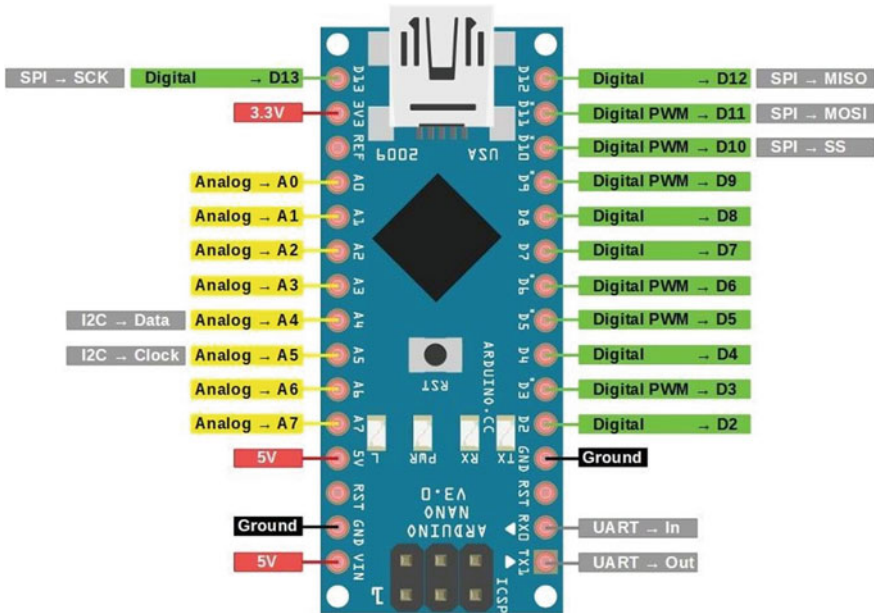


Fig. 10 Arduino NANO

### 6.2 Implementation Work

- On the breadboard, place the Arduino NANO.
- Using the male header pins, attach the Arduino relay module to the breadboard.
- Finally, attach the HC-05 Bluetooth module to the breadboard.
- Now, using the male-to-male jumper wires connect the:
  - the 5-V pin of the Bluetooth module to the VCC pin of the Arduino relay module;
  - the ground pin of the Bluetooth module to the ground pin of the relay module;
  - VCC pin of Arduino relay module to Arduino NANO 5-Volt pin;
  - ground pins of relay module and Arduino NANO;
  - IN pin of relay module to the second digital pin of Arduino NANO;
  - TX pin of Bluetooth module to RX pin of Arduino NANO;

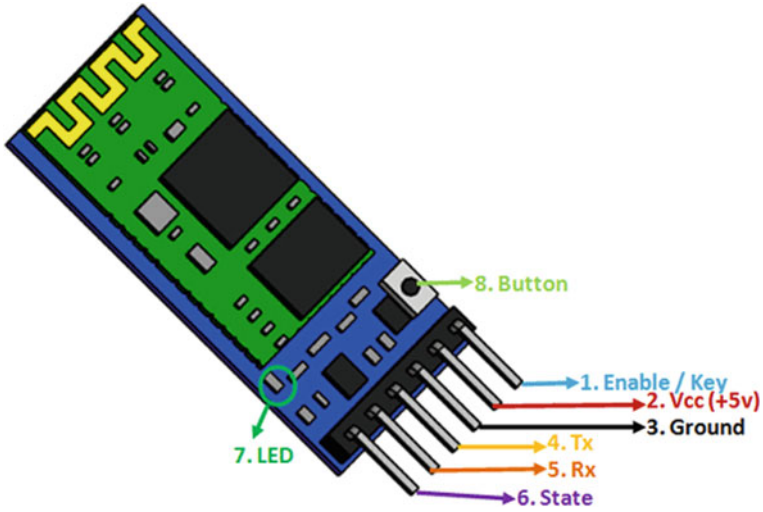


Fig. 11 HC-05 Bluetooth module

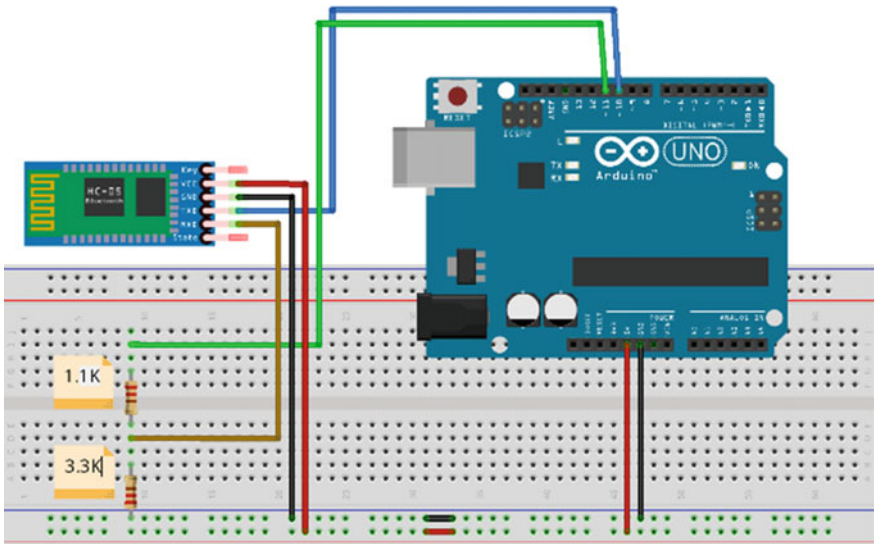


Fig. 12 Bluetooth HC-05 with Arduino

- RX pin of Bluetooth module to TX pin of Arduino NANO.
- To supply the external 5-V, the authors will connect the IN pin and ground pin.
- Before connecting the breadboard to the PC using a USB cable, make sure to disconnect the TX and RX pins from the Arduino NANO side.

- Using the Arduino IDE, select the appropriate settings and upload the required code. After uploading the entire code, disconnect the breadboard and PC as well as remove the USB cable from the breadboard.
- Now reconnect the TX and RX pins of Arduino NANO and connect the external 5 V.
- By using an app named Arduino Bluetooth controller (which is already available on Play Store), the user can connect their Bluetooth chip-controlled household appliances to their phone and later control them.

### ***6.3 Algorithm for Arduino NANO Chip***

1. Include the SoftwareSerial library for serial communication through Bluetooth.
2. Initialize a new SoftwareSerial object “Bluetooth” with pins 0 and 1 for communication.
3. Declare a variable “BT\_input” of data type char for storing the Bluetooth input data.
4. Define four output pins R1, R2, R3, and R4 with their respective numbers.
5. In the setup() function, start the Bluetooth communication at a baud rate of 9600.
6. Set the pins R1, R2, R3, and R4 as output pins using the pinMode() function.
7. In the loop() function, check if any data is available from the Bluetooth module using the available() function.
8. If data is available, read the data into the “BT\_input” variable using the read() function.
9. Using the “if-else” conditional statements, check the received data and turn on/off the respective output pins.
10. Then add the following function to control different appliances:
  - (1) If the received data is ‘O’, turn off R1.
  - (2) If the received data is ‘F’, turn on R1.
  - (3) If the received data is ‘S’, turn off R2.
  - (4) If the received data is ‘E’, turn on R2.
  - (5) If the received data is ‘T’, turn off R3.
  - (6) If the received data is ‘K’, turn on R3.
  - (7) If the received data is ‘L’, turn off R4.
  - (8) If the received data is ‘D’, turn on R4.
  - (9) End of the loop () function.

## 7 Advantages of Home Automation

The ease and comfort of living distinguish the lifestyles of those in urban India from those in rural India. Although technology has largely spread throughout India over the last ten years, there is still a long way to go. The authors can anticipate the expansion of technology in rural areas now that everyone in India, both urban and rural, possesses a smartphone and has access to the Internet. The introduction of home automation is one of the many methods to enhance living comfort and lead a lavish lifestyle. The authors can implement many technological breakthroughs that the contemporary world has already witnessed in such regions using the technology that has already been established in rural areas.

### A. Management of Home Devices

Home automation allows an individual to single-handedly manage all their appliances and gadgets from an easy-to-use single interface. Smart homes provide enormous comfort [1]. Home automation is a big leap forward in technology as well as home management systems. In this technology, all the user has to learn is how to operate a single application through their mobile device. Once the user becomes familiar with the application, they are ready to faucet into a plethora of functions and devices all across their home. This comfortable and convenient interface, i.e., the application, helps lower the learning curve for them.

### B. Flexible Addition of New Technology

Smart homes provide greater flexibility in adding new devices and appliances to the pre-existing network of devices. Using home automation pushes an individual to acquire and accommodate gadgets with newer technology embedded in them [7]. This makes their home not only pleasing to outsiders but also helps them in managing and securing their homes. Individuals can accommodate these newcomers without facing any difficulty. This helps the owner to keep in touch with the latest home-related technologies.

### C. Wireless Home Security

Home automation systems offer tremendous security advantages. They give you genuine peace of mind by allowing you to monitor your house from a distance. Some systems provide remote arming and disarming of your house's security system and communicate with your surveillance system [11]. You may be notified by phone, text, or email whenever there are any strange movements inside your home by some full-home automation systems. By managing and lowering your energy usage, you can easily save on your finances monthly. Perhaps most crucially, full-home automation enables you to adapt your house to your family's needs and way of life.

#### D. Remote Controlled Home

Remote access to your home can prove to be of great advantage in every possible aspect. For instance, you can easily manage your home's temperature which you desire to have when you are about to reach home or set your oven to preheat while you do the rest of the preparation of your meal [13]. Additionally, you can manage your home appliances while you are away or check on your entrance door and windows whenever you wish to do so.

#### E. Increases Energy Efficiency

An individual can easily make their home and its appliances more energy efficient by using home automation in a well-mannered way [2]. For instance, a temperature controller can recommend energy-efficient settings to you, by studying your daily patterns and requirements which you manually set or change according to your surroundings, you can set your lights to automatically dim or your drapes to automatically set themselves according to the time of day [14]. You can also make sure that all the appliances were turned off after you left from home to save not only on your monthly budget but also save you and your home from hazardous unwanted situations or accidents.

#### F. Home Management Insights

Additionally, your capacity to gain knowledge and have detailed insights about how your house functions. You can track your energy use patterns over time, by keeping an eye on how frequently you watch Television, how often you prepare your meals in your oven, and what kinds of items you store in your refrigerator [10]. With the help of these revelations, you might be able to evaluate your routines and behaviors and make necessary changes to lead the lifestyle you wish.

#### G. Convenience

Being home when the kids arrive at the door or the repairman arrives can be challenging due to life and traffic. The simplicity of being able to access your home equipment remotely can also be a significant time saver because you cannot be at two places at once. Without getting out of bed, switch off every light in your house [12]. Turn on/off your wireless house security alarm system using your cell phone or a portal device, or use voice commands to operate appliances throughout the house.

#### H. Saves Money and Time

The authors don't even have time to think about our house because the authors live in such a fast-paced environment. By using home automation, the authors could save time returning home to check on things like whether the kids locked the door after school or turned on the lights when the authors got home.

The main benefit of home automation is this. Homeowners will save money if they can manage the lights, either by dimming them or turning them on and off at particular times. Keeping your home at a comfortable temperature can help you

save money when your window treatments and thermostat are properly automated. In addition, you can save gas by staying put if you forgot to lock the door or switch off the appliances at home.

## 8 Conclusion

In today's modern world, every human being wishes to lead a luxurious and comfortable lifestyle. These days none of the people residing in urban cities want to go back to the rural areas because the rural areas lack many services that are easily available in cities. So, in this research paper, the authors have introduced different methods with which the authors can provide a smart home lifestyle to people living in rural areas. These methods include technologies that the authors have discussed in our paper some of which are, Zigbee, Global System for Mobile (GSM), Bluetooth, and a combined system using all these technologies. With the help of our research, the authors want to provide everyone with a lifestyle that is both economically feasible and energy efficient for them.

By the study of this research paper, the authors can get a clear idea of how the authors can create an ideal system for home automation that can be accessed single-handedly from a remote destination [6]. Based on all the systems discussed in the paper and considering all their advantages and disadvantages the authors can conclude one method that is an optimal methodology to implement people-friendly home automation in a rural area in a convenient way. From the data gathered in the paper, the authors are clear that the Global System for Mobile (GSM) network is a contender in this. A data channel of the Global System for Mobile (GSM) network can provide worldwide Internet access and to make sure that access is available anytime anywhere only the Internet can guarantee that.

To provide a user interface via a web-based application that is connected to a phone application which allows the user to access the device from anywhere via any device. As the proposed system is for rural area people then the convenience of installing the system should be considered, that is the whole system including the phone application should be easy to install and the web application should be easy to use [1]. While designing the system the interface should be interactive and attractive to users. Plug-and-play capabilities can play a gratuity part in the system. And even if the user changes or adds a new device then that should also be easy to do.

These are the future applications of this system, which makes homes even smarter through installation. Numerous sensors can be integrated into homes, including motion sensors, temperature sensors, light sensors, and automatic device switching based on conditions [10]. Additionally, energy conservation measures are taken, such as checking the luminance and shutting off lights when not required. The next stage should be to expand this system that controls a big size area because it offers cybersecurity and protection for homeowners.

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# An Intelligent Diabetes Predicting Model for Diverse Ethnicities



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and Vaishnavi Deulkar

**Abstract** Diabetes is a metabolic disorder comprising high glucose level in blood over a prolonged period in the body as it is not capable of using it properly. Diabetes is a major cause of blindness, kidney failure, heart attacks, stroke, lower limb amputation, retinal damage, and foot ulcers. The condition is a result of the inter-linkage of lifestyle choices, xenogenetic, psychological, socioeconomic, medical disorders, and geographic attributes. Machine learning-based decision support systems for the prediction of chronic diseases have become immensely popular for better prognosis/diagnosis support to health professionals. Current computational methods for diabetes diagnosis have some limitations and are not tested on varied datasets or people from different countries which limits the practical use of prediction methods. This study identifies classifiers which work with optimal accuracy over three ethnicities. Three unique datasets were identified for this study which are an Indigenous population of USA, European population, and South Asian population for accurate prediction, diagnosing, and treatment of disease. Machine learning algorithms were applied on the datasets, and a comparative study was made. For South Asian ethnicity, GPC, RF, DT predicted with accuracy of 91.62% each. For European ethnicity, the same was performed with 97%, 98.2%, and 97.8%, respectively. For Indigenous Tribe of USA when GPC, RF, and DT were applied, the performance was 61%,

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78.6%, 71.8%. SVM and LDA performed better with 80.2% for Indigenous Tribe of USA. Random forest performed with high accuracy on South Asian and European population and comparable accuracy for tribe of USA. Our study provides a base for reducing the gap in polygenic risk prediction accuracy.

**Keywords** Diabetes · Prediction · Machine learning

## 1 Introduction

According to the International Diabetic Federation, in 2045, the number of persons suffering from Diabetes will reach 783 million. A 10% fraction of the adult population will acquire diabetes, and in some cases, the individual may not be aware of the critical situation. Diabetes has a devastating effect on people and societies, irrespective of age, community, and continent. It is a major contributor in morbidity with 4 million deaths per year [1]. Diabetes was responsible for 6.7 million deaths in 2021—1 every 5 s. Hence, there is urgent need of mechanism which will lead to identifying individuals with high risk of acquiring glucose intolerance. In addition, an intelligent system is required which will calculate risk scores. This system will be a blessing in disguise to the medical practitioners as well as the people bracketed in the risk zone.

Researchers have developed many computational models but they were restricted to demographically and ethnically restricted populations. They were not validated by multi-ethnic datasets or populations from multiple races. Due to this lacunae, the prediction models could not be implemented successfully for real-life scenarios of multi-ethnic populations. The performance of a diabetes risk prediction model for a multi-ethnic population should be at comparable level for individual population. But it has been observed that there are substantial divergence in diabetes risk when compared on the basis of ethnicity [2]. The risk score devised from the Framingham Study had to be adjusted accordingly for multi-ethnicity population. Otherwise, there is a possibility of degraded performance of the prediction due to over or underestimation of events. This study aims to compare the performance of prediction models on three diabetes datasets derived from European, Indigenous American and South Asian population. To do so, we performed a cohort analysis summarized to evaluate if the model works univocally on American, European, and South Asian races.

## 2 Literature Review

This section explores peer researchers' contributions in recent years in predicting diabetes mellitus with focus on ethnicity using machine learning classifiers.

Wei et al. [3] applied random forest (RF) with the least absolute shrinkage and selection operator (LASSO) regression on multi-ethnicity of USA dataset for prediction of diabetes. The researcher [4] proposed a novel hybrid machine learning framework for the prediction of diabetes using artificial neural network (ANN) with genetic algorithms and tested it on Pima Indian Dataset (PIDD). Ismail et al. [5] compared accuracy on PIDD, Bangladesh dataset, and multi-ethnic group dataset and found bagging LR to be most accurate. Krishnamoorthi et al. [6] worked on PIDD and found LR to be most effective classifier.

The researcher [7] accounted for incredible accuracy of 94.87% with a fusion ML model using SVM, artificial neural network, and fuzzy logic on PIDD. Momenzadeh et al. [8] tested the predictive model for diabetic complications on multi-race dataset of Australia and found that random forest and AdaBoost gave the best results. The study performed by [9] on PIDD for prediction of diabetes achieved 81.25% accuracy while using gradient boost.

Mushtaq [10] developed a unique voting model where the best combination of machine learning classifiers. The model was tested on four datasets comprising white and black population and voting classifier was evaluated and found to be 81.7% accurate on the original dataset and 81.5% accurate on the balanced dataset. Kraege et al. [11] used logistic regression on dataset of Switzerland and compared it with risk scores of French and US Clinical data. The model was validated on three cohorts—Europe, Iran, and Mexico.

Chang et al. [12] tested NB classifier, random forest, and J48 decision tree on PIDD. The study showed that Naïve Bayes predicted diabetes with the highest accuracy with feature reduction. It did not perform well for multitude of correlated features. Random forest performed with greater accuracy for high-dimensional data. Chikowore et al. [13] concluded that an African-American-derived polygenic risk score performs better in predicting diabetes in continental Africans as compared with European and multi-ethnic risk models.

Márquez-Luna et al. [14] compared the prediction accuracy for diabetes firstly on only Europe population and then with combined European + Latino + South Asian population. The data from the combined population attained more than 70% increased accuracy as compared to training data from a single race. Chahal et al. [15] developed a bootstrapping model to assist clinicians in categorizing people with high risk of cardiac arrest with no history of heart complications on Caucasian, African-American, Hispanic, or Chinese-American patients.

### 3 Methodology

In this study, the aim was to develop a machine learning (ML) model to predict type 2 diabetes employing ten classifiers—kNN, decision tree, Naïve Bayes, support vector machine, random forest, QDA, linear discriminant analysis, GPC, and AdaBoost. Table 1 elaborates on the advantages and limitations for each of the ten classifiers. The classifiers were applied to three diverse datasets of Indigenous Tribe (USA),

**Table 1** Comparative study of different ML classifiers

|    | Methods             | Advantages   | Disadvantages   |
|----|---------------------|--|---|
| 1  | k Nearest neighbor- | No training period, new data can be added seamlessly, easy to implement  | Does not work well with large datasets, high dimensions, needs feature scaling, sensitive to outliers, and missing values |
| 2  | Decision Tree       | Can be applied with great accuracy on datasets with missing values. No need to remove instances with incorrect or missing data | Unstable compared to other methods  |
| 3  | Naïve Bayes         | Highly scalable Suitable for solving multi-class problems  | Zero frequency is an issue  |
| 4  | SVM                 | More productive for high dimensions and out-of-sample data   | Not suitable for large dataset. Difficulty in interpreting results. Selection of kernel difficult                         |
| 5  | Logistic regression | Suitable for large dataset. Easy to interpret. Has greater accuracy as compared to other methods                               | Not suitable for linear data and small datasets with more features  |
| 6  | Random forest       | Can handle large datasets  | Poor performance on imbalanced data   |
| 7  | QDA                 | More flexible, better data fitting   | Not suitable when a number of observations exceed features  |
| 8  | LDA                 | Simple, fast, and works for all size datasets  | Underperforms when features are few   |
| 9  | GPC                 | Fast, easy to use, good at data fitting  | Poor data scaling   |
| 10 | AdaBoost            | Reduces over-fitting. Easy to interpret  | Does not work properly for noisy data and large datasets  |

European, and South Asian, and a comparative analysis was made. The performance metrics used in the study were accuracy, precision, F1-score, and recall.

In this experiment, the accuracy, the recall rate, and precision were used as the evaluation indexes of the classifier performance. These evaluation parameters are based on four values true positives, true negatives, false positives, and false negatives which form the confusion matrix given below:

|                  |    |    |
|------------------|----|----|
| Confusion Matrix | TP | FN |
|                  | FP | TN |

$$\text{Recall} = \frac{TP + TN}{TP + TN + FN + FP}$$

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{Accuracy} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

$$\text{F1Score} = \frac{2 * \text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$

## 4 Experimental Setup, Analysis, and Discussion

### 4.1 Data Collection

- (a) South Asian–BITS (Mesra) dataset contains 972 records local Indian population with 17 features such as age, gender, family history, BMI, consumption of junk food, physically active or not, sleeping hours, quality of sleep, consumes alcohol, smoking, pregnancy, prediabetic, stress level, high blood pressure, regular medication for BP, urination frequency.
- (b) European–Frankfurt (Germany) dataset has total of 2000 instances of local population of Germany containing 1316 diabetic and 684 non-diabetic persons. The features are sugar level, BP, skin thickness, and insulin. Body mass index, family history, age, and result (1 for diabetic, 0 for non-diabetic) were also recorded.
- (c) Indigenous Tribe of USA–Pima Indian diabetes dataset was obtained from Machine Learning Laboratories, University of California, Irvine, USA. This dataset is of the indigenous population of Pima Indian tribe of USA. It has 768 instances of dataset with eight attributes which are pregnancy instances, glucose level after 2 h in an oral glucose tolerance test, BP, triceps skinfold thickness, insulin, BMI, history of diabetes in family and age.

### 4.2 Data Processing

Normalization is the process of incorrect or missing values. After the normalization process, European diabetes dataset instances left were 1035 and for Indigenous Tribe of USA dataset instances left were 392. In Indigenous Tribe of USA dataset five people recorded zero for glucose, 11 people recorded zero body mass index, and blood pressure was incorrectly entered zero for 28 people. Skinfold thickness of 192 people was wrongly entered as 0. Other than these, 140 had serum insulin levels of zero. In European, 13 instances had glucose 0, 25 had insulin 0, 20 had BP 0, 573 had skin thickness 0, and 28 had BMI 0.

After the removal of physiologically impossible data, the performance of prediction accuracy would improve. After this cleaning of data process, the discretization of data is a necessity. Only after this step classification can be performed. Indigenous

Tribe of USA dataset, outcome feature had to be converted to numeric from character value to have a consistent and homogeneous format. In South Asian dataset, age feature was bifurcated into ranges of less than 40, 41 to 50, 51 to 60, 60–80, and more than 80. Physical fitness was decided on duration of activity as none, less than half hour, more than half hour, one hour, or more. Junk food consumption was decided on occasionally, often very often. Stress was categorized as not at all, sometimes, and very often. Urination frequency was classified as quite often and not much.

### 4.3 Implementation and Results

Ten classifiers were applied to the three datasets. For South Asian dataset GPC, decision tree, and random forest predicted with accuracy of 91.62%. For European dataset, random forest gave 98.2% accuracy, whereas decision tree performance was 97.8% and GPC gave 97%. SVM and LDA gave 80.2% for Indigenous Tribe of USA dataset, whereas the top performers GPC gave 61% and decision tree gave 71.8%. GPC, random forest, decision tree worked accurately on diverse ethnicities of Germany and USA. A comparative analysis is depicted pictorially for South Asian ethnicity in Figs. 1 and 2. A comparative analysis is depicted pictorially for European ethnicity in Figs. 3 and 4.

|                    | Accuracy | Precision | F1 score | Recall   |
|--------------------|----------|-----------|----------|----------|
| <b>SVM</b>         | 0.691099 | 0.484848  | 0.351648 | 0.275862 |
| <b>Navie Bayes</b> | 0.366492 | 0.322034  | 0.485106 | 0.982759 |
| <b>LDA</b>         | 0.680628 | 0.463415  | 0.485106 | 0.327586 |
| <b>QDA</b>         | 0.371728 | 0.325843  | 0.491525 | 1.000000 |
| <b>GPC</b>         | 0.916230 | 0.920000  | 0.851852 | 0.793103 |
| <b>AdaBoost</b>    | 0.659686 | 0.414634  | 0.343434 | 0.293103 |
| <b>DT</b>          | 0.916230 | 0.484848  | 0.851852 | 0.275862 |
| <b>LR</b>          | 0.664921 | 0.425000  | 0.346939 | 0.293103 |
| <b>RF</b>          | 0.916230 | 0.920000  | 0.851852 | 0.793103 |
| <b>KNN</b>         | 0.816754 | 0.725490  | 0.678899 | 0.637931 |

**Fig. 1** Performance analysis for South Asian dataset

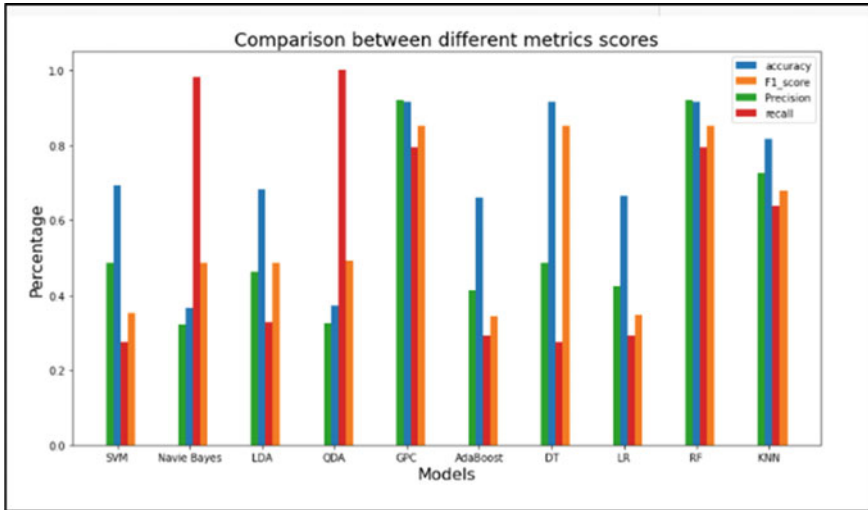


Fig. 2 Comparative performance of the ML classifiers on South Asian dataset

|                    | Accuracy | Precision | F1 score | Recall   |
|--------------------|----------|-----------|----------|----------|
| <b>SVM</b>         | 0.778    | 0.706767  | 0.628763 | 0.566265 |
| <b>Navie Bayes</b> | 0.758    | 0.657343  | 0.608414 | 0.566265 |
| <b>LDA</b>         | 0.766    | 0.689922  | 0.608414 | 0.536145 |
| <b>QDA</b>         | 0.758    | 0.671756  | 0.592593 | 0.530120 |
| <b>GPC</b>         | 0.970    | 0.946746  | 0.955224 | 0.963855 |
| <b>AdaBoost</b>    | 0.826    | 0.792593  | 0.710963 | 0.644578 |
| <b>DT</b>          | 0.978    | 0.937853  | 0.967930 | 1.000000 |
| <b>LR</b>          | 0.772    | 0.713115  | 0.604167 | 0.524096 |
| <b>RF</b>          | 0.982    | 1.000000  | 0.972136 | 0.945783 |
| <b>KNN</b>         | 0.812    | 0.733766  | 0.706250 | 0.680723 |

Fig. 3 Performance analysis for European dataset

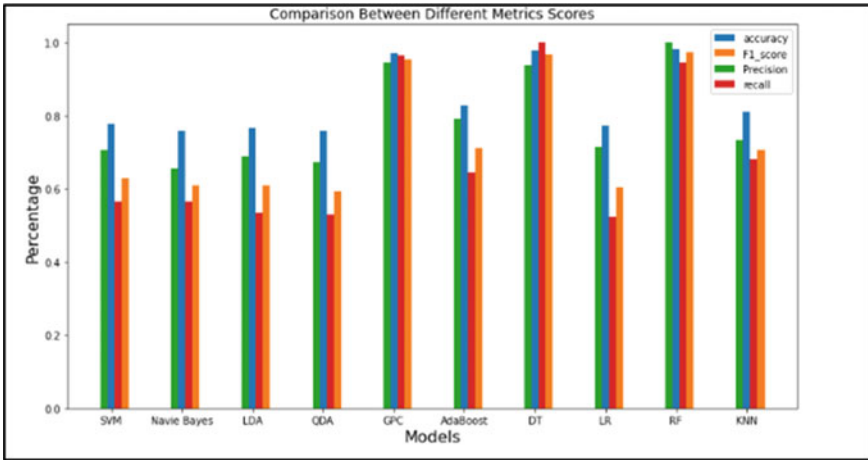


Fig. 4 Comparative performance of the ML classifiers on European dataset

A comparative analysis is depicted pictorially for Indigenous Tribe of USA in Figs. 5 and 6.

|                    | Accuracy | Precision | F1 score | Recall   |
|--------------------|----------|-----------|----------|----------|
| <b>SVM</b>         | 0.802083 | 0.740000  | 0.660714 | 0.596774 |
| <b>Navie Bayes</b> | 0.765625 | 0.673469  | 0.594595 | 0.532258 |
| <b>LDA</b>         | 0.802083 | 0.750000  | 0.594595 | 0.580645 |
| <b>QDA</b>         | 0.796875 | 0.716981  | 0.660870 | 0.612903 |
| <b>GPC</b>         | 0.619792 | 0.412698  | 0.416000 | 0.419355 |
| <b>AdaBoost</b>    | 0.776042 | 0.661017  | 0.644628 | 0.629032 |
| <b>DT</b>          | 0.718750 | 0.564516  | 0.564516 | 0.564516 |
| <b>LR</b>          | 0.791667 | 0.711538  | 0.649123 | 0.596774 |
| <b>RF</b>          | 0.786458 | 0.714286  | 0.630631 | 0.564516 |
| <b>KNN</b>         | 0.755208 | 0.631579  | 0.605042 | 0.580645 |

Fig. 5 Performance analysis for Indigenous Tribe of USA dataset

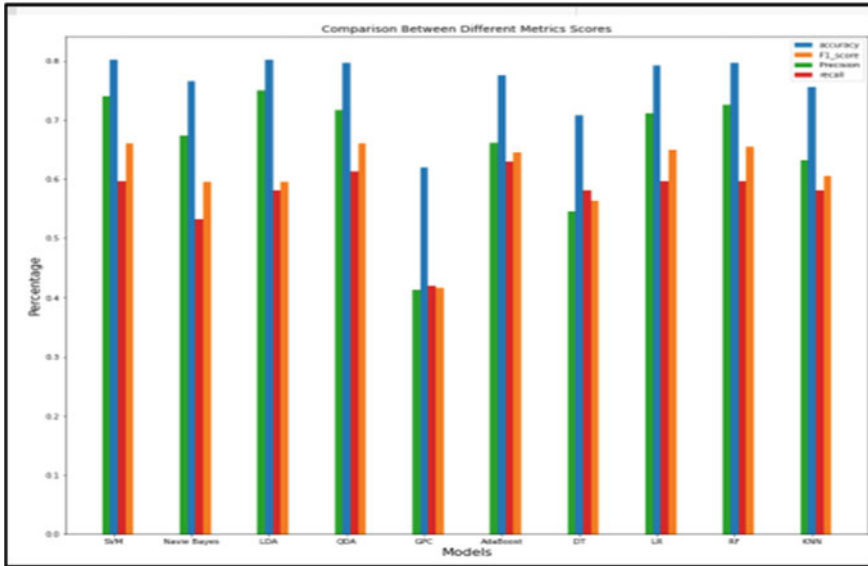


Fig. 6 Comparative performance of the ML classifiers on Indigenous Tribe of USA dataset

## 5 Conclusion

In this study, we developed a prediction model for estimating the risk of developing diabetes based on common risk factors which can be easily available in the primary care setting. We believe that this model will be helpful to medical practitioners to identify and focus on patients that do not have diabetes at present, but are at high risk of developing it in the future. Random forest performed with high accuracy on South Asian and European population but performed with slightly lower accuracy for tribes of USA. Our study will provide a base for reducing the gap in polygenic risk prediction accuracy.

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# Detection of Punjabi Newspaper Articles Using a Deep Learning Approach



Atul Kumar  and Gurpreet Singh Lehal 

**Abstract** For many years, newspapers have been excellent providers of information. To extract meaningful information, it is imperative to digitize these newspapers. In the case of Punjabi newspapers, the same is necessary. In this study, we used newspaper image segmentation to separate the various articles from the Punjabi newspapers. Different barriers in the extraction of Punjabi newspapers are discussed. Also, we have assembled a dataset of 400 newspaper images, and these images have been trained using cutting-edge object detection models Faster RCNN. The experimental results show that these models for extracting articles produced good outcomes with average accuracy of 81.8% for all classes.

**Keywords** Punjabi newspaper · Faster RCNN · Article extraction · Segmentation · Layout analysis

## 1 Introduction

The shelves of large media archives and libraries are home to vast volumes of information originating from classical print media. Digital technologies have revolutionized access to these archives, expanding their reach and enabling efficient research. However, the preservation of physical print media continues to be crucial for historical and cultural reasons. Together, these repositories serve as invaluable resources, providing a wealth of knowledge to those seeking to explore and understand our world. Since newspapers have long been a primary source of information for the general public, their layout is carefully designed to present a wide range of news articles, editorials, advertisements and other relevant content in an organized and

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visually appealing manner. However, as the world has transitioned from physical newspapers to digital platforms, the need for efficient layout analysis has become more pronounced.

By analysing the layout of newspapers, researchers and archivists can organize and categorize digital newspaper archives effectively. Layout analysis techniques can automatically detect and extract key elements such as headlines, bylines, images, captions and advertisements, enabling the creation of structured databases that facilitate easy retrieval and access to newspaper content.

Newspaper article is an important part of any newspaper, and in this research, we mainly focus on extracting newspaper articles. To extract the articles, we have used deep learning objection detection methods. We have created a dataset on various newspapers to label the articles. We have done the following things in this research:

- Discussed various barriers in article extraction of Newspapers.
- We introduced a data set of around 400 images labelling three classes of articles, advertisements and titles.
- Trained the dataset on Faster CNN model.
- Proposed a model to extract the articles.
- Get the inference to get the newspaper articles segmented.

The rest of the paper is structured as follows: The literature survey on newspaper image segmentation is discussed in Sect. 2. Section 3 discusses various barriers to newspaper article extraction. Section 4 elaborates model architecture description, training part and dataset. Section 5 discusses the experimental results, and Sect. 6 is the conclusion part.

## 2 Literature Survey

Deep neural networks (DNNs) have set new benchmarks in several academic fields thanks to hardware advancements, particularly the incorporation of GPUs. Nowadays, a lot of work is going on with the help of deep learning methods leaving behind classical methods of solving the problems. Deep learning-based object detection techniques have surpassed conventional object detection techniques with the introduction of RCNN [1, 2]. In order to demonstrate high performance, Faster RCNN has been recommended [3]. Using [1], Almutairi et al. [3] trying to solve the segmentation of newspaper contents at a semantic level. Reference [4] developed toolkit for layout analysis of documents using objection detection models Faster RCNN and Mask RCNN. Reference [5] analysed advancements in object detection field in a period around 25 years. Reference [6] developed a system for document layout analysis that employs segmentation and detection methods, including transformer and Mask RCNN [1]. Reference [7] proposed article extraction using structure-based analysis. Reference [8] created a new dataset for complex Chinese books documents named SCUT-CAB and analysed layout using various object detection algorithms. Reference [8] performed segmentation using unified framework named VSR. Reference [9]

proposed layout analysis based on semantic approach tested on Arabic handwritten documents. Reference [10] gave the survey on document layout analysis, analysed various algorithms for article segmentation, postprocessing. Reference [11] firstly segmented blocks using RLSA and then passed through lightweight dilated network to perform document layout analysis. Reference [12] splitted newspaper pages into individual articles using a heuristic approach that incorporates embedded information. Reference [13] applied fully convolutional networks to convert the newspaper image into segmented image having different articles. Reference [14] used digitized historical newspaper archives to examine complex societal concerns and suggested a scalable and adaptable big data analysis framework using sophisticated text analysis technologies and layout techniques to examine big historical newspaper datasets. Reference [15] employed a combination of instance segmentation and detection frameworks to conduct newspaper layout analysis. Reference [16] drew attention to the difficulties that can arise when newspapers are digitized using conventional methods and find the solution to overcome these difficulties using deep learning methods.

### 3 Different Barriers in Article Extraction

Newspapers include complex layouts that combine text, photos, headlines, subheadings and adverts. It is challenging to distinguish clearly defined boundaries between articles because of the various font sizes, styles and column layouts. When images are inserted within the primary material, articles may occasionally overlap or have a wonky form resulting in difficulty of article extraction. The main headlines can take up numerous columns or sections. It might be difficult to determine an article's proper starting point, especially when headlines are stylized or positioned artistically. Moreover, In Punjabi newspapers, variety of article types exists, each with a unique structure, including news reports, opinion pieces, editorials and feature articles. Understanding the content and correctly segmenting them requires expertise. Also, optical character recognition (OCR) errors, misspellings, hyphenations and irregular formatting can cause noise in the text, which can produce inaccurate segmentation results. Moreover, newspapers in multilingual areas may publish articles in a variety of languages, making it harder to distinguish between individual pieces. Also, each newspaper has a different layout and style, and there is no common format used by all publications. Due to this lack of regularity, developing a segmentation strategy that works for all data is challenging. Newspaper article segmentation requires significant computational resources, especially when dealing with large volumes of data. As a result, newspaper article extraction is quite challenging task and requires a lot of efforts.

## 4 Methodology

An overall flowchart for the newspaper article extraction is shown in Fig. 1.

### 4.1 Convolutional Neural Network

A convolutional neural network (CNN) is a type of deep learning model that is specifically designed for processing and analysing visual data, such as images and videos. As compared to other conventional methods, CNN requires very less efforts in preprocessing. In case of Punjabi newspaper article extraction, we have different regions of interest so normal CNN architecture is not appropriate. Also, to extract these large regions of interest requires very high computational power. Various architectures in CNN have been proposed to overcome these problems one of them RCNN [2] used selective search able to classify 2000 regions. However, there are some problems in RCNN like it takes lot of time during training phase. Inferences drawn on these results into very long time. To overcome these problems Faster RCNN was originated [17]. The complete image and region suggestions are used as input in the CNN architecture of the Fast region-based convolutional network (Fast RCNN) [17], which uses one forward propagation. Convolutional layers, a region proposal network, and prediction make up its three components. When given an image as

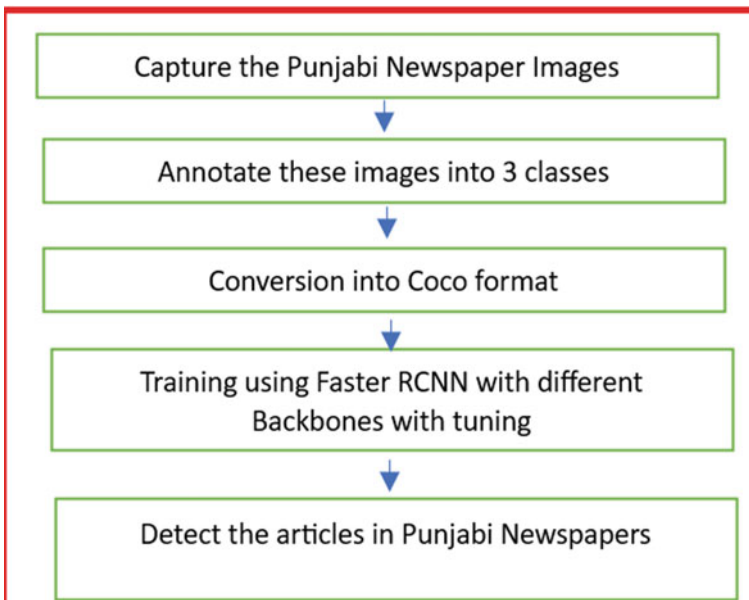


Fig. 1 Flowchart of Punjabi newspaper article extraction

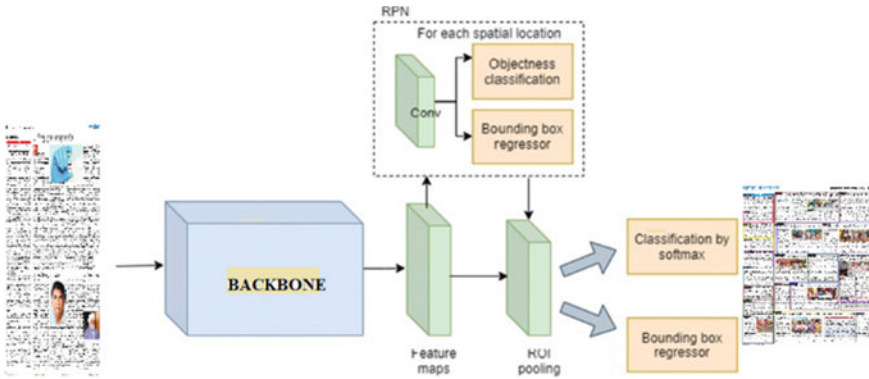


Fig. 2 Architecture of Faster RCNN

input, a region proposal algorithm creates a list of suggested areas (bounding boxes) or places that are likely to be home to objects of interest. This operates on a sliding window over convolutional feature map. At each sliding window position, RPN predicts two outputs. Objectiveness score (whether the anchor contains an object or not) and refined bounding box coordinates). Once proposed regions are generated by the RPN, they are used to extract the fixed size feature map. These region proposals are fed into the ROI pooling layer allowing them to fixed size processed by classifier. Output of ROI is given to fully connected layers divided into two parts one is the classification layer to predict which class this object belongs to, i.e. labels of object and bounding box regression refine the bounding box coordinates for each proposed region. In this paper, we have used Faster RCNN architecture to detect newspaper articles. Figure 2 shows architecture of Faster RCNN.

### 4.2 Dataset Preparation

We have explored various resources to collect Punjabi newspapers. The main source to collect the Punjabi newspapers access is Internet. We have explored various e-papers’ websites of newspapers in Punjabi language and collected around 400 images. These images are then annotated using labelling tools Roboflow, Labelme. Figure 3 shows labelling of Punjabi Newspaper using Roboflow environment.

We have used three classes to annotate these newspapers. These include

1. **Article:** They typically follow a standard news format, presenting the most important information at the beginning (the lead or headline) and then providing further details in subsequent paragraphs, photographs.
2. **Advertisement:** They include text, photographs, cartoons, etc.
3. **Title:** Text on top of newspaper.



Fig. 3 Labelling of Punjabi newspapers using Roboflow environment

In Fig. 3, each article that is annotated contains a mixture of text, headline and paragraph. In order to train the model, we have created the training and test images. Since Faster RCNN is used that take data in COCO format, the newspaper annotated are first converted into COCO format. We have divided the dataset into 70% training, 20% validation and 10% testing format having 280 images in training folder, 80 images into validation folder and 40 images into testing folder. We have used data augmentation to improve the dataset that includes resizing, picture enhancement.

### 4.3 Evaluation Metrics

In newspaper article extraction firstly find the news article and then draw the bounding box over it. For this, intersection over union is used to evaluate the accuracy of object detection and segmentation algorithms, particularly in the field of computer vision. It measures the degree of overlap between the predicted bounding box or segmented region and the ground truth (the actual bounding box or region) of an object or class in an image. IoU is calculated as the ratio of the area of intersection (the overlapping region) to the area of the union (the combined region) of the predicted and ground truth regions. The formula for calculating IoU is as follows:

$$IoU = \text{Area of Intersection} / \text{Area of Union} \tag{1}$$

A prediction greater than set threshold is called true positive (TP) and less is called true negative (TN). Prediction that has  $IoU = 0$  is false negative (FN) and  $IoU$  less than or equal to threshold is false positive (FP). Precision and recall are defined as shown in Eqs. 2 and 3, respectively.

$$\text{Precision} = TP / (TP + FP) \tag{2}$$

$$\text{Recall} = TP / (TP + FN) \tag{3}$$

The mAP is a common measure for object detection with a threshold that ranges from 0.5 to 0.95.

## 5 Experimental Results

The model configurations are given in this part, along with the results, presentation and analysis. For training part, we have used 280 training images, 80 validation images and 40 testing images. The configuration used as shown in Table 1.

To improve the dataset, data augmentation like resizing is done. Figure 4 shows the classification and segmentation outcomes using the model created in this experiment (Fig. 5).

We have compared different backbones of Faster RCNN and Resnet 101 is giving good accuracy over others. In Table 2, mAP for 0.5 to 0.95, mAP 0.5, mAP 0.75 show the performance metrics of different Faster RCNN models using different backbones. The metrics used to evaluate the models are mean average precision (mAP) and mean average recall (mAR) at different intersection over union (IoU) thresholds. Higher values for mAP and mAR indicate better performance, as they reflect the accuracy and robustness of the object detection models. Table 3 shows the results of recognizing

**Table 1** Configuration parameters

| S. No. | Parameter            | Value                                 |
|--------|----------------------|---------------------------------------|
| 1      | GPU                  | 1                                     |
| 2      | NUM_WORKERS          | 4                                     |
| 3      | MODEL WEIGHTS        | faster_rcnn_X_101_32 × 8d_FPN_3x.yaml |
| 4      | BATCH SIZE           | 4                                     |
| 5      | BASIC LEARNING RATE  | 0.001                                 |
| 6      | STEPS PER EPOCHE     | 300                                   |
| 7      | BACKBONE             | Resnet101                             |
| 8      | PER IMAGE BATCH SIZE | 64                                    |
| 9      | CLASS                | 3                                     |
| 10     | VALIDATION STEPS     | 200                                   |





Fig. 4 Results of article extraction using Punjabi newspapers

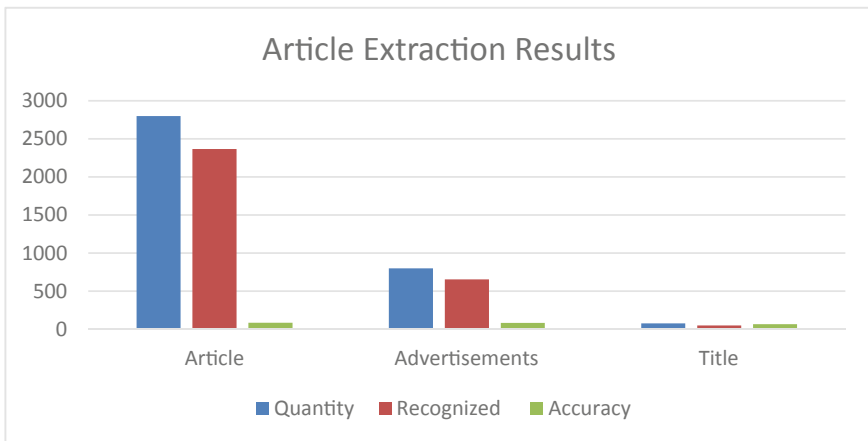


Fig. 5 Different classes accuracy of Punjabi newspapers

**Table 2** Comparing different backbones for detection results of experiment

| Architecture | Backbone        | mAP0.5:0.95 | mAP0.5 | mAP0.75 | mAR0.5:0.95 |
|--------------|-----------------|-------------|--------|---------|-------------|
| Faster RCNN  | Resnet 50 FPN   | 0.67        | 0.73   | 0.63    | 0.68        |
|              | Resnet101 FPN   | 0.68        | 0.72   | 0.634   | 0.687       |
|              | ResNeXt-101-FPN | 0.669       | 0.723  | 0.629   | 0.673       |

**Table 3** Segmentation results of different classes

| Class          | Quantity | Recognized | Accuracy |
|----------------|----------|------------|----------|
| Article        | 2798     | 2365       | 84.52    |
| Advertisements | 798      | 654        | 81.95    |
| Title          | 76       | 60         | 78.94    |

three different classes: “Article,” “Advertisements,” and “Title” on different untested newspapers model are tested. The system’s accuracy is measured as the percentage of correctly recognized instances out of the total quantity for each class giving average of 81.8%.

## 6 Conclusion

In this research, we have highlighted different barriers during article extraction of Punjabi newspapers such as complex layouts, varying font sizes and column layouts, as well as the presence of images within articles. The goal of this study was to use deep learning object detection techniques to retrieve newspaper articles from digital newspaper archives. We have prepared a dataset for Punjabi newspaper article extraction. We have originated a technique based on object detect model for the detection of articles. We have set three classes in dataset for this task. We have compared different backbones of Faster RCNN and found Resnet 101 gives better accuracy over others. As this is first step to extract the article from Punjabi newspapers. The proposed method gives good accuracy. In future, it can be extended to newspapers in other languages. Overall, this methodology demonstrated the effectiveness of deep learning-based object detection for extracting newspaper articles.


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# Artificial Intelligence-Enabled Smart Parking System



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**Abstract** The aim of this study is to explore the development and integration of a smart parking system enabled by advanced AI, which relies on Internet of things (IoT) technologies. The intent behind this system is to enhance the utilization of parking spaces while uplifting driver experience, all possible through delivering dynamic updates regarding parking availability. The technical infrastructure employed for building the system revolves around an amalgamation of smart sensors and cameras using IoT interactions to collect data associated with parked vehicles. This information gets subsequently processed by sophisticated AI algorithms that offer up-to-the-minute details about available parking spots stored in a prevalent database. Further, owing primarily to the technology's highly functional characteristics, each occupant status predictably ascertains effective insights into plausible available space during driving, via display boards or mobile-based applications. After conducting a comprehensive review, the suggested smart parking system has been found to surpass traditional parking systems in critical areas such as accuracy, dependability, and efficiency. As a result of this new system being utilized, traffic congestion will significantly decrease, resulting in a noticeably improved parking experience and higher park management revenues. One profound advantage of the proposed system is that it has the capability of collecting real-time data on available parking spaces. The benefit of having access to this data is that car owners are guaranteed shorter searches. This study offers ideas for additional study and development in this field and demonstrates how AI with Internet of things technologies might enhance urban transit networks. By improving parking efficiency and giving drivers a better parking experience, the adoption of an “artificial intelligence-enabled smart parking system” offers an opportunity to revolutionize the parking sector.

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Supported by Symbiosis Institute of Technology, Pune, Symbiosis International Deemed University

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**Keywords** Smart parking · Administration · Raspberry Pi · Infrared sensors · Ultrasonic sensors · OpenCV · Internet of things

## 1 Introduction

Conventional parking structures are sometimes faulty and may frequently result in angry motorists circling for what may seem like hours. This issue requires a fix, which prompted the creation of intelligent parking management systems that make the most use of parking spots by using cutting-edge technology like AI and IoT. The automated parking system can deliver precise and current details on the availability of parking by using AI algorithms and immediate information processing. By reducing traffic congestion and improving parking efficiency, this technology will help drivers by making parking easier. Numerous studies have contrasted smart parking systems that make use of AI and IoT technology against conventional parking systems. These studies have demonstrated an unambiguous benefit of intelligent systems over their conventional counterparts in terms of accuracy, reliability, and efficiency.

## 2 Literature Review

It is clear from reading up on smart parking systems that combining the Internet of things and artificial intelligence may significantly enhance parking management. Many approaches, including predictive analytics, machine learning, and image processing, have been suggested in the study as ways to create these systems. However, current studies possess certain limitations; there still needs to be a holistic solution that integrates all components. Therefore, future research endeavors should prioritize enhancing accuracy and dependability by incorporating various data sources.

The research introduces a novel smart parking algorithm that considers driver behavior as well as parking traffic predictions. The authors begin by reviewing the existing literature on smart parking algorithms, emphasizing the shortcomings of present techniques. They then discuss their proposed system, which employs machine learning techniques to forecast parking behavior using historical data and real-time traffic statistics. The method is tested with simulations, and the findings reveal that it surpasses previous algorithms in terms of parking success rate, waiting time, and journey time. This paper contributes significantly to the advancement of efficient and sustainable smart parking systems [17]. The paper describes a power management method for EV parking lots. The authors conduct a literature study on EV power management algorithms and emphasize the shortcomings of current techniques. They present a new method that optimizes charging schedules depending on user preferences and electricity pricing by using fuzzy logic inference. The method is tested using simulation tests, and the findings suggest that it can lower charging

costs while also increasing user satisfaction. This research contributes significantly to the creation of long-term and cost-effective EV charging infrastructure [14]. The study proposes a cloud-based smart parking system based on Internet of things (IoT) technology. The authors conduct a literature study on smart parking systems and identify the shortcomings of existing techniques. They propose a novel system that monitors parking places with IoT sensors and analyzes and processes parking data in the cloud. In addition, the system includes a smartphone application that allows users to find available parking spaces in real time. Experiments are used to evaluate the system, and the findings suggest that it can increase parking efficiency and user happiness. This work contributes significantly to the advancement of smart city infrastructure [21]. The study describes a novel approach to smart parking based on fog computing. The authors review the existing research on smart parking systems and fog computing, stressing the limitations of present techniques. They propose a new system that uses fog computing to handle parking data in real-time and reduce latency. The system also contains machine learning techniques for predicting parking behavior and optimizing parking space distribution [25]. The impact of public transportation on parking behavior, the possible benefits of a new public transportation line in reducing parking demand, and a methodology for measuring its impact are discussed [11]. Parking structures and administration, parking problems in smart towns, and possible advantages of intelligent parking systems are all explored. The research places a strong emphasis on the requirement of integrating parking options with other initiatives related to smart cities, including automated parking structures and real-time data on parking systems, in addition to alternative methods of designing and managing parking facilities [23]. The challenges involved in charging electric cars (EVs) in intelligent parking structures, as well as the possible advantages of ideal charging regulation. The study discusses several strategies for optimum charge control, including algorithmic heuristics and model prediction oversight, and highlights the relevance of incorporating charging management into other intelligent parking solutions [2]. A theoretical framework for a more effective and automated smart vehicle parking solution using IoT-enabled networks is provided after discussing the limitations of current smart parking systems [24]. For intelligent parking management systems, the Sampark protocol is put up as a simple and secure replacement for the drawbacks of the current methods of communication and safety precautions [16]. The most current developments in the area of smart parking are examined in-depth in this study. The authors look at a number of technological solutions that have been proposed to address parking-related issues, including detectors, smartphone applications, and data analytics. The study addresses the advantages and disadvantages of every approach, as well as possible future fields of inquiry in the subject of intelligent parking. Practitioners and researchers engaged in creating environmentally friendly and effective parking systems may find the paper to be a helpful tool [7]. The concept of smart parking is first introduced, along with some of its potential advantages, including reducing traffic congestion, enhancing the user experience, and generating income for parking operators. The report then discusses the key technologies used in innovative parking systems, including sensors, networks for communication, cloud computing, mobile apps, statistical analysis, machine

learning, AI, and blockchains. The authors draw the following conclusion: intelligent parking structures have the ability to revolutionize parking management and enhance the parking experience overall, but effective implementation and acceptance depend on careful evaluation of technical, social, economic, and policy factors [18]. The authors present a full overview of various technologies and their roles in optimizing parking management. The authors include technical details on the implementation of various applications, such as sensor location, communication protocols, data processing algorithms, and user interfaces. Technical obstacles related to the adoption of smart parking systems were also noted, such as sensor accuracy, communication dependability, data privacy and security, and system scalability. The use of enhanced sensors, the creation of secure communication protocols, the application of authentication and encryption protocols, and the usage of cloud-based architectures are only a few of the options suggested by the authors as answers to these problems [10]. Using surveillance camera video streams, the authors provide a deep learning-based technique for forecasting parking spot availability. The suggested method classifies photos as either occupied or unoccupied parking spots using convolutional neural networks (CNNs). A publicly accessible dataset was used to train the CNN model, which produced results with high accuracy along with low false-positive rates. The authors also suggest an IoT-based architecture for a smart parking system, which includes sensors for detecting vehicle presence, communication networks for transmitting sensor data, and cloud-based platforms for data processing and storage. The authors emphasize the advantages of this design, such as real-time monitoring, automatic billing, and remote management. The report includes a case study of the proposed system in action at a shopping mall parking lot. The authors assess the system's effectiveness in terms of parking space availability, detection accuracy, and response time. The results show that the suggested system can detect parking space availability and offer real-time information to users [3]. The report provides useful insights into the potential problems of smart parking system design and implementation. The authors highlight the value of careful planning, stakeholder engagement, and comprehensive testing in the success of a smart parking system. In addition to ongoing evaluation and improvement, the study emphasizes the necessity of a user-centered approach to system design. Analytics and optimization of data: Smart parking systems generate enormous amounts of data that may be utilized for analysis and these processes. Prediction analytics, algorithms for machine learning, and optimization models are a few of the strategies that have been suggested in numerous research to improve parking management. These actions can improve parking use, speed up search times, and lessen traffic congestion. Artificial intelligence (AI): To improve parking management's precision and effectiveness, smart parking systems make use of AI tools like image recognition and the processing of natural languages. These technologies enable automatic vehicle identification, license plate recognition, and chatbot dialogue with users [22]. The paper describes a method for creating smart parking systems that rely on fog computing and decentralized architectures. The authors describe an approach for building such systems, which includes deterministic propagation modeling and practical deployment considerations. The report also analyzes the advantages and disadvantages of adopting fog computing in smart

parking systems [9]. The research compares several policies for managing parking lots that accommodate electric vehicles. The authors present a simulation model for testing and comparing different policies depending on characteristics such as charging demand, battery capacity, and parking length. The study provides insights into the development of efficient regulations for managing parking lots for electric vehicles [5]. The study presents a novel smart auto parking system that uses dynamic resource allocation and pricing to optimize the utilization of parking spaces. The authors present a simulation-based approach for evaluating system performance, which incorporates elements such as real-time data collecting and analysis. The study offers insights into the construction of efficient and effective smart parking systems [15]. The study describes a smart parking smartphone application that uses deep learning algorithms to analyze parking lot photos and deliver real-time information on available parking spaces. The authors detail the application's architecture and implementation, as well as the usage of convolutional neural networks for picture processing. The research delves into the use of deep learning in the development of intelligent parking systems [8]. The study provides an in-depth examination of science and technology parks (STPs) and their role in stimulating innovation and economic growth. The writers go on the major features of STPs, such as their physical infrastructure, management approaches, and support services. The report also looks at the future of STPs in light of developing technologies like artificial intelligence and blockchain. The document contains useful information about the design and operation of STPs [19]. In order to achieve smart city status, the study provides a framework for deploying urban computing in Saudi cities. The authors assess the current state of urban computing in Saudi Arabia and make recommendations for the creation and implementation of a complete urban computing framework. The study provides useful information about the possible benefits of urban computing in the context of smart city development [4]. The research examines the distribution and readiness of artificial intelligence (AI) applications in global mobility projects. The authors explore the current level of artificial intelligence in mobility initiatives and identify characteristics that contribute to AI application suitability in this context. The report gives useful insights into worldwide trends and problems in the development and application of artificial intelligence in mobility projects [20]. The research compares two types of sensors often found in smart parking systems: proximity sensors and light sensors. The performance of these sensors is evaluated by the authors based on parameters such as accuracy, response time, and cost. The report gives useful insights into sensor selection and application in the design of functional smart parking systems [6]. The research uses cluster analysis to examine parking behavior in Munich, Germany. The authors employ clustering techniques to detect various patterns of parking behavior by analyzing parking data acquired from sensors. The research delves into the possible application of cluster analysis as a technique for understanding and managing parking behavior in metropolitan environments [12]. The study describes a decision support system for regulating roadside parking in metropolitan settings. Utilizing current data from parking sensors, the tool helps automobiles locate parking places by providing information about available spaces. The system's development and use are described by the authors, along with



any possible advantages it could have for easing traffic congestion and boosting urban mobility. Insightful information about the creation of decision support systems for intelligent parking is provided by the research [13]. Based on IoT technology, the paper outlines a smart parking system. The authors propose a sensor-based intelligent parking structure that uses real-time data to provide cars with information and uses sensors to identify available parking places. The article discusses the system's implementation, design, and possible advantages for enhancing urban mobility and alleviating traffic congestion. The study provides useful insights into the use of IoT technologies in smart parking systems [1].

### **3 Methodology**

Smart parking systems have emerged as a viable alternative for managing parking lots in urban settings. The approach for creating and implementing a smart parking system utilizing artificial intelligence is presented in this research study. The system employs the OpenCV library to integrate a variety of technologies, including a Raspberry Pi board, ultrasonic sound sensors, light-emitting diode, resistors, and a camera module, to create the ideal smart parking environment for automobile parking.

#### ***3.1 Designing the System Architecture***

The first stage in designing a smart parking system is to define the system architecture. Identifying the system's hardware and software requirements falls under this. The main controller for this project will be the Raspberry Pi board, which will oversee the numerous sensors and cameras. Additionally, a camera module that recognizes number plates will employ OpenCV as an open-source computer vision library, ultrasonic sensors, LEDs, resistors, and various other components. The first step in creating a smart parking structure utilizing artificial intelligence is to create a system design that details all of the hardware components and how they will be connected. The software architecture which will be employed in the project is also defined at this stage. Key software modules required to create a smart parking system are identified.

#### ***3.2 Developing the Hardware Components***

The second phase in constructing the smart parking system is to create the hardware components. Hardware for this project will mostly consist of the Raspberry Pi. A robust and reasonably priced microprocessor called the Raspberry Pi has become easily adaptable to a wide range of sensors and modules. To do this, many sensors and gadgets must be built and connected to the Raspberry Pi device. To determine if

**Input:** Raspberry Pi, Ultrasonic Sensors, LEDs, resistors, Camera Module, OpenCV library, Artificial Intelligence algorithm  
**Output:** Smart Parking System

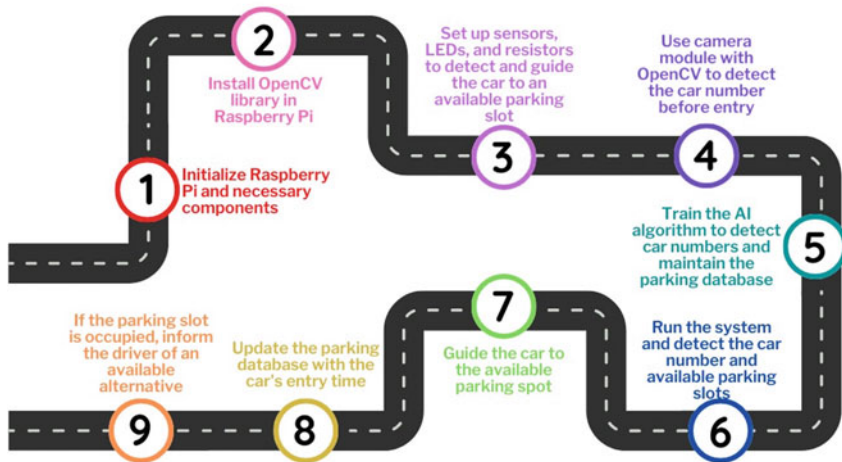


Fig. 1 Flow diagram for hardware implementation

a car is present in a parking space, we shall employ ultrasonic sensors in this project. In order to alert drivers about parking place availability, resistors, and LED lights will be used. The camera module will be used to photograph the parked vehicle's license plate (Fig. 1).

**Raspberry Pi** Through the use of Internet of things (IoT) gadgets and AI, the artificial intelligence (or AI)-enabled intelligent parking system aims to effectively oversee and track spots for parking. In this project, the ultrasonic detectors, LEDs, resistors, and camera parts that are employed to determine and monitor parking spot availability are controlled and communicated with by the Raspberry Pi. Additionally, the Raspberry Pi gathers information from cameras and sensors and connects with an artificial intelligence algorithm to make choices about the availability of parking spaces and traffic flow. This project uses a Raspberry Pi, which makes the system affordable, reliable, and readily scalable. It provides a strong platform for building IoT applications that can be readily expanded to cover bigger lot sizes or even whole towns. Because of its flexibility and agility, it serves as a vital piece of an "AI-enabled smart parking system" as a useful tool for creating one-of-a-kind IoT applications.

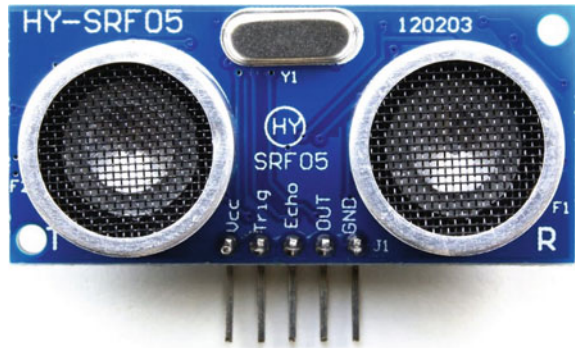
**Ultrasonic Sensors** Ultrasonic sensors are used to detect the presence of automobiles in the parking lot. To detect car presence, we will use four ultrasonic sensors, two for each parking place. These sensors will be attached to the Raspberry Pi's GPIO pins (Figs. 2 and 3).

**Infrared Sensor** Detecting vehicle entrance and departure in the parking area is done with the use of infrared sensors. An adjacent item reflects the infrared sensor's released beam of energy back to the device. The infrared beam is blocked when a

Fig. 2 Raspberry Pi



Fig. 3 Ultrasonic sensor



car enters or quits a parking place, prompting the detector to detect the vehicle’s presence or absence. Due to its capacity to provide real-time information on the state of occupancy of parking spots, infrared sensors enhance the system’s precision and dependability. The AI algorithm then makes use of this data to forecast parking space availability and direct vehicles to the closest place that is easily accessible.

**LED Indicators** We will use LEDs to indicate the availability of parking places. Green LEDs will show available parking spaces, while red LEDs will indicate occupied parking spaces. The LEDs will also be linked to the Raspberry Pi’s GPIO ports.

**Servo Motor** Servo motors can be utilized in the artificial intelligence-enabled smart parking system to regulate the movement of physical barriers that restrict access to parking spaces. Depending on whether a parking space is available, the gadget may autonomously move these barriers. This can assist in assure that only authorized cars are allowed entry to the lot and can help avoid unauthorized parking. Additionally, the use of servomotors enables precise and precise control of the obstacles, enhancing the system’s overall dependability and efficiency (Figs. 4 and 5).

**Camera Module** The camera module will be used to capture photos of vehicles entering and exiting the parking area. These photos will be analyzed with OpenCV

Fig. 4 Infrared sensor

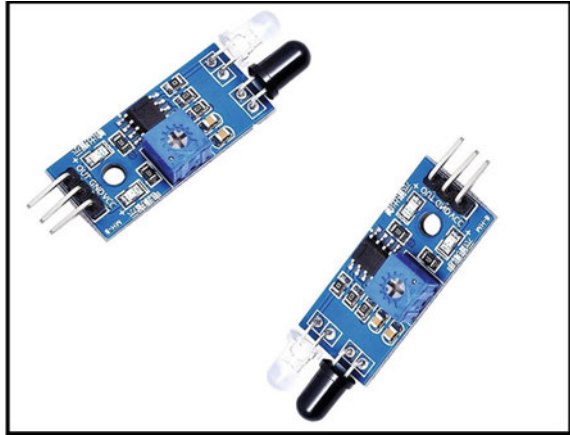
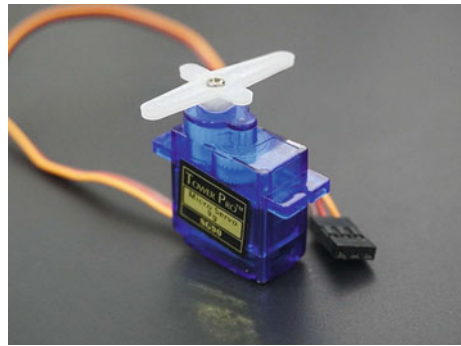


Fig. 5 Servo motor



to retrieve the vehicle’s license plate. The camera module will be linked to Raspberry Pi’s camera module interface (CSI) port.

**OpenCV** The camera module’s pictures will be processed using the computer vision library OpenCV. We will apply number plate recognition algorithms from OpenCV to identify a license plate in the vehicle’s picture.

**Database** Data will be stored in a database for the camera module and ultrasonic sensors. The information will be kept in a database created with MySQL (Figs. 6 and 7).

**Web Application** An internet application will be created to give consumers real-time information on parking availability. The PHP-written web application will be hosted by the Raspberry Pi-based website server. The web application will make use of the information stored in the database created by MySQL to give users the most recent information regarding parking availability.

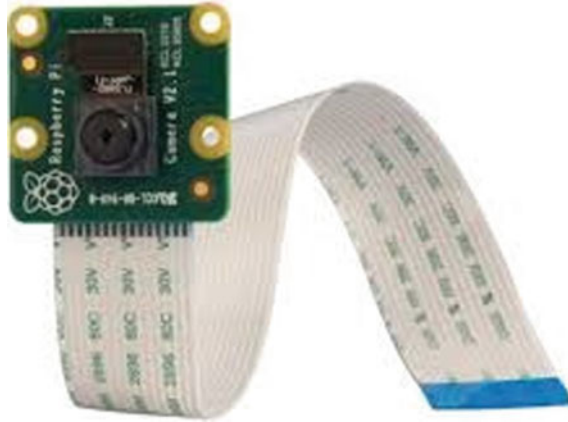


Fig. 6 Camera module in Raspberry Pi

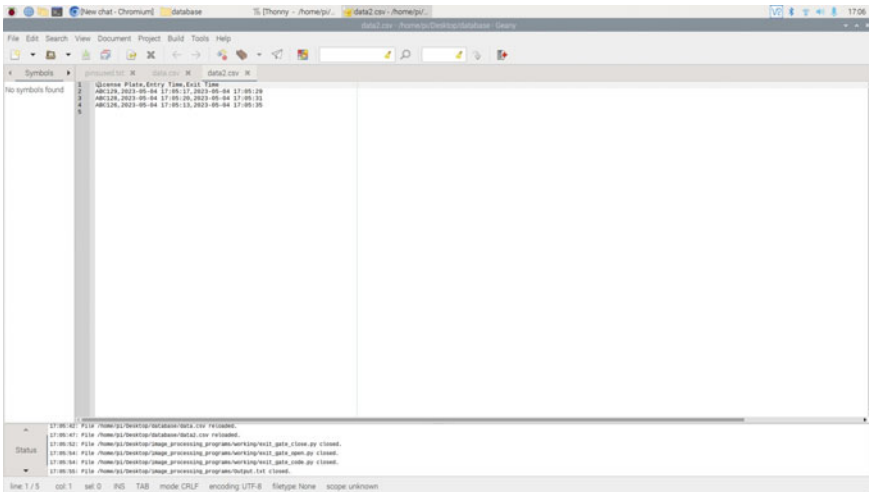
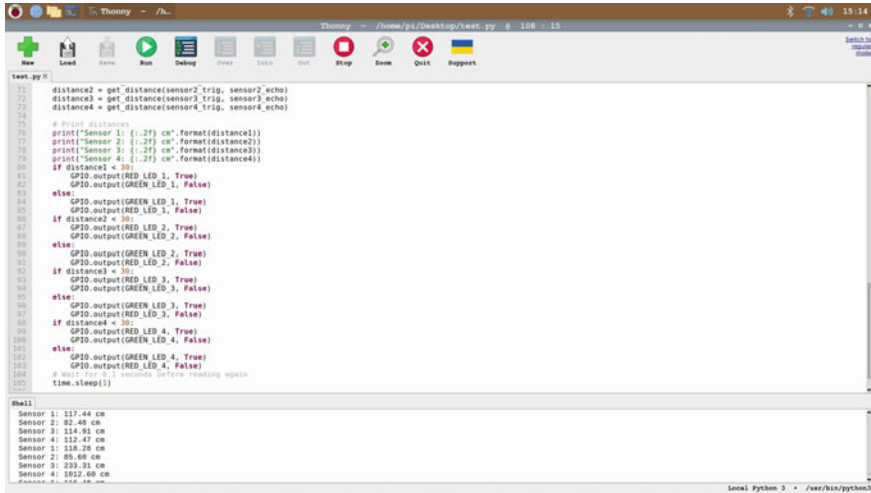


Fig. 7 Data collection

### 3.3 Developing the Software Components

The creation of the software components is the third stage in the construction of the smart parking system. The myriad sensors and gadgets linked with the Raspberry Pi boards need to be programmed in order to do this. We will be employing OpenCV in this project to take and process images of license plate frames. In order to identify the license plate of the parked car and verify it, the information gathered will be processed using machine learning algorithms (Fig. 8).



```
11 distance2 = get_distance(sensor2_trig, sensor2_echo)
12 distance3 = get_distance(sensor3_trig, sensor3_echo)
13 distance4 = get_distance(sensor4_trig, sensor4_echo)
14
15 # Print distances
16 print("Sensor 1: {:.2f} cm".format(distance1))
17 print("Sensor 2: {:.2f} cm".format(distance2))
18 print("Sensor 3: {:.2f} cm".format(distance3))
19 print("Sensor 4: {:.2f} cm".format(distance4))
20
21 if distance1 < 30:
22     GPIO.output(RED_LED_1, True)
23     GPIO.output(GREEN_LED_1, False)
24 else:
25     GPIO.output(GREEN_LED_1, True)
26     GPIO.output(RED_LED_1, False)
27
28 if distance2 < 30:
29     GPIO.output(RED_LED_2, True)
30     GPIO.output(GREEN_LED_2, False)
31 else:
32     GPIO.output(GREEN_LED_2, True)
33     GPIO.output(RED_LED_2, False)
34
35 if distance3 < 30:
36     GPIO.output(RED_LED_3, True)
37     GPIO.output(GREEN_LED_3, False)
38 else:
39     GPIO.output(GREEN_LED_3, True)
40     GPIO.output(RED_LED_3, False)
41
42 if distance4 < 30:
43     GPIO.output(RED_LED_4, True)
44     GPIO.output(GREEN_LED_4, False)
45 else:
46     GPIO.output(GREEN_LED_4, True)
47     GPIO.output(RED_LED_4, False)
48
49 # Wait for 0.1 seconds before reading again
50 time.sleep(0.1)
```

```
Shell
Sensor 1: 117.44 cm
Sensor 2: 82.48 cm
Sensor 3: 114.91 cm
Sensor 4: 112.47 cm
Sensor 1: 118.28 cm
Sensor 2: 85.68 cm
Sensor 3: 223.31 cm
Sensor 4: 1012.68 cm
```

Fig. 8 Raspberry Pi code of ultrasonic sensors for vehicle detection

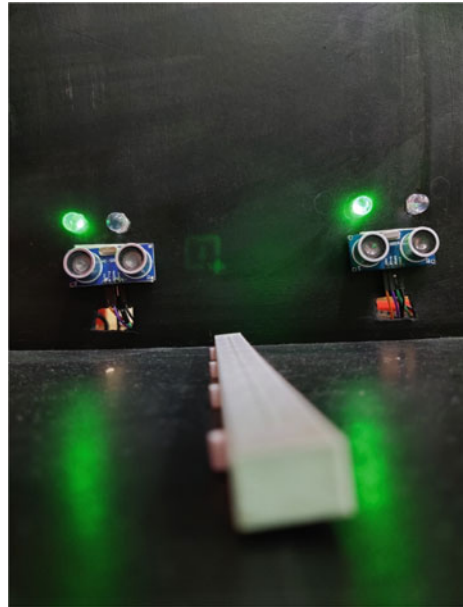
### 3.4 Testing and Evaluation

Testing and outcome review is the fourth step in developing the smart parking system. Run tests to make sure that it is dependable and satisfies the standards it requires as a component of this procedure. In this study, we will assess the system’s reliability while communicating with the database, accuracy in recognizing license plates, and effectiveness in handling parking spots (Figs. 9, 10, 11, and 12).

Fig. 9 Setup when the vehicle is not present



**Fig. 10** Indication of vacant space using LEDs for parking

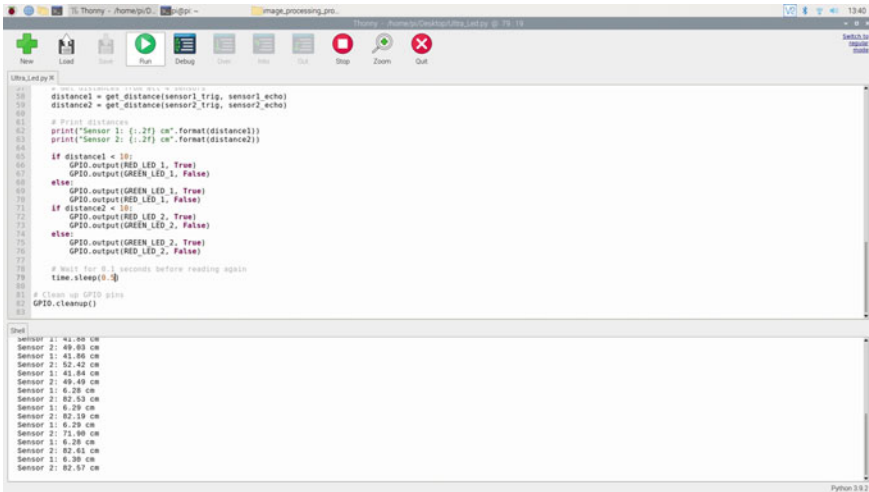


**Fig. 11** Setup when the vehicle is present



### ***3.5 Deployment and Monitoring***

The smart parking system’s final phase in development is to deploy it in a real-world context and monitor its performance. This includes setting up the hardware at a parking lot and maintaining the database. The device is installed in lots of parking, and the data gathered by the machine learning algorithm is used to optimize parking lot utilization. Parking lot operators receive data to assist them to optimize their parking facilities while users are provided with current details on the number of



```
#!/usr/bin/env python3
import RPi.GPIO as GPIO
import time

# Sensor pins
TRIG_PIN = 18
ECHO_PIN = 24

# LED pins
GREEN_LED1_PIN = 12
RED_LED1_PIN = 13
GREEN_LED2_PIN = 16
RED_LED2_PIN = 17

# Initialize GPIO
GPIO.setmode(GPIO.BCM)
GPIO.setup(TRIG_PIN, GPIO.OUT)
GPIO.setup(ECHO_PIN, GPIO.IN)
GPIO.setup(GREEN_LED1_PIN, GPIO.OUT)
GPIO.setup(RED_LED1_PIN, GPIO.OUT)
GPIO.setup(GREEN_LED2_PIN, GPIO.OUT)
GPIO.setup(RED_LED2_PIN, GPIO.OUT)

def get_distance(sensor1_trig, sensor1_echo):
    distance = 0
    GPIO.output(sensor1_trig, True)
    time.sleep(0.00001)
    GPIO.output(sensor1_trig, False)
    start_time = time.time()
    while GPIO.input(sensor1_echo) == False:
        pass
    end_time = time.time()
    duration = end_time - start_time
    distance = (duration * 34300) / 2
    return distance

# Print distances
print("Sensor 1: {:.2f} cm".format(get_distance(TRIG_PIN, ECHO_PIN)))
print("Sensor 2: {:.2f} cm".format(get_distance(TRIG_PIN, ECHO_PIN)))

if distance1 < 10:
    GPIO.output(GREEN_LED_1, True)
    GPIO.output(RED_LED_1, False)
else:
    GPIO.output(GREEN_LED_1, False)
    GPIO.output(RED_LED_1, True)

if distance2 < 10:
    GPIO.output(GREEN_LED_2, True)
    GPIO.output(RED_LED_2, False)
else:
    GPIO.output(GREEN_LED_2, False)
    GPIO.output(RED_LED_2, True)

# Wait for 0.1 seconds before reading again
time.sleep(0.1)

# Clean up GPIO pins
GPIO.cleanup()
```

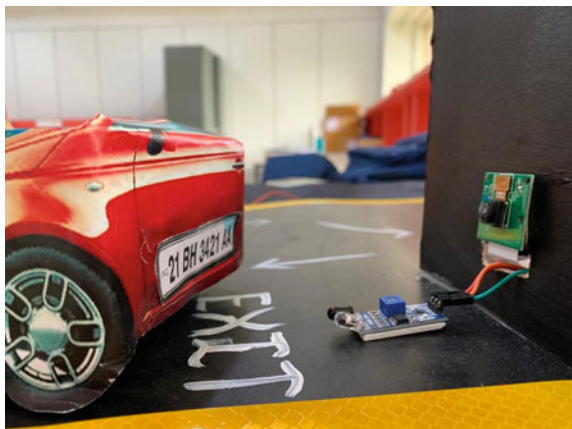
```
Shell
Sensor 1: 41.00 cm
Sensor 2: 49.00 cm
Sensor 1: 41.00 cm
Sensor 2: 52.42 cm
Sensor 1: 41.84 cm
Sensor 2: 49.49 cm
Sensor 1: 6.28 cm
Sensor 2: 62.53 cm
Sensor 1: 6.28 cm
Sensor 2: 62.19 cm
Sensor 1: 6.28 cm
Sensor 2: 71.90 cm
Sensor 1: 6.28 cm
Sensor 2: 82.61 cm
Sensor 1: 6.28 cm
Sensor 2: 82.67 cm
```

Fig. 12 Raspberry Pi code of infrared sensors for vehicle detection

parking spaces. To suit the requirements of various parking lots, the system may be turned up or down. In summary, the process for the artificial intelligence-enabled smart parking system project entails configuring the hardware components, which include ultrasonic sensors, LEDs, camera modules, and Raspberry Pi. The number plate will be extracted from photos recorded by the camera module using OpenCV. The sensor and camera module data will be stored in a MySQL database hosted on the Raspberry Pi (Fig. 13).

This project uses the Raspberry Pi, ultrasonic detectors, LEDs, resistors, and module cameras to create a smart parking system utilizing the Internet of things (IoT) and artificial intelligence (AI). In order to save time, reduce traffic, and enhance the

Fig. 13 Number plate of the vehicle is getting detected





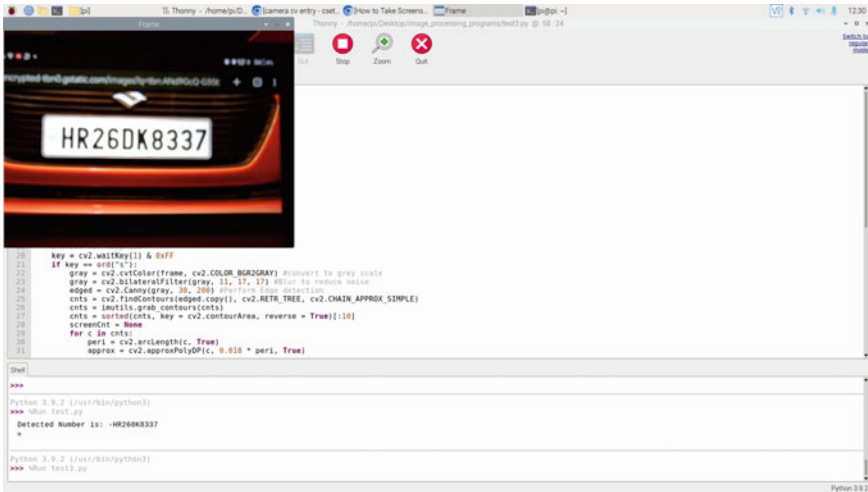


Fig. 14 Code for number plate detection

overall driving experience, the system aims at creating it quick and simple to track and handle parking locations (Fig. 14).

Additionally, the system may be accessed remotely, giving users access to real-time parking data via online or mobile apps. In the near future, machine learning methods may be used to improve the precision of parking space availability projections and to identify infractions. In order to reduce the requirement for parking attendants and to save time and money, automated payment systems might be developed, enabling automobiles to pay for parking places without the need for tangible payment methods.

Additionally, the smart parking system could be integrated into navigation systems to provide drivers with real-time parking information and help them find free parking spots quickly and effectively, easing traffic congestion, and helping to improve traffic flow in general. Data from the smart parking system might potentially be used to identify high-demand parking areas and plan the construction of new parking structures or the conversion of vacant spaces into parking slots.

## 4 Result

With the use of ultrasonic sensors, LEDs, resistors, and camera modules integrated with OpenCV software onto a Raspberry Pi platform, this innovative system allows city managers to oversee parking spaces more efficiently therefore saving valuable street space for purposes like public transit and making it conducive to traveling by foot or bicycle in populous areas. This automated parking management platform

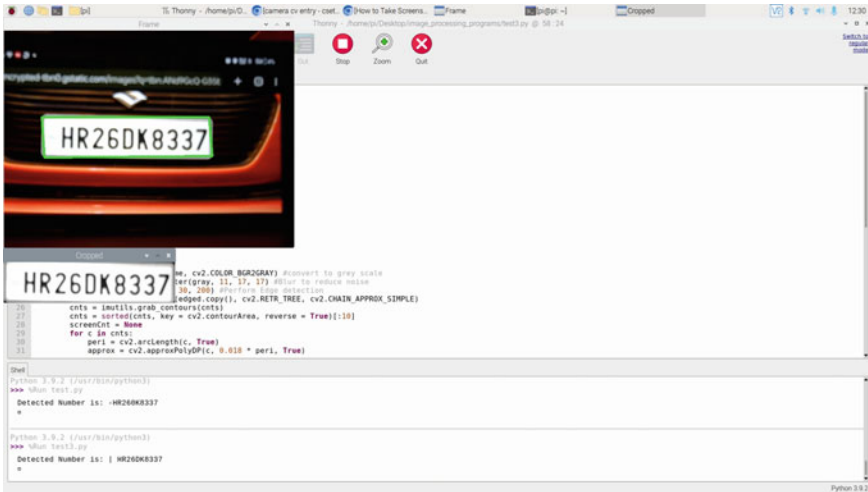


Fig. 15 Code and output for number plate detection

reduces driver wait time searching for a spot which can take up to 20 min per driver on average in cities around the globe (Fig. 15).

By delivering an effective and dependable parking experience, this technology attempts to reduce the challenges associated with traditional parking systems, such as traffic congestion and driver annoyance.

In terms of accuracy, dependability, and efficiency, the study compared the proposed smart parking system to standard parking systems. In all of these areas, the results revealed that the smart parking system based on AI and IoT technology outperformed traditional parking systems. The AI algorithms in the system processed the data acquired from sensors and cameras in real time, sending real-time parking availability information to the database.

The emergence of smart parking technology has allowed drivers to easily find vacant parking spaces, which leads to a more pleasant driving experience and fewer traffic holdups. The utilization of AI and IoT technologies in modern parking systems offers many benefits that traditional methods simply cannot match. For instance, the system engineers can receive live data updates on available spots, resulting in better management as well as more efficient resource usage when it comes to finding vehicles quickly.

## 5 Future Scope

The “artificial intelligence-enabled smart parking system” project contains various potential future scopes that could improve the system. These are a few examples:

### ***5.1 Implementation of License Plate Recognition Technology***

The existing system detects car numbers before entry using cameras, but it may be improved further by using license plate recognition technology. This technique has the potential to improve vehicle detection accuracy while also reducing errors. The technology can also detect authorized and unauthorized cars by recognizing license plates.

### ***5.2 Integration with Mobile Applications***

In the future, the system might be coupled with mobile applications to allow cars to reserve parking spots ahead of time. By doing this, you can reduce city traffic congestion and improve driving comfort. The smartphone app additionally provides navigation assistance and real-time parking availability details for drivers.

### ***5.3 Expansion to Multiple Parking Lots***

The system can be expanded to cover many parking lots in a city. This can assist enhance parking availability and alleviate traffic congestion. The technology can also be connected with a centralized management system to monitor and administer many parking lots.

### ***5.4 Real-Time Data Analysis and Prediction***

The AI model may be enhanced even more by including immediate analysis of data and prediction. This can help forecast parking supply and traffic flow, enabling drivers to make better parking choices. In order to give drivers real-time parking information, this feature may also be connected to navigation systems.

### ***5.5 Integration with Electric Vehicle Charging***

The technology can be connected with electric vehicle charging facilities to provide a more comprehensive parking service for electric vehicles. The AI model can also be trained to forecast the availability of charging outlets. This can stimulate the usage of electric vehicles while lowering greenhouse gas emissions.

## 5.6 *Integration with Payment Systems*

The system can be connected with payment systems to allow drivers to pay for parking via the mobile application. This can give drivers a more seamless and convenient experience. The payment system can also be coupled with the reservation system, allowing vehicles to purchase parking spaces.

## 5.7 *Integration with Security Systems*

To increase the security of parked automobiles, the system can be connected with security systems. Cameras, alarms, and other security systems are examples of this. In addition, the AI model can be trained to detect and identify questionable activity. The security system can also be linked to the reservation system, allowing for secure access to booked parking spots.

Finally, the “artificial intelligence-enabled smart parking system” has enormous development and integration potential in the future. The incorporation of license plate recognition technology, mobile applications, multiple parking lots, real-time data analysis and prediction, electric vehicle charging, payment systems, and security systems can improve the system’s functionality and effectiveness, making it a necessary tool for managing parking spaces in urban areas.

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# Performance Measurement and Analysis of Partial Cloud-Dependent Application Hosting



Shantanu Chaturvedi, Sanjoy Das, Subrata Sahana, Tanya Lillian Borges, and Ankush Ghosh

**Abstract** Cloud services provide numerous advantages over private servers, but there are certain drawbacks, such as vendor lock, budget overrun due to an unexpected spike in computing demand, and migrating existing system to the cloud. In this study, we deployed, measured, and compared the performance of application hosting on virtual private servers with integrated cloud storage and cloud-based hosting. Cloud services and virtual private servers (VPSs) may be evaluated using a range of performance indicators that can be applied to various components of the service. We recommend combining a cloud service with an application running on a virtual private server to store and retrieve file objects, allowing the application to grow by utilizing cloud platforms like Amazon web services and other public cloud technology. Organizations may create safe and scalable apps while avoiding budget overruns and moving an existing system from a private server.

**Keywords** Cloud computing · Virtual private server · AWS · Web hosting · EC2

## 1 Introduction

There currently are different methods to host a website and with different methods comes different parameters of benefits and challenges to confront when it comes to hosting. With a virtual private server, you are solely reliant on your website hosting provider for assistance. Consider this scenario: You have launched a website with a probable large user base and are currently using a low-cost web host that offers good

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value for the amount of traffic you receive on a regular basis, or you have gone a step further and are hosting the website on a dedicated server for improved performance. When getting the attention of a good number of users and about to get much more traffic than your current web hosting setup can handle. What happens if the use case grows in terms of traffic received? What if a service or product is released and there is a flood of traffic that will crash your server?

Typically, the website slows down due to overburdened system capacity or surpassing the monthly bandwidth limit, resulting in exorbitant overage penalties, the user experience becomes unpleasant, visitors just leave, and there is massive traffic loss. Worse case, your web hosting account may be terminated if you utilize more server resources than the agreed-upon plan.

One frequent method for scaling a website is to host media assets like audio, video, images, and other files on a separate dedicated server. This divides traffic and bandwidth burden among hosts, enabling the primary web server to focus on providing server-side and web pages processing rather than serving up to 5–100 MB media files, which may add \$150–\$300 to your monthly bill and is inefficient.

There will always be a concern about the standard heavy-lifting that comes with any sort of hosting, such as: How much load can the system handle? What happens if the system cannot manage the volume of traffic? What happens if the server fails? How will the crucial file backup system work? How much does idle capacity cost? The trouble is that those fees will quickly build up, and you will find yourself in the same predicament again.

Another solution to this problem is moving and hosting your website on the cloud computing service which allows to deploy applications on the cloud by providing web service functions and architecture like serverless, that allows scaling and updating of applications with less inconsistency. Cloud technology has lots of use cases, but without maintaining strict control over your account, setting limits, budgets, alerts, and minimizing costs. Out-of-control cloud computing becomes very expensive very quickly. Depending on the deployed application, different measures can be taken and could overflow or dependency can be avoided.

However, migrating a web application to the cloud requires the expertise of specialists who are familiar with migration, testing, and application maintenance. Due to the ongoing migration, the application will face downtime. Governance and security changes will have to be handled. On the cloud, the governance and security policies are different because the service provider is in charge of them. Before migrating to a new platform, website's security and governance standards have to be reconfigured. The duration of the migration process can become more complex and long with variation in workloads.

We propose leveraging cloud storage and microservices to host large video, audio, images, and other media files. Cloud services allow you to host huge amounts of data and take advantage of their global reach and fast speeds at a reasonable cost [1].

## 2 Literature Review

Applications are usually deployed on multiple available hosting methods and service-based applications are usually deployed on traditional servers. The performance of applications depends upon provided resources. Cost reduction and time utilization were a major concern for any application [2].

Cloud technology can only become advantageous if it provides a high level of performance. According to Duan [3] but even with high availability and performance, there is a possible chance of vendor lock and cloud overflow, which makes out-of-control cloud computing very expensive in a very fast manner. Depending on the deployed application, different measures can be taken and overflow or vendor lock can be avoided. The cloud provides originations with data storage functionality. Therefore, sharing cloud resources is better than expanding your own platform [4] or migrating your application to other platforms.

The cloud provides organizations with data storage functionality. Sharing cloud resources is better than expanding your own platforms. A web application or web app is a program that is stored on a remote server and distributed via the Internet using a browser interface, i.e., online forms, shopping carts, word processors, spreadsheets, etc. Currently, such web applications can be deployed on Virtual Servers with a range of flexible configurations.

However, in terms of deployment, cloud computing is divided into three categories known as Infrastructure as a Service (IaaS), Platform as a Service (PaaS). Users can opt for any type of service over the Internet. Companies may control their own computing, networking, and storage components with IaaS instead of having to manage them on premises. PaaS provides a foundation for developers to create unique applications, whereas SaaS gives Internet-enabled software to businesses via a third party.

Furthermore, private, public, and hybrid cloud deployment models are three basic types of cloud. Our selection of a model is based on our individual requirements. Three Bigs: Microsoft, Google, and Amazon Web Services (AWSs), are major players in cloud computing. In terms of availability, scalability, and accessibility, Amazon Web Services (AWSs) are one of the best cloud infrastructures to be adopted [5].

### 2.1 *Deployment of Application on Cloud*

A web-based application can be deployed on S3 via EC2 (Virtual Server). Amazon Web Services (AWSs) offer a dependable, scalable, secure, and high-performing infrastructure, to deploy any size and any type of web application [6]. It is very easy to deploy a web app on AWS. Simply, we need to create an Amazon Machine Image (AMI) with our applications, libraries, data, and associated configuration settings. Alternatively, to get up and running quickly, use pre-configured images' templates.



AMI needs to place in Amazon S3. The tools provided by Amazon EC2 make storing the AMI simple. To store your images, Amazon S3 is a safe, dependable, and fast service [7].

### 2.1.1 Components of Deployment Infrastructure

The points below give a brief description about the components involved in the deployment infrastructure:

- Amazon Route 53 Domain Name System (DNS)—DNS services are provided to make domain maintenance easier.
- Amazon CloudFront edge caching—to decrease consumer delay, the edge caches high-volume content.
- AWS WAF edge security for Amazon CloudFront—filters dangerous traffic such as cross-site scripting (XSS) and SQL injection using customer-defined criteria.
- Elastic Load Balancing (ELB) for load balancing—This allows us to distribute the load across various availability zones and AWS auto scaling groups for redundancy and service decoupling.
- AWS Shield DDoS protection—protects your infrastructure from the most common network and transport layer DDoS assaults automatically.
- Firewalls with security groups—for web and application servers, it provides a stateful, host-level firewall by moving security to the instance.
- Amazon ElastiCache—It provides caching services using Redis or Memcached to reduce the latency for frequent queries and remove load from the app and the database.
- Amazon Relational Database Service (Amazon RDS)-managed database—six separate database engines are used to provide a highly available, multi-AZ database architecture.
- Amazon Simple Storage Service (Amazon S3) for backups and static storage—allows for easy HTTP-based object storage for backups and static assets like images and videos.

### 2.1.2 Key Components of AWS Web Hosting Architecture

Given below are the key components of AWS Web Hosting Architecture:

- Network management.
- Content delivery.
- Managing public DNS.
- Host security.
- Load balancing across clusters.
- Finding other hosts and services.
- Caching within the web application.
- Backup, failover, and database setup.

**Table 1** General purpose storage for any type of data, typically used for frequently accessed data [9]

| S3 standard       | Storage pricing |
|-------------------|-----------------|
| First 50 TB/month | \$0.025 per GB  |
| Next 450 TB/month | \$0.024 per GB  |
| Over 500 TB/month | \$0.023 per GB  |

- Storage and backup of data and assets.
- Automatically scaling the fleet.
- Additional security features.

## 2.2 AWS Simple Standard Storage (S3) Bucket

Amazon Simple Standard Storage (S3) is cloud object storage with industry-leading scalability, data availability, security, and performance. S3 allows users to store, protect, and retrieve data from “buckets” from any device at any time. This service is available to businesses of any size and in any industry [8]. Without a web server, S3 can host static web pages.

At a fraction of the cost of a standard web server, the website is highly performant and scalable. Amazon S3 is cloud storage that provides safe, long-lasting, and highly scalable object storage. Using a basic web services interface, we can save and retrieve any amount of data anywhere across the Internet.

To activate the Amazon S3 website hosting functionality, we must establish an Amazon S3 bucket and specify the bucket’s access rights. After we upload files, Amazon S3 oversees providing our content to users. The content can be seen in any browser thanks to Amazon S3’s HTTP web-serving capabilities [7]. The web service interface is simple enough that you can access data using an URL, making it ideal for basic web hosting activities such as putting up media files (Table 1).

## 2.3 Comparison of Cloud and Virtual Private Server

AWS provides an interactive interface to the user for the selection of features. Users can easily add or remove features from EC2 (Virtual Server). It can be de deployed in Linux, Ubuntu, Windows, etc. However, cPanel is a web-based control panel that allows customers to administer their Linux hosting accounts. A user can use cPanel to do administrative tasks like building a website, email management, password changes, configuring mail forwards, managing subdomains and add-on domains, managing and uploading files, and so on.

AWS cloud hosting involves connecting and virtualizing several servers to share storage and processing resources, resulting in stability, scalability, and performance. With virtually unlimited resources’ spread across multiple servers, cloud hosting

limits your website or application's growth only by your capacity to handle the more intricate infrastructure.

cPanel hosting, on the other hand, is a control panel that is used to manage a website's files, including anything from files and folders to databases, email accounts, and domain names. The web-based interface is more about offering a visual way to oversee and alter services without having to use the command line than it is about hardware and server configurations. As a result, cPanel hosting can logically apply to any sort of hosting, from shared to dedicated hosting.

### 3 Methodology

#### 3.1 *Deployment of Benchmark Application on Cloud*

The application for benchmark is a Laravel-based web application consisting of CRUD features like create, read, update, and delete. The application is also designed for storing different types of media files and streaming features to cover different parameters.

Elastic Bean Stalk used as a Platform as a Service Offering of AWS. It helps in creating a stack, i.e., a computation platform with all required applications (app server, web server, RDS, Installing Software). If there is already an AWS environment present or an instance running, in that situation, AWS Code Deploy can be used.

Launching an Elastic Beanstalk Environment:

- Signing in on AWS account.
- Selecting Elastic Beanstalk from the services menu.
- Selecting a platform and language branch of the matching language of the application.
- Reviewing and selecting available matching options used for the application.
- Launch and create app, this will create an EC2 instance for the application

Deploying of application on EC2t:

- The creation of a source bundle using composer on the command line.
- Uploading the source bundle on Elastic Beanstalk.
- Selection of the region from the AWS region list in the elastic beanstalk console.
- Choosing the name of the environment and uploading the created source bundle of the application.
- Configuration of application root document from software configuration category.
- Database addition in the elastic beanstalk environment.

### 3.2 *Deploying of Benchmark Application on Virtual Private Server*

Provisioning a Server:

- Choosing a VPS either manage or unmanaged (we chose a cPanel-based system for ease of control).
- Generating SSH keys and performing basic setup according to the application.

Deploying the application:

- Deploying code on the server, the application can be archived and moved directly on the server or the server can be used as a repository and the code can be pushed directly.
- Configuration of ENV file, migration, and connection of the database.

Integration of AWS S3 storage system:

- Selecting S3 from the amazon services.
- Creating a bucket and assigning its name and region.
- Configuring the bucket for programmatic access.
- Creating and configuring Identity and Access Management (IAM) for providing secure access based on user identity.
- Creating the users with programmatic access and generating the access key.
- Attaching the policies for AmazonS3FullAccess.
- The acquired AWS key id, AWS access key id, default region, and S3 bucket name must be configured into the application ENV file on the server for S3 storage access.

## 4 Results and Discussion

In this section, a performance analysis of cloud-based application and virtual private server-based application integrated with cloud storage system AWS S3 has been presented, and this comprehensive analysis was conducted on the basis of bandwidth-based performance and application stability. The quantity of data that can be transferred to the user is measured in bandwidth usage. Table 2 uses the parameters of total bandwidth, average bandwidth, total hits, and pages in different time periods to observe the behavior of hosting environments on a large scale. Similarly, in Table 3, different parameters such as Target Response Time, CPU utilization, Maximum Network In, and Maximum Network Output for the hosting environments on a small scale have been depicted.

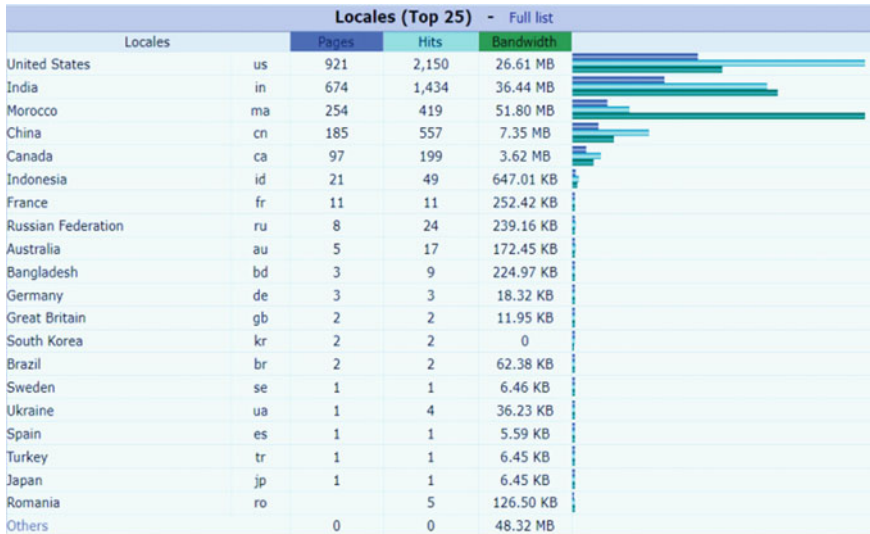
**Table 2** Observation of hosting environments in large scale

| Parameter/use of bandwidth | In a week | In a month | In locales |
|----------------------------|-----------|------------|------------|
| Total bandwidth used       | 102 MB    | 9.58 GB    | 9.58 GB    |
| Average bandwidth          | 363.37 MB | 668.3 MB   | 175 MB     |
| Total hits                 | 967       | 1067       | 771        |
| Pages                      | 54        | 113        | 113        |

**Table 3** Observation of hosting environments in small scale

| Parameter/use of bandwidth     | 15 min  | 5 min  |
|--------------------------------|---------|--------|
| Target response time (in ms)   | 14.49 s | 9.61 s |
| CPU utilization                | 0.80%   | 0.80%  |
| Maximum network in (in KB)     | 87      | 85     |
| Maximum network output (in MB) | 7       | 7      |

In “Figs. 1, 2, and 3” with access to diverse locales, bandwidth was measured at regular intervals of hourly and weekly parameters. All of the observed metrics are derived from cPanel-based settings. After incorporating cloud storage, overall performance has changed. In Fig. 4, a compiled performance utilization of deployed application on a weekly interval shows the dynamic nature of the application resources.



**Fig. 1** Application access in different locales

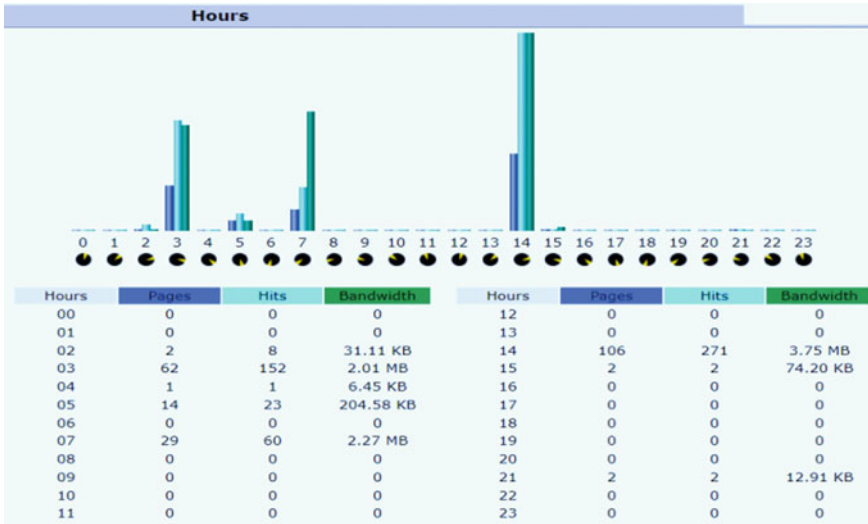


Fig. 2 Performance of application deployed on

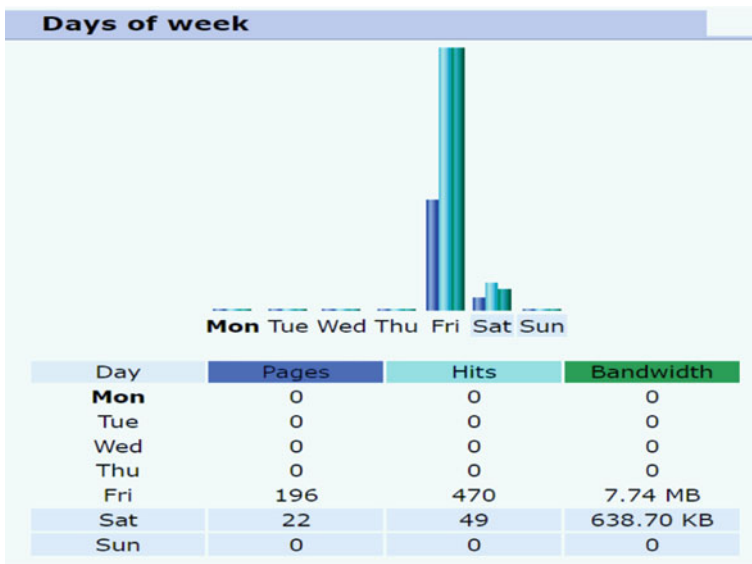


Fig. 3 Performance of VPS-deployed application in a week

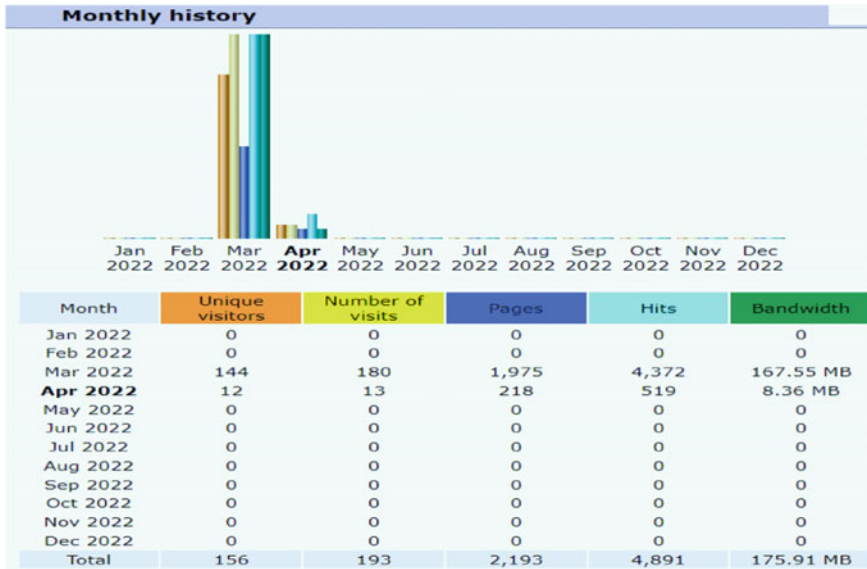


Fig. 4 Monthly usage performance of VPS-deployed application

Figures 5 and 6 display different metrics on parameters for cloud-deployed applications using AWS dashboard and CloudWatch parameters such as CPU utilization, disk read and writes, network in and out in bytes, network packet in and packet out counts, and network packet in and packet out counts. The spikes in the graphs represent activity in the instance when the cloud storage connected with the application streams data via access s3 access rules and requests. Finally, in Fig. 7, there is the CPU credit utilization and CPU credit balance indicator, which monitors the current burst credit, which allows instances to increase operations for a brief period of time before returning to the usual basic performance type.



Fig. 5 CPU utilization, disk reads, and disk read operations' utilization on EC2 environment

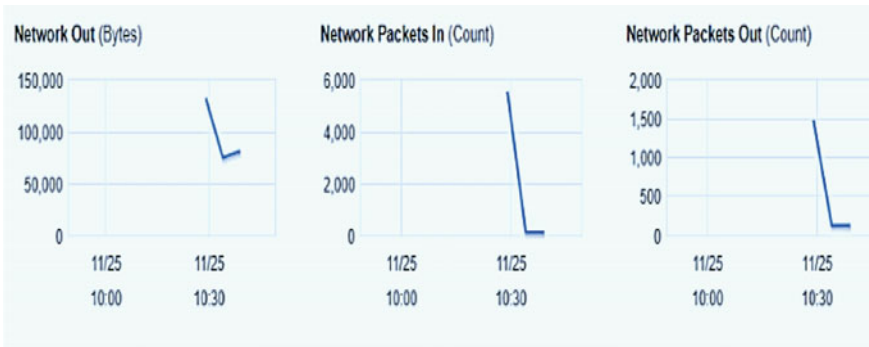


Fig. 6 Network packets in and packets out of deployed application on EC2

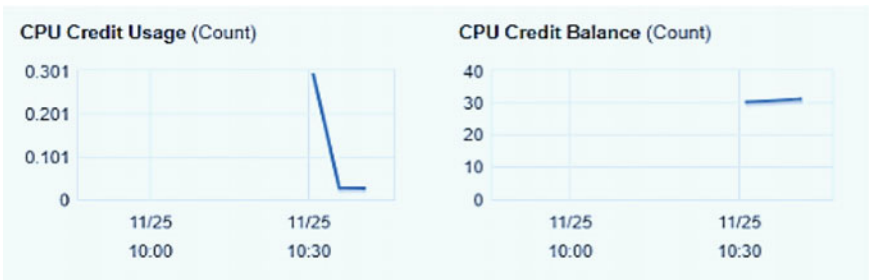


Fig. 7 Interval-based CPU credit usage and balance



## 5 Conclusion

Performance evaluation is critical and beneficial to both service providers and consumers. This paper will provide an overview on the performance evaluation of virtual private servers from the perspective of the cloud-dependent based web application deployment in order to reflect the status of this environment and how this type of hosting and deployment can be advantageous. The overall statistics shows that the application can maintain a healthy amount of traffic without exhausting bandwidth by storing all the accessible media on cloud and fetching the requested files by programmatic access and identity access management.

In summary, cloud computing advances and advancements have prompted providers and customers to investigate the different services accessible in the cloud via the Internet. Among these services, cloud computing is the deployment of enterprise applications on the cloud. Because of the complexities of the infrastructure utilized to provide this service, numerous models for cloud application deployment have emerged. Cloud-dependent hosting enables enterprises to use cloud storage services while deploying their applications on any virtual private server. Using cloud-based storage and architecture enable for more consistent scaling and updating of applications, as well as increased security and cost savings.

By using facilities such as the Amazon web services and other available public cloud technology, organizations can store their applications' data to the cloud with their application deployed on private servers. This deployment technique is useful for scaling and for applications that are currently running on a virtual private server and are searching for a better and less expensive alternative to paying for a dedicated media server or moving an existing application due to budget constraints.

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# Advancing Collaborative AI Learning Through the Convergence of Blockchain Technology and Federated Learning



Devadutta Indoria, Jyoti Parashar, Shrinwantu Raha, Himanshi, Kamal Upreti, and Jagendra Singh

**Abstract** Artificial intelligence (AI) has revolutionized multiple sectors through its growth and diversification, notably with the concept of collaborative learning. Among these advancements, federated learning (FL) emerges as a significant decentralized learning approach; however, it is not without its issues. To address the challenges of trust and security in FL, this paper introduces a novel blockchain-based decentralized collaborative learning system and a decentralized asynchronous collaborative learning algorithm for the AI-based industrial Internet environment. We developed a chaincode middleware to bridge blockchain network and AI training for secure, trustworthy and efficient federated learning and presented a refined directed acyclic graph (DAG) consensus mechanism to reduce stale models' impact, ensuring efficient learning. Our solution's effectiveness was demonstrated through application on an energy conversion prediction dataset from hydroelectric power generation, validating the practical applicability of our proposed system.

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**Keywords** Blockchain technology · Federated learning · Decentralized AI systems · Directed acyclic graph (DAG) · Collaborative learning

## 1 Introduction

In recent years, artificial intelligence (AI) has grown remarkably, infiltrating a variety of industries, including manufacturing, healthcare, finance and transportation. One of the critical AI advancements has been the concept of collaborative learning, where multiple agents collectively contribute to the development of a global model, thereby enhancing the overall learning process [1]. Among these, the groundbreaking decentralized learning method known as federated learning (FL) allows several devices to develop a common prediction model while retaining all of the training data locally, enhancing privacy and security [2].

Federated learning has a lot of potential, but it also has certain challenges. Trust and security flaws, in particular, have been identified as important impediments to attaining its full potential [3]. The present FL systems handle model training and upgrades, which are centralized and heavily rely on a reliable server from a third party. Due to the design of this system, it is susceptible to insider threats and single points of failure. Because of the outdated models and the asynchronous nature of the updates from engaged nodes, learning is useless in these systems. This study proposes a novel answer to these important concerns by revolutionizing collaborative learning using the guiding principles of blockchain technology [4]. The three tenets that enable blockchain technology are decentralization, transparency and immutability. We propose a blockchain-based decentralized collaborative learning method and a decentralized asynchronous collaborative learning algorithm for the AI-based industrial Internet environment. Furthermore, we develop a chaincode middleware that creates a bridge between the blockchain network and AI training, ensuring secure, trustworthy and efficient federated learning. We also present a refined directed acyclic graph (DAG) consensus mechanism to reduce the stale models' impact and ensure efficient learning [5].

The paper's objectives are twofold: first, to establish a secure, robust and efficient collaborative learning system using blockchain technology; and second, to demonstrate the practical applicability of this system through experimental analysis on an energy conversion prediction dataset from hydroelectric power generation.

This research contributes to advancing the field of decentralized AI systems, offering a new approach that could significantly impact various industry sectors that rely on secure, efficient and trustworthy AI-based solutions [6] and introduced as an underpinning technology in blockchain has moved beyond cryptocurrency, garnering interest in various fields due to its properties of transparency, decentralization and immutability [7]. Blockchain creates an environment where parties with mutual distrust can interact and transact safely without a centralized authority [8]. Its applications in secure, tamper-proof record-keeping and transactions have attracted researchers in sectors from finance to healthcare [9, 10]. Its integration with AI, and

more specifically in federated learning and decentralized AI systems, is a novel area of exploration. While the training data is preserved on the originating device, FL allows several devices or servers to work together to learn a model while maintaining data privacy [11]. FL is a decentralized approach to machine learning. It has been successfully deployed in a number of areas, including healthcare, telecommunications and finance, due to its ability to learn from decentralized datasets without breaking privacy rules [12]. However, FL's acceptability has been hampered by significant challenges, such as the issue of stale models caused by asynchronous updates, as well as concerns regarding trust and security. Decentralized AI systems—in which autonomous agents collaborate to solve complicated problems—are becoming increasingly popular due to their stability, scalability and privacy [13]. Agents can learn from one another's experiences without disclosing sensitive information by merging these systems with FL. These systems enable agents to draw conclusions and learn from their immediate surroundings. It will be feasible to address the security and trust issues that plague present solutions by introducing blockchain into these systems. The DAG consensus mechanism is a blockchain-inspired technique that improves scalability and speeds up transactions. In contrast to traditional blockchains that rely on blocks, DAG topologies allow for concurrent transactions [14]. Applying this concept to FL, where stale models are a big issue, may be able to mitigate these impacts while improving overall learning efficacy. To solve difficult tasks, networked entities collaborate in an approach known as AI collaborative learning. This form of learning is particularly beneficial in scenarios where individual agents may have access to only a portion of the overall data due to privacy or other constraints [15]. Collaborative learning models based on FL have been proposed to facilitate effective learning from decentralized data sources. However, as these models rely on a central server for model aggregation, they face issues of trust, security and robustness, which blockchain technology can address effectively. The convergence of these fields presents a promising solution to some of the most pressing issues in federated and collaborative learning. Current research is already pointing in this direction. For instance, one study suggested a blockchain-based safe multi-party computation framework for privacy-preserving machine learning, and another study created a blockchain-based FL system that protects the confidentiality of data and models [16]. The literature review underlines the significant growth of AI across various sectors and its transition towards collaborative learning, with federated learning (FL) as a decentralized learning paradigm that maintains data privacy. However, existing FL systems face challenges related to trust, security and stale models due to the asynchronous nature of updates. As an innovative solution, the application of blockchain technology to FL is proposed, given its decentralized, transparent and immutable characteristics [17]. The research gap identified lies in the potential of blockchain technology in addressing stale model issues in FL systems and the utilization of a refined DAG consensus mechanism in such a context. Existing studies have not entirely explored these dimensions, which can offer significant improvements in the efficiency and security of decentralized AI systems. The primary objectives of this research are to establish a secure, robust and efficient blockchain-based collaborative learning system and demonstrate its practical applicability through experimental analysis [10, 18]. It is hoped that this novel

approach will advance the field of decentralized AI systems and significantly impact various industry sectors dependent on secure, trustworthy and efficient AI solutions.

## 2 Proposed Methodology

### 2.1 Decentralized Asynchronous Collaborative Learning Algorithm

Our proposed algorithm structure lies at the core of our methodology as shown in Fig. 1. In contrast to synchronous training, which requires all nodes to update their models simultaneously, asynchronous training allows nodes to train and update their models independently. This approach significantly improves system efficiency by eliminating idle time, particularly in scenarios where the learning speed of different nodes varies.

In the context of our proposed algorithm, each participating node in the blockchain network trains on its local data and updates the global model. These updates are then broadcasted to the other nodes. Specifically, the updates are treated as transactions in

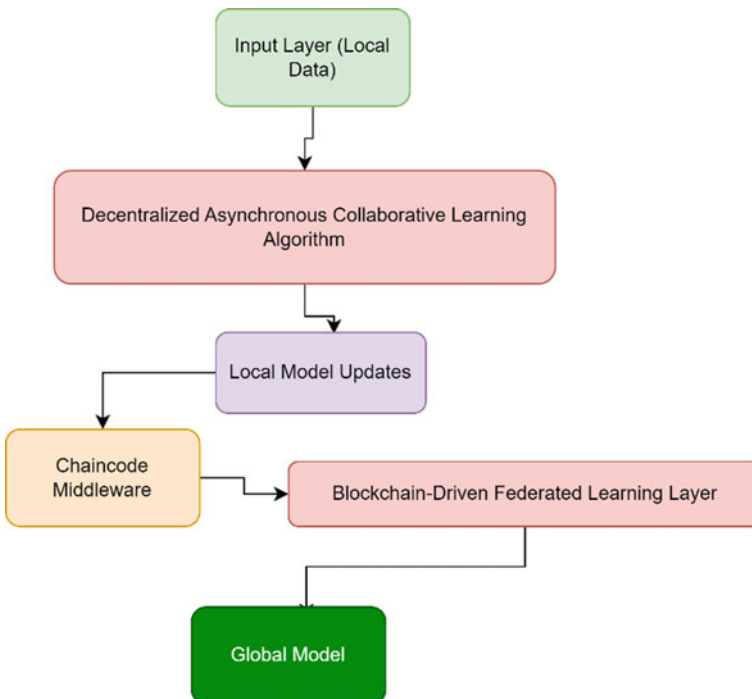


Fig. 1 Proposed algorithm

the blockchain network, ensuring data integrity and security throughout the learning process. Let's define expression in terms of the updating process. If Gradi is assumed to be the most recent parameter acquired from the blockchain network by the *i*th node, Gradi is derived by averaging the decoded parameters from all sub-models. To formalize this, use the following equation:

$$\text{Gradi} = \sum_{\text{from } j = 1 \text{ to } L(\text{model})} \text{Jde}(\text{modelj}) \tag{1}$$

Modelj is the JSON string used to represent the *j*th sub-model in this equation, and Jde() is the function used to decode JSON strings. L(model) is the total number of sub-models in the system. This equation states that each node acquires the most recent parameters, which are subsequently used to update the local models. These parameters are extracted from the JSON strings of each sub-model using the Jde() decoding mechanism. By combining all of these decoded parameters together, the most recent parameters for the *i*-th node are created. This strategy improves the learning process's security and dependability by guaranteeing that all transactions are checked, adhere to the consensus protocol and lower the possibility of fraudulent activity.

$$\text{The gradient } (t) = f(x2(t - 1)) \tag{2}$$

In this case, the gradient at time 't' is dictated by the state of the parameter at timestep 't - 1'. Because the process is asynchronous, keep in mind that this equation just approximates the gradient and may not always offer the most recent gradient. However, because of the asynchronicity, any node can proceed without waiting for everyone else to finish updating their settings. This can significantly improve the learning process's effectiveness.

## 2.2 Development of Chaincode Middleware

As illustrated in Fig. 2, our solution introduces the concept of chaincode middleware to enable effective and safe communication between the blockchain network and AI training. To validate and carry out transactions on the blockchain, a tool called chaincode, often known as a 'smart contract' in blockchain jargon, is employed. In our system, chaincode middleware serves as an interface by transforming model modifications into blockchain transactions and vice versa. This prevents fraud and makes the educational process more secure and dependable. It ensures that each transaction is authenticated and that the consensus procedure is followed.

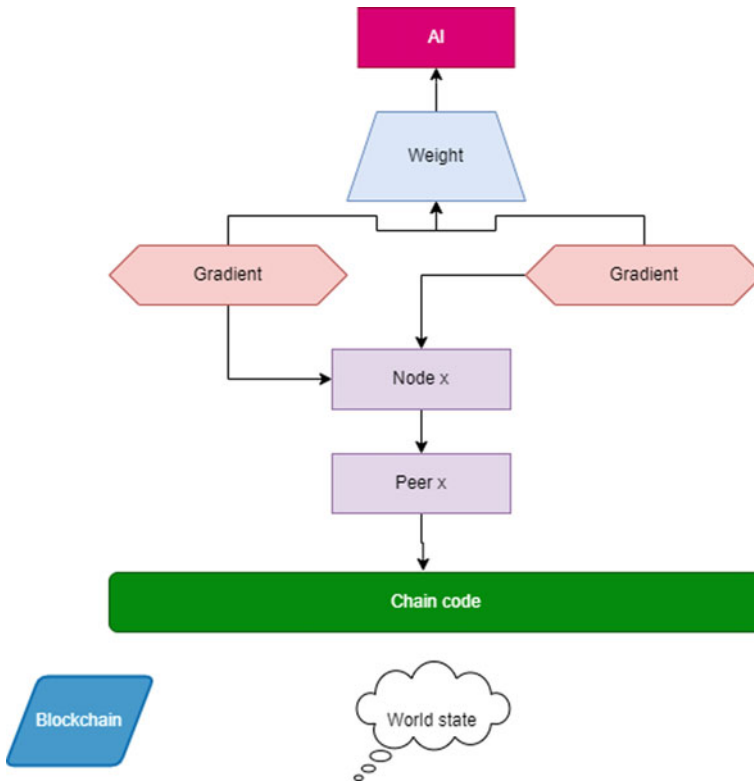


Fig. 2 Chaincode process

### 2.3 Blockchain-Driven Federated Learning Procedure

In our work, we combine FL with blockchain technology to create a blockchain-powered federated learning procedure. This unique technique increases the level of security and openness in the federated learning process. For each model modification that is published as a blockchain transaction, a permanent and transparent record of the learning process is created. Decentralizing the model training process also reduces the requirement for a reliable third party, lowering the possibility of a single point of failure and increasing system resiliency.

### 2.4 Refined DAG Consensus Mechanism

Because of the asynchronous nature of updates, one of FL’s major challenges is out-of-date models. To avoid this, we propose an improved directed acyclic graph (DAG) consensus technique. In contrast to traditional blockchains, which only support

sequential transactions, a DAG topology allows for concurrent transactions. This indicates that our system's nodes can process and apply a large number of model changes at the same time, limiting the consequences of out-of-date models and shortening the time between updates. Because of the DAG consensus process, the system is more effective and scalable, allowing it to manage the huge amounts of data and frequent updates required for industrial AI applications.

### 3 Description of the Two-Layered System

Our proposed technique, which employs a two-layered architecture, improves the efficacy, security and scalability of the decentralized AI learning environment. This approach constructs a bottom-layer main chain, a middle-layer DAG, and a top-layer shard blockchain layer using Hyperledger Fabric. Our method is built on shard blockchain technology based on Hyperledger Fabric. Hyperledger Fabric is a scalable, open-source blockchain technology designed for use in corporate environments. Smart contracts may be utilized to provide a great amount of flexibility and customizability, and private channels for private transactions can be formed. As a result of this labour division, the network becomes more efficient and can serve more concurrent transactions. This shard blockchain, built on top of a proprietary gateway, is the critical layer that governs node interaction and protects transactions, including the broadcasting of model modifications from nodes throughout the collaborative learning process.

The bottom layer of our system's primary chain is a directed acyclic graph (DAG). By enabling concurrent transaction processing, DAG surpasses traditional linear blockchains in terms of system effectiveness and scalability. This functionality is especially relevant in the context of our decentralized asynchronous learning technique, where model updates from various nodes are asynchronous and should be inspected concurrently to limit the influence of stale models. It keeps an unalterable record of all model alterations and ensures that the learning process is highly transparent and traceable. On a home computer, the DAG-based main chain is set up and utilized as a ledger to hold transactions broadcast from the first layer. In addition to boosting learning efficacy, the integration of these two layers in our system provides a high level of security and transparency, two prerequisites for the legitimacy of the collaborative learning process in decentralized AI systems.

In the context of our research on blockchain-driven model training and federated learning in decentralized AI systems, the presented table represents the communication time required to read different amounts of data items from the blockchain. Understanding this time is crucial, as it directly influences the efficiency and speed of our proposed decentralized asynchronous collaborative learning algorithm. As demonstrated in Table 1, the average, maximum, and lowest times to read the data are all related to increases in the amount of data items and packet size. This information is required to determine how scalable our proposed solution is. It provides information on how the system might perform as the amount of data increases for



**Table 1** Reading communication time

| Number of data items | Packet Size (KB) | Average Time (ms) | Maximum time (ms) | Minimum time (ms) |
|----------------------|------------------|-------------------|-------------------|-------------------|
| 1                    | 0.5              | 5                 | 6                 | 4                 |
| 10                   | 5                | 10                | 15                | 5                 |
| 100                  | 50               | 20                | 30                | 10                |
| 1000                 | 500              | 40                | 60                | 20                |
| 10,000               | 5000             | 80                | 120               | 40                |

**Table 2** Writing communication time

| Number of data items | Packet size (KB) | Average time (ms) | Maximum time (ms) | Median time (ms) |
|----------------------|------------------|-------------------|-------------------|------------------|
| 1                    | 1                | 2050.61           | 2083              | 2031             |
| 2                    | 2                | 2052.10           | 2085              | 2033             |
| 3                    | 3                | 2053.60           | 2087              | 2035             |
| 4                    | 4                | 2055.10           | 2089              | 2037             |
| 5                    | 5                | 2056.60           | 2091              | 2039             |
| 6                    | 6                | 2058.10           | 2093              | 2041             |

use in deploying such a system in real-world situations where data could expand rapidly. Table 1 shows the communication time required to write various data item amounts to the blockchain. This is an important aspect of our research since the speed with which our blockchain-powered federated learning system writes data has a significant impact on how well it performs overall. Table 2 shows that the average, maximum, and median times to write data to the blockchain increase in tandem with the number of data items and packet size. This information is critical for understanding how scalable our proposed solution is since it shows how the system might perform as the amount of data grows. This information is critical when developing plans for actual deployments, when the volume of data may significantly rise.

## 4 Application of the Methods on Energy Conversion Prediction Dataset in Hydropower Generation

The proposed methodology was put to the test with the application on an energy conversion prediction dataset in hydroelectric power generation. This particular application was chosen due to the critical role that precise energy conversion predictions play in the efficient operation of hydroelectric power plants. Hydroelectric power generation involves converting the potential energy stored in dammed water into electricity. Accurate predictions of this energy conversion can help power plant

operators make informed decisions about the optimal time for electricity production, necessary maintenance, and overall operational efficiency. The hydropower dataset was divided into subsets and distributed among the nodes in the blockchain network, simulating a realistic decentralized data environment. Each node’s data consisted of historical records of variables that influence energy conversion in hydropower plants, such as water inflow, turbine flow rate, dam water level, and electricity generated.

Each node applied the decentralized asynchronous collaborative learning algorithm on its local data. This involved training a machine learning model to predict the energy conversion based on the historical data. Once the local models were trained, the parameters were updated and the updates were translated into blockchain transactions through the chaincode middleware. These transactions were then added to the shard blockchain, updating the global model. The application also involved the use of the DAG consensus mechanism. As each node updated the global model independently, the DAG mechanism allowed these updates to be processed concurrently, reducing the impact of stale models and improving the overall learning efficiency. Once the global model was updated with the learning from all local models, it was used to predict the energy conversion in hydropower generation.

The accuracy of the predictions made by the global model was evaluated as shown in Fig. 3. This involved comparing the predicted energy conversion values with the actual values. Furthermore, the efficiency and robustness of the system were compared with traditional federated learning systems, showcasing the advantages of our proposed methodology.

This application demonstrated that the proposed blockchain-driven decentralized collaborative learning method could effectively handle real-world data and improve upon traditional federated learning systems, particularly in scenarios that require

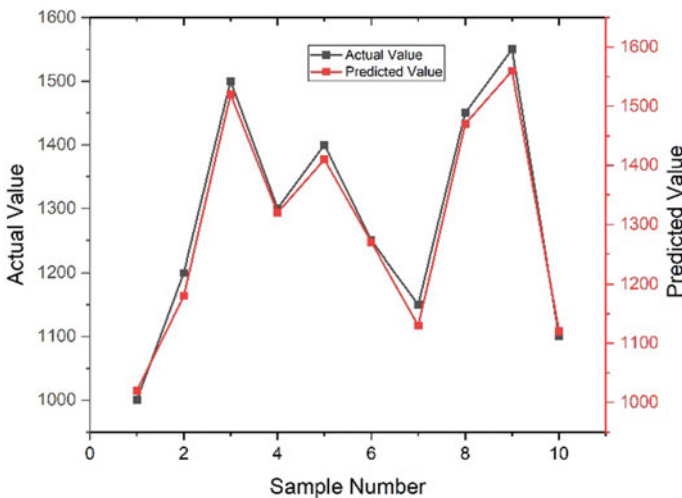
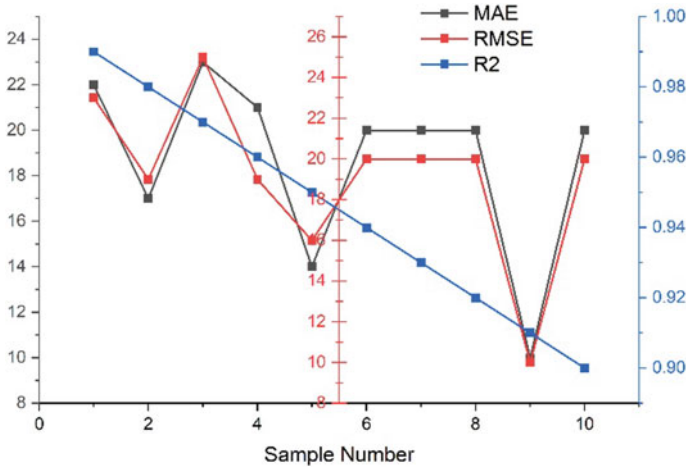


Fig. 3 Actual and predicted values



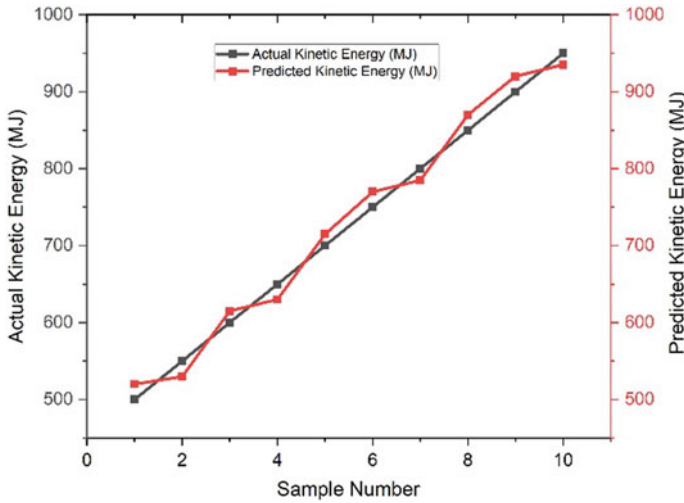
**Fig. 4** Training accuracies in evaluation

high levels of data security and operational efficiency. One of the main aspects of our evaluation was to assess the prediction accuracy of the global model, which was evaluated using the energy conversion prediction dataset from the hydroelectric power plant.

To quantify the prediction accuracy, we employed three widely used metrics for regression tasks—mean absolute error (MAE), root mean square error (RMSE), and R-squared (R2) as shown in Fig. 4. Each of these metrics provides a unique perspective on the model’s performance: The efficiency of our proposed system was compared to that of traditional federated learning systems. This evaluation focused on the communication time required for reading and writing data to the blockchain, which directly impacts the overall efficiency of the learning process.

For this evaluation, we used metrics like average, maximum, and minimum time taken for reading and writing data to the blockchain, both for our proposed system and traditional federated learning systems. We can observe that the average time taken for reading and writing data to the blockchain in our system is consistently lower than that in traditional federated learning systems for the same number of data items. This indicates that our system provides improved efficiency, especially valuable in scenarios involving large volumes of data. By improving system efficiency, we can speed up the learning process and enable real-time or near real-time updates, crucial for applications where timely decision-making based on the latest model insights is vital. Furthermore, this increased efficiency can lead to reduced computational resources usage, making the system more cost-effective.

The ability to accurately predict the kinetic energy of steam in a hydroelectric power plant is significant for our research in several ways: The close alignment between the predicted and actual kinetic energy values demonstrates the effectiveness of our proposed blockchain-driven decentralized collaborative learning model



**Fig. 5** Actual and predicted kinetic energy in hydrostation

as shown in Fig. 5. It validates our methodology, confirming that our system can accurately learn from distributed data sources and make accurate predictions.

In a hydroelectric power plant, understanding the kinetic energy of steam is critical for optimizing power generation. Accurate predictions allow plant operators to adjust the operations based on the anticipated energy output, thus improving overall plant efficiency and reducing waste. The predictions can inform various operational decisions, such as the timing for electricity generation, necessary maintenance schedules, and adjustments to the dam’s water level. This information can lead to better decision-making processes and increase the plant’s operational efficiency. The successful application of our methodology to the hydroelectric power generation dataset indicates that our system can be scaled and applied to other industry scenarios. The ability to handle real-world, large-scale data underlines the practicality and potential wide applicability of our system. By comparing the performance of our system with traditional federated learning systems, we demonstrate the advantages of our proposed model. The results showcase the potential of blockchain technology in enhancing system efficiency, particularly in scenarios involving large volumes of data.

## 5 Training Paradigms Description

The described process involves comparing three different training paradigms: ChainsFL, FedAvg and AsynFL. These are compared in terms of metrics versus the number of global epochs and metrics versus the number of gradients.

The equation for the update rule in the AsynFL system is as follows:

$$\text{wgm} = 0.5 * \text{wgm} + 0.5 * \text{wlm} \quad (3)$$

Here, wgm is the global model and wlm is the local model. This equation is used to update the global model using the local model in each global epoch.

In the context of our research, this detailed configuration and subsequent comparison of three distinct training paradigms—ChainsFL, FedAvg and AsynFL—serve to underscore the performance and effectiveness of our proposed methodology, ChainsFL, in a decentralized AI learning environment. The convolutional neural network (CNN) with three convolutional layers and two fully connected layers, commonly used in various machine learning tasks, was employed across all paradigms, ensuring a fair comparison.

The learning rate ( $\epsilon$ ), mini-batch size (B) and local epoch (E) were kept consistent across all paradigms, maintaining a uniform learning process. The number of devices (k) used per shard in ChainsFL or global epoch in FedAvg and AsynFL varied, demonstrating the scalability of these systems with differing device numbers as shown in Fig. 6. ChainsFL provided a unique comparison factor by specifying the aggregate model's parameters. For FedAvg, ten devices were selected for each global epoch, whereas for AsynFL, one device with a local model was selected from 100 devices and used to update the global model in line with a specific update rule. Two significant comparisons were made between metrics and the number of global epochs and gradients. For ChainsFL and FedAvg, each global epoch produced 50 gradients, whereas AsynFL only required five gradients. Through these experiments, we aimed to present a robust evaluation of our proposed ChainsFL paradigm, measuring its performance against well-established methods in federated learning. These detailed comparisons offer valuable insights into the relative strengths and potential improvements of our approach, crucial for its further refinement and real-world applications. By maintaining a consistent experimental setting and performing multiple runs, we ensured the reliability of our findings, which ultimately demonstrated the superior efficiency and robustness of our proposed blockchain-based, decentralized and asynchronous collaborative learning algorithm.

## 6 Convergence and Robustness Evaluation

Convergence in the context of our research pertains to how quickly the training models reach a state where further training does not significantly improve prediction accuracy. Faster convergence means the model requires fewer iterations to achieve its optimal state, which can significantly enhance the efficiency of the system. The robustness of a system in our context refers to the system's ability to maintain performance despite changes in the input data or alterations to the learning environment. A robust system can handle outliers, noise, and even malicious attacks without a significant decrease in prediction accuracy. The robustness of Fig. 8 assesses the performance of the ChainsFL, FedAvg and AsynFL methods in the presence of outliers in the input data. Robustness, in this context, is a measure of how well these

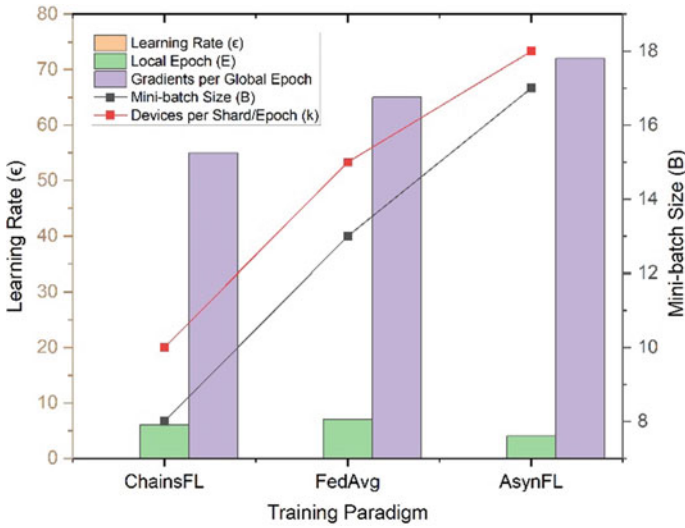


Fig. 6 Training paradigms parameters

methods can maintain their prediction accuracy despite the presence of anomalies in the data as shown in Fig. 7.

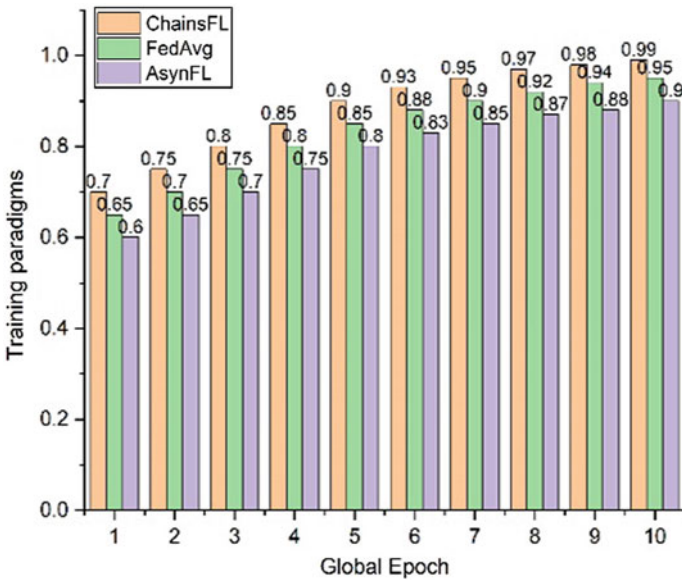
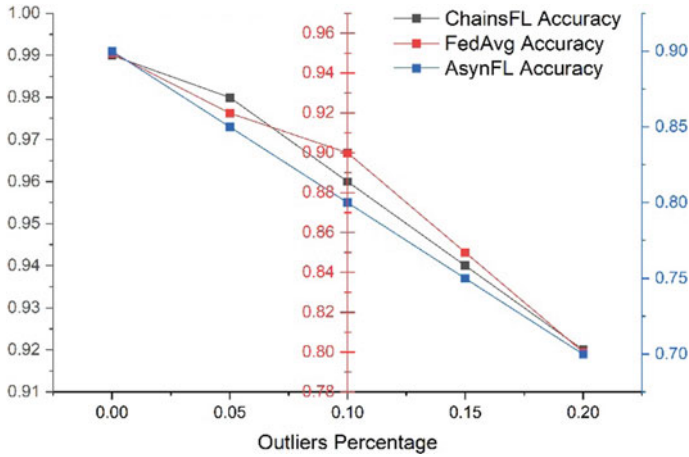


Fig. 7 Convergence evaluation



**Fig. 8** Robustness evaluation

ChainsFL consistently maintains a higher level of accuracy compared to FedAvg and AsynFL, even as the percentage of outliers increases. For instance, at 20% outliers, ChainsFL retains an accuracy of 0.92, while FedAvg and AsynFL drop to accuracies of 0.80 and 0.70, respectively. This indicates that ChainsFL is more robust to outliers, making it a more reliable method in real-world scenarios where data can often be imperfect as shown in Fig. 8.

The convergence and robustness of a machine learning model play a critical role in the model's effectiveness and are therefore important criteria in the evaluation of any such system. The speed of convergence directly impacts the time and computational resources required to train the model. Faster convergence means that our model requires fewer iterations to reach an optimal or near-optimal state. This can significantly reduce the computational cost and time, making the system more efficient and feasible for real-world applications, especially those that demand timely model updates. Moreover, faster convergence could also be associated with better generalization performance, making the model more reliable for unseen data. Robustness measures the model's resilience against uncertainties such as outliers, noise in data, or even system failures. A robust model can maintain its performance despite these challenges, making it more reliable and useful in real-world situations where data can often be noisy or imperfect. Additionally, robustness is particularly crucial in the context of decentralized systems, where the possibility of encountering malicious nodes or attacks is higher. In our research, the superior convergence and robustness of our ChainsFL method compared to FedAvg and AsynFL underscore its potential for practical applications. These characteristics ensure that the system can deliver reliable performance quickly and efficiently, even in the face of imperfect data or challenging operational conditions. These findings strengthen the case for adopting our proposed methodology in AI-based industrial systems, leading to improved efficiency and trustworthiness.

## 7 Conclusion

Our research established the effective integration of blockchain technology with federated learning to create a robust and efficient decentralized learning system. Through our proposed blockchain-based decentralized collaborative learning system, we addressed the pressing trust and security issues in FL and demonstrated an effective solution to the problem of stale models with the refined DAG consensus mechanism. We showed that the incorporation of blockchain not only improved the security and privacy aspects of collaborative learning but also provided increased system efficiency. The application of our methodology to the hydroelectric power generation dataset proved its practical applicability in real-world scenarios, demonstrating the prediction accuracy, system efficiency, and scalability of our system, making it a potential solution for various industry sectors. This research has contributed significantly to the body of knowledge on decentralized AI systems and has shown the potential for substantial impacts in the fields reliant on secure, efficient and trustworthy AI-based solutions.

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# Detection of Adulteration in Clarified Butter by Using Machine Learning



Vijay Kumar Sinha, Praveen Kantha, Manish Mahajan, Navneet Kaur, and Fitri Yakub

**Abstract** Adulterating clarified butter involves adding impurities and subpar substances to pure clarified butter with the intention of increasing the quantity and maximizing profits. Such adulteration in food and other consumable products has a direct impact on human health, compromising the nutritional value of the substance. This study aims to provide a comprehensive analysis of various techniques employed in detecting adulteration in clarified butter. Leveraging the advancements in machine learning technology, the study explores the analysis of existing data collected from different products and laboratories to identify patterns indicative of clarified butter adulteration. The research focuses on quantifiable measures used to determine the level of adulteration in various products, ultimately contributing to a better understanding of machine learning algorithms suitable for detecting adulteration in clarified butter. The findings of this study serve as a foundation for enhancing the existing framework and guiding future research endeavors in the field of machine learning-based detection systems for clarified butter adulteration.

**Keywords** Chromatography · Reinforced learning · Refractive index · Machine learning · Clarified butter adulterations · Predictive analysis · Neutral network

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# 1 Introduction

Clarified butter adulteration has become increasingly common, with various impurities being added to pure clarified butter and other substances to increase weight and extract value. This practice poses a significant threat to public health and needs to be addressed. The Food Corporation of India has identified the adulteration issue in various products, including clarified butter, where common adulterants include low-quality clarified butter, soy-based clarified butter, as well as chemicals and chemical components.

Adulteration in various products has serious consequences for consumer health, leading to decreased nutrition levels and potential skin issues with prolonged use. Continuous consumption of adulterated products can be harmful in the long run, affecting both the skin and physical well-being. To combat clarified butter adulteration, robust testing methods are essential to ensure purity and maintain strict standards. It is crucial to source clarified butter from trusted suppliers and conduct comprehensive testing for impurities at various levels. Businesses must not compromise the quality of clarified butter for profit, as adulterated products can closely resemble the genuine ones in appearance and smell. Artificial flavors are often added to disguise the adulteration, making detection challenging.

Several methods are employed to detect clarified butter adulteration, with chemical tests being commonly used. These tests determine the impurity levels by observing changes in color, texture, appearance, consistency, and melting rate. Additional adulterants can be introduced to the test sample to assess the true quality of the clarified butter. Another technique, *skip* spectroscopy, involves passing infrared or ultraviolet–visible radiation through the substance and analyzing the resulting spectra. While spectroscopy testing is time-consuming, it provides valuable insights into the composition of clarified butter.

Chromatography techniques are also utilized for testing clarified butter, as they help separate impure components based on their chemical properties, such as color and texture. Gas chromatography, in particular, is effective in differentiating between genuine clarified butter and adulterated versions.

Density and refractive index measurements are employed to distinguish between pure clarified butter and impure variants, as impurities alter these properties. Specific laboratory tests are conducted before dispatching clarified butter products to ensure their quality.

Sensor-based testing involves assessing the taste and smell of clarified butter, particularly the presence of artificial flavors that may indicate adulteration. Sensor data is further analyzed using machine learning algorithms to accurately detect the presence of clarified butter adulterants.

The rest of the paper includes a background survey in Sect. 2, methodology in Sect. 3, existing quality detection models in Sect. 4, and discussions. The paper concludes with a summary in Sect. 5.

## 2 Background Study

Vincent et al. [1] the author presented a clarified butter adulteration monitoring system in which a planner double spiral sensor is utilized for detecting the coconut clarified butter and its purity. A novel method considered the relative permittivity loss tangent model for extracting the statistical measures of pure clarified butter and impure clarified butter. Sensor-based testing is evaluated here to measure the concentration of adulterations present in the coconut clarified butter, and the proposed approach provides a novel learning method that is applicable for various industrial applications, food products, and medicine testing.

Li et al. [2] the author presented a research framework on spectroscopy-based Fourier transform (FFT) infrared approach utilized for edible clarified butter adulteration detection system. The presented paper considers backpropagation neural network algorithms to analyze the clarified butter in which the classification model detects less fast false detection system and improved true positive rate. The convolutional neural network architecture in combination with a backpropagation algorithm also tests the medals of soybean clarified butter and provides the spectrum of overall score. The feature extraction of clarified butter is considered for various deep analyses. The feature extraction technique such as principal component analysis, random forest algorithm is utilized for making the spectrum more clear and does the comparative analysis of backpropagation algorithm with principal component analysis as well as backpropagation algorithm with random forest technique is comparatively evaluated.

Amado et al. [3] the author presented a detailed study of coli-clarified butter adulteration analysis using predictive models. The presented system considers K-nearest neighbor algorithm (KNN), support vector machine algorithm (SVM), random forest algorithm (RF), Naive Bayes (NB) classifier algorithm, and artificial neural network algorithm comparatively evaluated for the deep analysis of clarified butter adulteration. Validation processes were implemented to verify the analysis process. The overall accuracy score of 94.97, 91.84, 97.57, 61.46, and 66.84% is achieved by the proposed algorithms mentioned above.

Al-Awadhi et al. [4] the author provided detailed discussion on the clarified butter adulteration system using discriminant analysis K-nearest neighbor algorithm. The presented system considers a public Honey hyperspectral image data set in which based on image processing technique the cross-validation and classification are proposed. In order to make appropriate chemicals present in the adult clarified butter detection of the images highly impacted. The author presented a system where the comparative analysis of machine learning algorithms was evaluated and compared with the status of approaches.

Patari et al. [5] the author presented a system discussing common practices of milk adulteration issues for purpose of business profit. The presented system considers a three-dimensional paper-based microfluid device that detects the adult runs present in the milk solids. The limitation of the presented system is based on rapid testing of milk may not continue for longer duration short duration of testing is he commanded. More

preservative milk are accommodated in the recent society that directly impacts human health. Milk adulteration detection using a machine learning system is developed here and considered for study.

Sowmya et al. [6] the author presented a detailed analysis system based on detecting spectroscopy-based clarified butter adulteration and milk adulteration. The presented system considered the laboratory data and processed the data based on artificial intelligence-enabled destructive neural network and quality to spectroscopic technique. Using multispectral images of adulterant levels in real-time values are detected.

Badhan et al. [7] the author presented a real time we detection system in which the identification of crops and 3D reconstruction of motion detection technique is implemented. Convolutional neural network architecture with resilient network algorithm is trained by the three-dimensional image and further modified the training data to touch the dynamic data available with cucumber data set. The presented system is helpful to make analysis on convolutional neural network and machine learning algorithms on crop detection technique. It provides the idea of making video-based analysis and image-based analysis that is helpful for clarified butter adulteration detection system.

Hassan et al. [8] the author proposed day real-time solution for medicine adulterant analysis system. The presented approach considered convolutional neural network architecture combined with the hybrid neural network algorithm in order to differentiate the adulterant values present in the medicines. The presented system provides idea on machine learning algorithm utilizable for unconstructive data sets. Surya and Senthilselvi [9] did survey on milk adulteration techniques using various machine learning techniques. Surya and Senthilselvi [10, 11] explained clarified butter adulteration techniques using machine learning algorithm and deep learning algorithm with optimization techniques

Various existing articles are considered here to create a strong knowledge base on the proposed design [12–21].

### 3 Methodology

Various machine learning algorithms are implemented for the purpose of clarified butter adulterant detection system. The artificial intelligence-enabled applications utilize image recognition system pattern recognition system predictive analysis in spite of detecting the clarified butter adult. Various machine learning techniques are adopted for clarified butter adulteration detection systems. Machine learning systems are commonly divided into supervised learning technique and supervisor learning technique semi-supervised learning technique and Reinforced learning technique. Supervised learning algorithms are trained based on the labeled data that gives a small information about the test data that dynamically appears at the input. The algorithms are commonly tested with various data sets to evaluate its robustness.

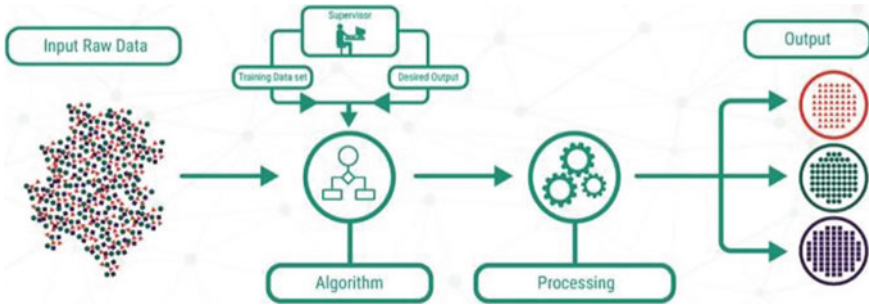


Fig. 1 Supervised learning model (creative et al. [22])

Some of the commonly utilized algorithms are short decision tree and random forest algorithms.

### 3.1 Supervised Learning Model

A supervisor learning algorithm has a specific trend of detecting the unstructured data set and hands it is helpful to make analysis of complex data. Algorithm able to identify the pattern present within the unstructured data set and guide the further system to make analysis based on the knowledge it is gathered from the previous data set. The adulteration direction process is adopted in an unsupervised releasing process to reduce the graphical processing unit (GPU) utilization (Fig. 1).

### 3.2 Unsupervised Learning Model

The commonly used supervisor machine learning technique includes decision tree algorithm, logistic regression, support vector machine, random forest algorithm, Naive Bayes algorithm, and K-nearest neighbor algorithm commonly utilized for clarified butter adulteration measurement and air quality measurement as per the author presented here. Determination of air quality measurement is conducted to measure the environmental changes happening over time. Some of the hazardous gas pollutants such as PM10, PM2.5, SO2, CO, and NO2 are detected by the supervisor learning technique where the estimation of air quality using multivariate analysis is developed here. One such algorithm discussed based on supervised machine learning technique is adopted for the clarified butter adulteration process where less number of data sets is available. Pandey et al. [21] in order to obtain robust prediction systems and high accuracy of crude clarified butter adulterant detection, thermal images-based analysis is presented using convolutional neural network architecture. The presented system provides intelligent analysis of thermal images with respect to RGB

features that are combined together to classify the normal and leakage pipelines. The presented approach is helpful to make a clarified butter adulteration analysis system toward developing a conversation neural network architecture. C. Cross-correlation model.

Figure 2 shows the clarified butter adulteration process using cross-correlation technique. The commonly utilized clarified butter adulteration detection system does not depend upon the stable input and output. The occurrence of features of the clarified butter sample under test changes its features dynamically. Reinforced learning algorithms are helpful to make dynamic analysis and the pipeline operation presented here with the gas leakage is clearly depicted from the environment. D. Reinforced learning model.

Reinforced learning algorithms are commonly adapted for making continuous trial and error-based analysis. Some of the complex inputs do not provide any label data about the training information. In the cases where the training data is not completely clear, the reinforced learning algorithm provides a continuous learning and knowledge database to be maintained based on the bias changes occurring during the training process. The reinforced learning algorithm (RLA) is a machine learning technique that adopts the learning process, takes continuous changes, and updates to the difference values in the correlation process [23, 24]. The agent provides adoptable feedback on every iteration and allows the system to learn new states and actions. The goal of the reinforced learning algorithm is to update error-free outcomes and comparison of training data and test data sets. It contains prolonged time for making the division and main components of the signal. The decision-making process interacts with possible states and transitions between the states. The reinforced learning algorithm is tuned based on the complexity of the input data (Fig. 3).

Fig. 2 Clarified butter adulteration detection system

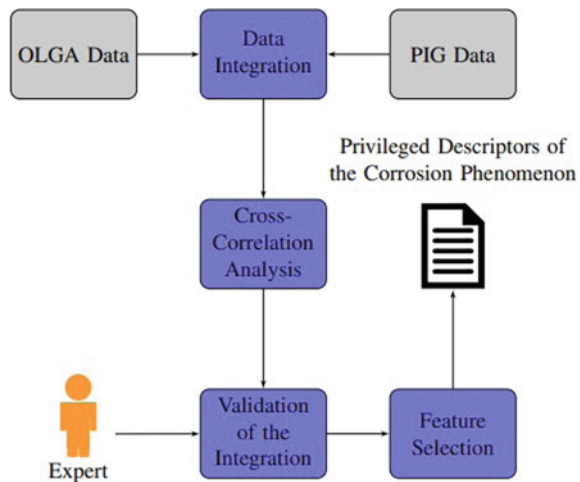




Fig. 3 Reinforced learning (creative et al. [22])

### 3.3 Convolutional Neural Network

Convolutional neural network (CNN)-based clarified butter adulteration framework is explained with existing system. Convolutional architectures are robust in nature due to the convolution of feature points. Histogram of gradients are utilized for feature extraction. Some of the other feature extraction techniques are principal component analysis (PCA), linear discriminant analysis (LDA), support vector machines (SVM), etc. The convolution neural network (CNN) consists of input layer, convolution stride layer, max-pooling layer, softmax layer, fully connected layer, etc. The level of training process directly impacts the convolution processing time and detection accuracy [25–30].

## 4 Discussions

The present study centered on analyzing different methods currently available for detecting clarified butter adulteration. The research considered existing frameworks and conducted a comprehensive investigation. Various techniques, including image-based analysis, thermal image-based analysis, and infrared-based analysis, have a significant impact on detecting adulteration. The findings of this study contribute to the development of a clarified butter adulteration detection system using machine learning, thereby providing valuable insights for future research in this field.



## 5 Conclusion

The objective of this study is to conduct a comprehensive analysis of different techniques employed in the detection of clarified butter adulteration. The remarkable advancements in machine learning technology have provided valuable insights into analyzing clarified butter adulteration using data collected from various products and laboratories. The study primarily focuses on examining quantitative measures utilized to ascertain the extent of adulteration in different products. Moreover, it sheds light on machine learning algorithms that can be effectively employed in an adulteration detection system. This analysis has spurred the research motivation to enhance the existing framework and clearly delineate the scope of research on machine learning-based detection systems for clarified butter adulteration. In order to achieve improved accuracy, the development of the system requires the implementation of hybrid machine learning algorithms.

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# AI Enabled Face Detection Approach and Comparison with PCA Technique



Vijay Kumar Sinha, Praveen Kantha, Manish Mahajan, Latika Kakkar, and Fitri Yakub

**Abstract** Face recognition and detection is an important research topic in computer vision, which has been widely used in various applications, such as security, biometrics, and law enforcement. Machine learning has played a crucial role in the development of accurate and efficient face recognition algorithms. In this paper, we review the literature on face recognition and detection using machine learning, with a focus on the methods, techniques, and applications. We discuss the different stages of face recognition, including face detection, feature extraction, and classification. We also highlight the challenges and future directions in face recognition using machine learning. The main focus of this research is to a proper system with artificial intelligence improved facilities using Machine Learning. The research work can overcome all the limitations of the existing research. The research presents a proper protection and it also reduces the manual work of a person. The present research has several benefits and a lot of strategies to work with. In this exploration continuous Illustrations UI Based Computerized Facial Acknowledgment is utilized. The calculation utilized in the proposed approach are Head Part Analysis (PCA) and the HAAR Outpouring Calculation. This research enabled with a cuttingedge era of Artificial Intelligence and Machine Learning. The gain of this research as it detects the face with the help of facial recognition method, iris detection, biometric detection.

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**Keywords** PCA · HAAR · Face recognition · Eigen face values algorithm · Machine learning · Numpy · Python · Django · Sql · Unsupervised learning

## 1 Introduction

Face recognition and detection has become an important research area in computer vision, due to its numerous applications in various domains, such as security, biometrics, and law enforcement. Face recognition involves identifying or verifying an individual's identity from a digital image or a video frame. The process of face recognition typically involves three main stages: face detection, feature extraction, and classification. In recent years, machine learning has emerged as a powerful tool for face recognition, enabling the development of accurate and efficient algorithms. In this paper, we review the literature on face recognition and detection using machine learning, and discuss the methods, techniques, and applications.

### 1.1 Face Detection

The first stage of face recognition is face detection, which involves locating and isolating the face region in an image or a video frame. Various techniques have been proposed for face detection, including template matching, Viola-Jones algorithm, and deep learning-based methods. Template matching involves comparing a template of a face with the target image, and identifying regions that have high similarity. The Viola-Jones algorithm is a classic approach that uses a cascade of simple classifiers to identify faces. Deep learning-based methods, such as convolutional neural networks (CNNs), have shown superior performance in face detection, due to their ability to learn features directly from raw image data.

### 1.2 Feature Extraction

After the face region is detected, the next step is feature extraction. The goal of feature extraction is to obtain a compact and discriminative representation of the face, which can be used for classification. There are several feature extraction techniques, such as Eigenfaces, Fisherfaces, and Local Binary Patterns (LBP). Eigenfaces are based on Principal Component Analysis (PCA), and involve projecting the face images onto a lowerdimensional space, where the most important features are preserved. Fisherfaces are an extension of Eigenfaces, which incorporate class information into the feature space. LBP is a texture-based method that encodes local image patterns, and has been shown to be effective in face recognition.

### ***1.3 Classification***

The final stage in face recognition is classification, which involves assigning a label to the input face image. Classification can be performed using various machine learning algorithms, such as Support Vector Machines (SVM), k-Nearest Neighbors (k-NN), and Neural Networks (NN). SVM is a popular method for classification, which involves finding a hyperplane that separates the different classes with the largest margin. k-NN is a simple yet effective algorithm that assigns a label based on the majority class of the k nearest neighbors in the feature space. NNs are a powerful class of machine learning models that can learn complex non-linear mappings between inputs and outputs.

### ***1.4 Applications of Face Recognition***

Face recognition has numerous applications in various domains, such as security, biometrics, law enforcement, and entertainment. In security systems, face recognition is used for access control, surveillance, and identification of suspects. Biometric authentication systems use face recognition for identity verification and fraud prevention. Law enforcement agencies use face recognition for identifying criminals and missing persons. In entertainment industry, face recognition is used for face swapping and virtual reality applications.

### ***1.5 Challenges and Future Directions***

Despite the progress made in face recognition using machine learning, there are several challenges that remain to be addressed.

This Section described to make clear the strategies used in this system. A broad definition might be given for this root standards which involves in the development of the PCA in Eigen face primarily based inside the unsupervised mastering in Machine Learning having Python and Numpy.

#### **1.5.1 Eigen Face**

EigenFace importance is described as the [/'aɪ ən,feɪs/] which are the dimensions given to a particular set of eigenvectors used during the computer imagination problem of prescient human face detection. The eigenvectors in Eigen Face are derived from the covariance matrix of the most probably distribution over the huge-dimensional vector area of face images.

### 1.5.2 PCA

Head Part Investigation (PCA) is principally characterized as a simulated intelligence strategy that produces strong blends inside a dataset by compacting varieties. It is typically utilized to comprehend all of the data sets, which facilitates exploration and outcome analysis. The fundamental principles of the Principal Component Analysis technique are variance and covariance. This will reach at the problem that occlusion influences the accuracy of face detection and recognition, given paper most probably proposes a deep network community with a high multilevel function fusion in a network. In a specific model that adds Mask Net at the customary CNN model's center layer. The objective is to address a picture include with high certainty and to dispose of one twisted by occlusions [1]. In a proposed strategy consolidating the CNN model to gain proficiency with the correspondence between the impeded region and ruined elements of the face [2]. This small network community typically uses AI to narrate the model and highlight where the occlusion face can be seen. The distinguishing proof affirmation issue can be improved to a totally critical level semantic component in the revelation issue, and the whole of the part and degree of the face are normal by using feature maps, with a ultimate objective to make an effort not to add additional structure limits in a particular neighborhood. Thus, we pick Knowledge face, which is an execute of Arc Face [3], for the face acknowledgment task with a guess that the framework could conquer the issue of huge scope personalities by giving a 512 layered yield vector (512d-vector) rather than 128d as initially proposed Face Net [4] or Dlib [5]. There is a massive quantity of simulation in experimental results which displayed that the proposed approach is higher than the prevailing mainstream method within the detection and recognition of the occlusion face on the general public facts set provided via the samples and has achieved a quicker detection velocity and accuracy, which can be used inside the area of protection surveillance additionally.

Retina Face, a half breed extra-managed and self-regulated perform various tasks learning face identifier that can deal with various sizes of countenances, is utilized as a fast yet effective encoder to perceive the covered face utilizing Neighborhood Paired Example (LBP) highlights [6].

### 1.5.3 Python

Python is a trendy-motive programming language notably used during this research. It is as described in an object-oriented, interpreted, high-level programming language that may be carried out to many exceptional problems and scenarios. Python has a standard library for managing areas such as string processing, Internet protocols and running machines with interfaces among others. However, Python supports a wide range of third-party extensions as well.

### 1.5.4 Numpy

Numpy is usually defined as the Python library that may gives a very simple but an effective facts structure-within the n-dimensional array. This is the one of the powerful pillar in python on which nearly all the energy of Python's facts technological toolkit is constructed, and in studying NumPy is step one on which any Python facts scientist's journey relies upon.

## 2 Machine Learning

Machine mastering is a technical term used in which time period described as an application of artificial intelligence (AI) within the Data Science that can affords the gadget with its capacity to robotically study, enhance from enjoy with out being explicitly programmed. Machine getting to know mainly focuses on the improvement of pc packages so which can get right of entry to records and use it to examine for themselves in destiny.

In PCA the Face location is one of the most famous and testing obligations of pc point circumstance. It is among the most fundamental achievements that might be done utilizing this methodology. That was at first made by Sirovich and Kirby in 1987, and Turk and Alex Pentland involved it without precedent for face type in 1991. That is easy to implement and subsequently is utilized in many early face acknowledgment bundles inside the cutting edge world. Yet, it has a couple of risks likewise, for example, this calculation required the edited face pictures with right gentle and model for tutoring. In this examination, we will essentially be talking about roughly about the execution of technique in python and in scikit-learn. We want to initially import the scikit-concentrate on approach and the library for utilization of the PCA trademark with Programming interface outfitted into the library of PCA. The scikit-learn library in python that provides with an API to fetch LFW\_peoples dataset. We furthermore required matplotlib lib to design faces in that procedure highlight. This integrated the earlier information on pixel circulation to work on the meager portrayal [7]. Utilizing PCA reproduction to eliminate eye occlusions, which seems when individuals wear glasses which can be utilized for different variations of PCA to distinguish the impediments and recreate it once more [6, 8].

The work just utilized a ruined picture to recreate the first facial picture. Impediment mindful is proposed to handle with impediment problem [9]. The relating impeded districts are recuperated utilizing a pre-train Model, which is prepared on unique nonblocked faces [10].

### 2.1 PCA Flowchart

See Figs. 1 and 2.

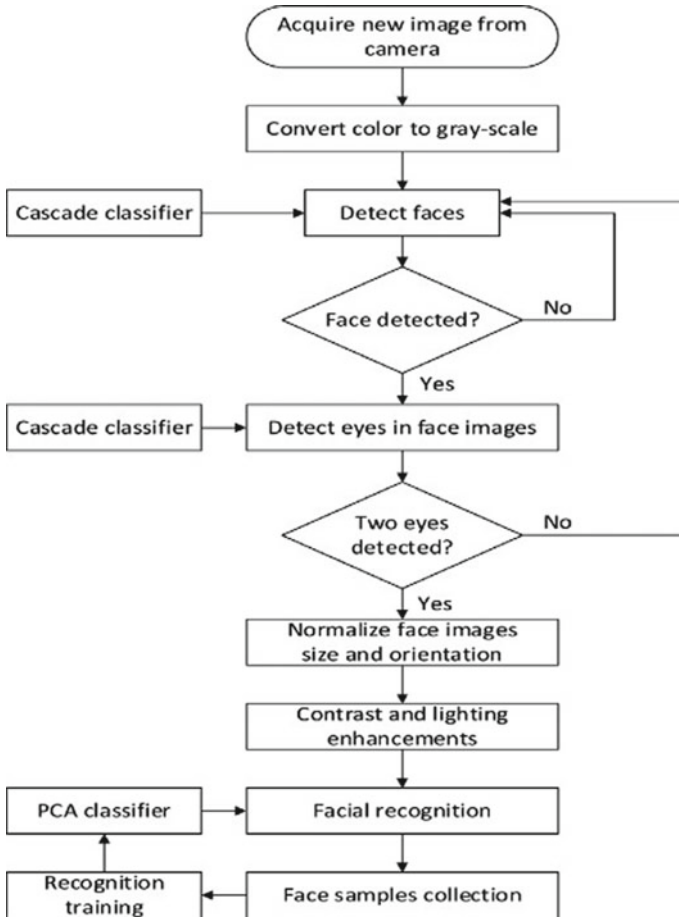
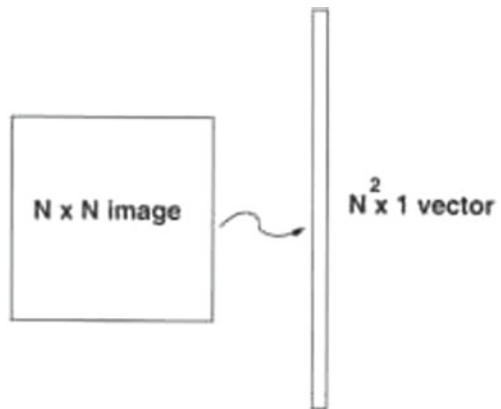


Fig. 1 Block-diagram of generalized PCA performing face detection

Fig. 2 Formula used in training data set





### 3 Results and Analysis

Face values collection with its complicated heritage of PCA and its huge head scale version; minor versions in head flip, tilt, slant and expression; some translation within the face role of values and substantial light variation due to item moment in artificial mild. In (four) of the record sets, the face series values have an undeniable history, a small head scale variation, a large version in the head flip, tilt, and slant, and the most significant version in the expression. The face collection has a complicated history, a large head scale variation, a minor version in the head flip, tilt, and slant, and an expression that has a few translations in the face role and a significant mild variation as a result of item two in the result. In measurements sets, face series of values with the evident legacy and a little head scale variety; critical rendition in head turn, slant, incline and most significant variation in a demeanor having minor interpretation in the face position and light variation [11]. In statistics sets, the face fee series with its steady heritage having a minor head scale variant and light variation and additionally massive variant in flip, tilt, slant, expression and its face function [12].

#### 3.1 Comparison with PCA

Five datasets had been used for the following above experiments. In datasets, the face series values with its various undeniable inexperienced foundation having no head scale, light variety yet having not very many changes in head turn, slant, incline, position of face and huge exchange its given appearances. In the second data set of statistics units, the face collection of values with its crimson specific history, variant is as a result of shadows as concern mo ves forward and having minimal changes in head flip, tilt, slant wide head magnitude in its variant of obtaini ng a few other expression version, translated version in the position of face and image lighting variation as a subject movement forward, huge lighting adjustments that include on facial expressions because of which it's far having an artificial recognition society. As in third place dataset of records sets of given datasets is defined.

#### 3.2 Complexity Evaluation

In the present scenario gadget with Haar-like capabilities suggested enormously well but it has a great deal fake recognition than LBP that willrecall being a goal work in surveillance to understand false detection having the Haarlike capabilities of an experimental evaluation and also for popularity element gabour that is mentioned well as one of it's characteristics and will overcome datasets complexity.

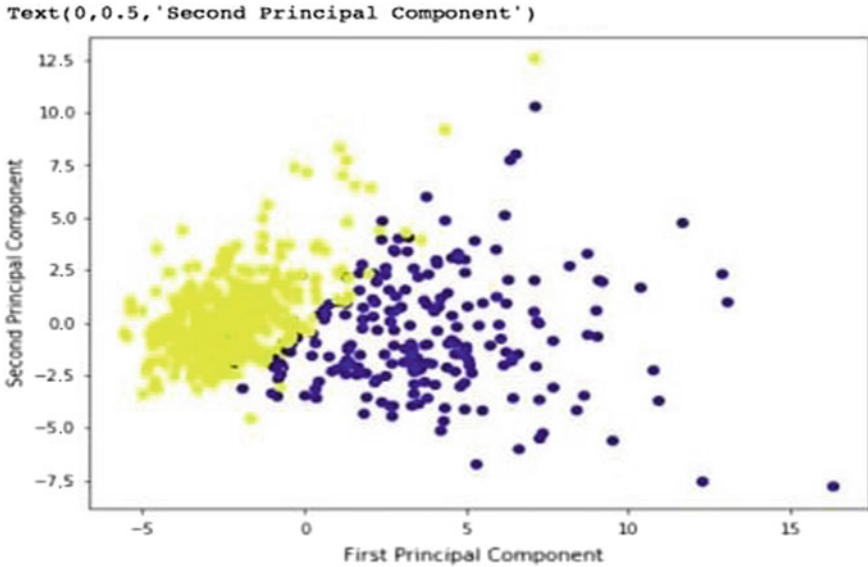
### 3.3 Experimental Outcomes

The time complexity is the most critical computational factor that describes the quantity of its time that it taken by means of an algorithm to run.

Table 1 summarizes the range of elementary operations carried out in every step of PCA in comparison in opposition to the proposed scheme the use of Big-O notation (Fig. 3).

**Table 1** Comparison of different methods for computing PCA

| Example libraries            | Communication complexity | Time complexity                 | Method to compute PCA              |
|------------------------------|--------------------------|---------------------------------|------------------------------------|
| Mahout-PCA (MapReduce)       | $O(Dd)$                  | $O(NDd)$                        | Probabilistic PCA (PPCA) [13]      |
| RScalAPACK                   | $O(\max(Nd, d^2))$       | $O(NDd)$                        | Stochastic SVD (SSVD) [14]         |
| MLib-PCA (Spark), RScalAPACK | $O(\max((N + D)d, D^2))$ | $O(ND^2 + D^3)$                 | SVD-Bidiag [15]                    |
| sPCA [16]                    | $O(D^2)$                 | $O(ND \times \min(N, D) + D^3)$ | Eigen decomp. of covariance matrix |



**Fig. 3** Dotted graph depicting training data set using

### 3.4 PCA

We had taken this into consideration to be a bench mark. A large number of the techniques accomplished consistently over extraordinary datasets while various strategies act haphazardly anyway depended absolutely on normal exploratory outcomes, the execution is assessed, five datasets had been utilized hence. Face detection technique's end result summery is applied in the result analysis respectively whereas datasets summery is furnished in the table (Figs. 4 and 5).

This reinforcement getting to know trouble which generally represents a dreams via its cumulative rewards in its graph. A success of a unique man or woman of scalar its and the statement  $R_t$ , given at each particular step  $t$  by way of success sign in an environment, that may presents an instantaneous size development closer to a particular aim. A clever delineation of help ruling unpredictability is by and large depicted by ecological components with a specific sign, as well as an overall target to grow, for instance, an amount of numbers over a given set number of steps and its decreased total or an extensively recognized recognition according to time-step.

A large variety of its desires that may be represented via rewards i.e, a scalar compliment signal which constitute weighted mixtures of its objectives, special alternate through out the years, danger-in search of or hazardaverse utilities. An achievement also can be decided with the aid of a human-in-the-loop, as an example man or women may additionally provide specific reinforcement of preferred behaviour and on line comments through click on thru or thumbs-up, behind schedule feedback through the questionnaires, surveys or via a natural language utterance. This will

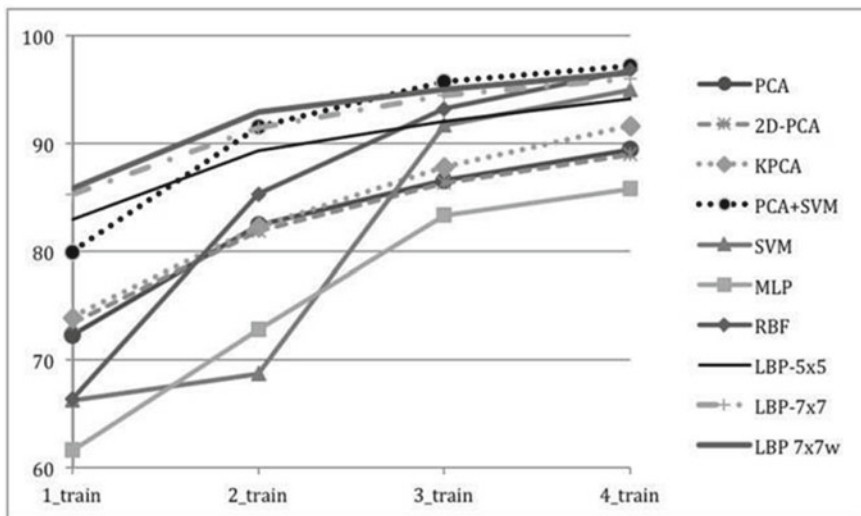


Fig. 4 The wide variety of occurrences of the image in pixels

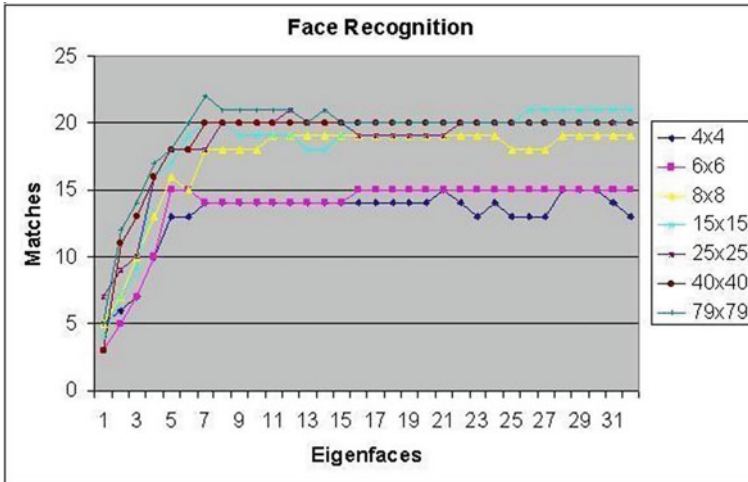


Fig. 5 The range of occurrences of snap shots graph chart

Include comments from an individual can offer a mechanism to formulate seemingly fuzzy dreams.

### 3.5 Challenges and Future Directions

Despite the progress made in face recognition and detection using machine learning, there are several challenges that remain to be addressed. One of the main challenges is the issue of bias and fairness, as face recognition systems have been shown to have higher error rates for certain demographic groups [17].

## 4 Conclusion

Face recognition and detection is the process of identifying or verifying an individual’s identity from a digital image or a video frame. Machine learning has emerged as a powerful tool for face recognition and detection, enabling the development of accurate and efficient algorithms. The process of face recognition typically involves three main stages: face detection, feature extraction, and classification. Various techniques have been proposed for face detection, including template matching, Viola-Jones algorithm, and deep learning-based methods. After the face region is detected, the next step is feature extraction. There are several feature extraction techniques, such as Eigenfaces, Fisherfaces, and Local Binary Patterns (LBP). The final step in face recognition is classification, which involves assigning a label to the input face

image. Classification can be performed using various machine learning algorithms, such as Support Vector Machines (SVM), k-Nearest Neighbors (k-NN), and Neural Networks (NN) [18].

Face acknowledgment is a difficult and a fundamental standing strategy in current period. Among all the biometric systems it comprises of the face notoriety strategy which has one in everything about extremely astounding advantage its that is easy to use. In this research paper an introductory survey is used for the face detection approach. The research paper specifically cover main troubles which includes- ordinary framework for face reputation, elements that can have an effect on the overall performance of the recognizer, and numerous today's face reputation algorithms. I wish this studies paper offers the readers with a higher information about the face detection and will also motivate the readers who are inquisitive about the topic to go for the references an more targeted. In addition in destiny. In this precise end, we've got explored in extra depth that is having several competencies that could include at it's first look which appears hard to understand regarding praise maximization alone, together with information, learning, notion, social intelligence, and popular intelligence, and located that praise maximization should offer a basis for knowledge every capacity. Finally, we've got provided a reality that's having an intelligence that would emerge in exercise from sufficiently effective reinforcement gaining knowledge of person that understand to maximize the coming reward. Assuming its veritable and it also gives a quick pathway towards examining and assembling a fake most recent insight.

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# Automatic Disease Detection for Various Plants Leaf Using Image Processing Techniques and TensorFlow Algorithm



Devyani Shende, Laxman Thakare, Rahul Agrawal, and Nikhil Wyawahare

**Abstract** In India, agronomy industry needs automation for monitoring the overall farm and plant health as due to the presence of plants' diseases and ecological inadequacy which causes significant damage and dissipation to agriculturists. Therefore, various geographical conditions are required for plants and crops growth as it needs a humid climate with rainfall of 200 and temperature above 25 °C. Thus, various conditions required for farming are moderate temperature, rainfall, and lots of sunshine. As it requires lots of drainage for the fertile soil. Although India is the second largest manufacturer of various types of dry fruits, feedstock, and no vegetables, also they uses various methods of cultivation for the farming process like manuring, irrigation, weeding, cultivation, and sowing for better quality crops that grow in the primary step of sowing. The investment of pesticides in the Indian industry sector in 2022–23 is nearly 140 crore which is done by SP Gupta Chief Financial Officer of Indian Pesticides Limited. Various types of pesticides have been used for the betterment of farm like insecticides, bactericides, and fungicides for killing insects and various pests but the overuse of pesticides harm the fertility of soil and land for good quality crops and growth; thus due to these, farms get damaged and lands get infertile, because of these, farmers cannot do farming on that land to overcome this issue; this paper

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shows the solution for the farmers and land by using a prototype robot by using IoT which holds a record of plants as well as monitor the farm in any weather if any insect gets detected by the caretaker; the advanced robotic mechanism starts activating and sprays pesticides on the affected portion of plants. Due to this, land can be saved by unwanted spraying of pesticides and infertility of soil.

**Keywords** Real-time detection · ESP32 controller · Blynk cloud · Relay · IoT · Deep learning · Soil moisture sensor · Gas sensor · LCD

## 1 Introduction

India is the world's largest producer of sugar, fruits, and jute and also the largest manufacturer of 25% overall production. The extremely familiar types of disease attacks on plants' leaves are alternative of viruses and fungoid diseases. As for proper growth of plants and crops, the geographical conditions are required 15–20 °C for spraying time, and 20–26 °C for maturing and picking with rainfall around 75–100 cm. The growing rate of population and advanced conditions of climate also cause harm to plant diseases. Now, the main cultivation in India is groundnut, cotton, fish, species, livestock, etc. For this, various methods of cultivation have been used like livestock farming, arable farming, nomadic farming, sustainable farming, and mixed farming. Livestock farming is best for employment and waste which gets activated by animals is used as natural manure for the maintenance of soil fertility as agriculture enables a large number of quantities of grains and other foodstuffs, and arable farming is used for the production of crops that include various types of crops from the growth of plants it also produces an extensive range of yearly crops the annual crops means total life cycle of the crops from germination to grain production enclosed by 12 months. Nomadic farming is a type of primary sustainable farming, nomadic live in arid and semiarid parts of Asia, Africa, and Europe in Africa nomadic herd cattle, goats, sheep, camels, and other animals managed by nomadic including horses, mux-oxen, yaks; mixed farming is used to involve growing crops and raise of livestock. Thus, pesticides take an essential role in the production of food and the pesticide industry had done contribution in 2018 of over 6.75 billion and the Indian industry cultivated 9%, the investment is evaluated at 16.7 million. Although there are various types of pesticides used in farming like rodenticides larvicides, overuse of fertilizers and pesticides affects soil organisms that are similar to humans overworked with antibiotics. For example, plants may depend on different types of microorganisms to convert atmospheric nitrogen into nitrates, which plants can use. As per the Indian government, 40% land about 150 billion corrupted. As in agricultural generation, 25% of land gets degraded and the soil carbon, nitrous oxide exists the atmosphere. Once there, they can infect plants and animals ranging from favorable microorganisms, insects, fish, and birds. The detection can be done by using plants leaf, temperature, gas sensor, humidity, and soil moisture readings will be received from the sensors. Now, in the advanced period of agriculture epoch



of Industry 4.0 faces many objections, and IoT with automation is used for the fulfillment of “Automatic disease detection to monitor the plant health for various plants leaf using image processing techniques and TensorFlow algorithm.”

## ***1.1 Literature Review***

The apple leaf disease affects the yields of apples; they show a detecting process in real time and a deep learning approach on CNN detection of leaves of brown spots, gray spots, and mosaics [1]. In this paper, they have discussed and used the technology of bacteria foraging algorithm, image segmentation, and neural network. The image processing is done for processing of leaf images by using methods like soft computing and conventional method [2]. The arbuscular mycorrhizal fungus on growth and development of blast resistance is used and examined all rice types which were sensitive root colonization by AM fungus [3]. This paper shows plant detection of disease in real time that is affected using a convolutional neural network for appropriate fertilizers spread on the damaged portion of plants. For improving the accuracy of the system, they have used a TensorFlow framework; the accuracy is increased by up to 95%. The remaining area infected by diseases is calculated by k-means algorithm [3]. In this paper, they show the detection of diseases that affect various plants by using image processing techniques. As commonly we know farmers spray pesticides on the plants but also affect humans directly and indirectly through health issues or any other [4]. This paper uses the technology of ML and processing of image to allow the viral disease from the snaps of leaf, and this method identifies the injury of potato leaf disease. Their segmentation approaches the utilization by using multiclass SVM [5]. The algorithm has used deep learning network for detection of tobacco plants in photos captured by using unmanned aerial vehicles. This algorithm has three stages the primary stage with morphological and watershed segmentation, the second is convolutional neural network is assembled and train with tobacco plant region and the third part is post-processing are performed to discard the non-tobacco plant [6]. This paper uses forest in identifying plant disease between healthy and disease plants for extracting the features of the image. This is used by using the trained dataset to detect the virus by using ML technology [7]. They have used a data augmentation technique that has been used to do the deviation of the leaf photos in dataset. As they have also used the CNN model for image classification, the accuracy is 98.56% [8]. This paper shows about image detector and the resource-constrained using a convolutional network implemented in a low-cost, platform to perform the types of plant infection [9]. In this paper, they discussed current trends and challenges for plant leaf disease using deep learning method using a k-means clustering algorithm [10]. This paper shows the present surveys on current techniques and prediction models for the validation and diagnosis of tomato leaf diseases based on image processing and the IoT for the verification and various types of tomato plant diseases [7]. They show leaf diseases that can be effectively used to detect the leaves of plants but the unhealthy plants that we get are unbalanced that's why it is

difficult to detect the diseases from the unhealthy plant's dataset for solving this they have used double GAN to generate higher-resolution pictures of unhealthy plants leaf using samples [11].

## 2 Methodology

First of all, the robot system will start activating and it will move into the farm for taking photos; it will check the height of plants; if it's too low, then the mechanism will spray the fertilizers for the proper growth of plants; if the height is proper, then it will again go for taking photos for detection of insects on plants; if any parasitic detected, then it will spray pesticides on the affected portion of plants and send alert message to the farmer (Fig. 1).

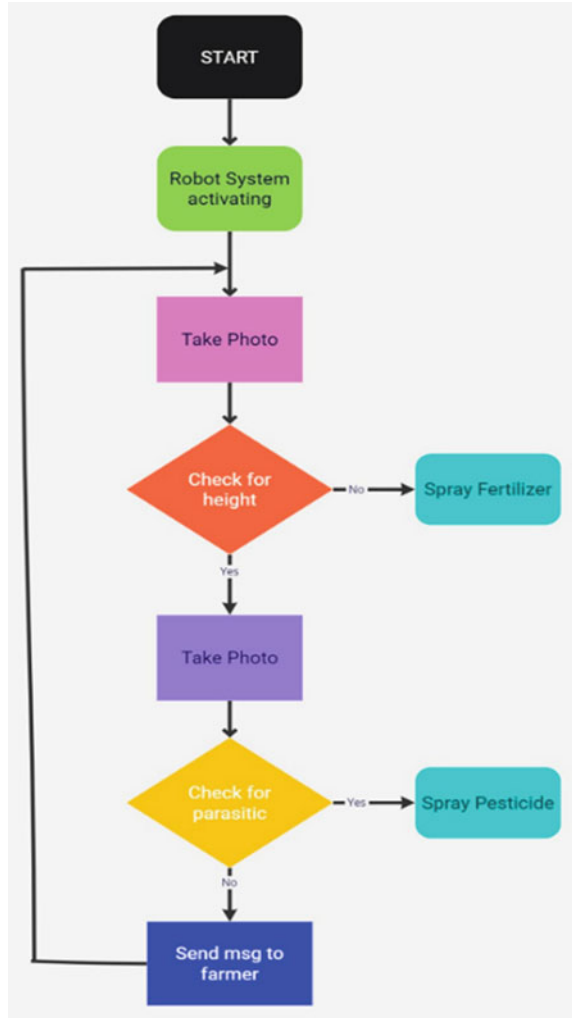
Algorithm Used for Plants Disease Detection:

- **TensorFlow:** It is a library of Python language used for rapid arithmetic calculations, and it can also create models of hierarchical learning exactly. This model detects leaf spot diseases and also predicts healthy leaves. The TensorFlow algorithm also uses a neural network for training the image classification model. The TensorFlow should be run on single central processing unit as well as on graphic processing unit and mobile devices. The used dataset is used in training and testing of dataset 1000 from that 700 images of plants are used for training and remaining 300 images are uses for testing. The dataset is identified across the model for the procedure of building to escape overfitting. The tested dataset is independent for the training set. The test dataset is used to identify the performance of model or accuracy of model, and the images of plants classify leaves based on the below parts:
  - **Healthful part:** In this case, the plants' leaves are healthy and show no symptoms of bacteria or infections of any kind (change in color, of leaves, etc.)
  - **Bacteria part:** In this, the bacterial spots are identified, and therefore, the system gives alert message to farmer.
  - **Viral part:** In this case, the color of leaves gets changed due to DNA virus that's why it changes the color.
  - **Late Blight part:** In this part, the harmful plants infection especially affects rice.

### 2.1 Block Diagram

Figure 2 shows systematic diagram for the observation of farms as the Esp32 module is used to collect all data from sensors like LDR. Various sensors are used in the farm like temperature, humidity, soil moisture, and gas sensor. As temperature sensor

**Fig. 1** Flowchart for prototype device



is useful while growing the crops which needs wet and dry climatic conditions, the temperature sensor measures the presence of heat energy of the soil and also determines whether it is good for plants growth. If the temperature rises high in the farm, then it causes erosion to the cultivation of yields. If temperature is too low on the farm, then it decreases the plant’s enzymes and it causes to stunt growth or may cause it to die. The humidity sensor is used for controlling and monitoring [12] the humidity as well as the air temperature of the farm. As if humidity arises high, then plants get to die and crops get fail. If it arises low, then the growth of plants takes more time for the growth and smaller leaves get to drop off and the quality of plants is not so good. The moisture sensor is used for the capacity of water level of soil and also for good irrigation management which gives better crops and increases

the profit of the farmer as well as the land; if the moisture level is too low in the farm, then plants may not mature and they may die. So for the betterment of crops and plants, normally 21–40% of moisture level is required. The gas sensor is used on the farm for how much amount of gas is present in the farm and environment or if anyone tries to spread petroleum in the farm at that time this sensor senses it and gives an alert message to the farmer; due to this, our farm can be saved due to unwanted gas spread. The DC motor is used in the farm as it plays a necessary part in the farm for scanning plants vertically and horizontally for the detection and monitoring of the plant’s health if the disease gets detected the LCD will display all the desired conditions. And servomotor is used for spraying the pesticides on the affected portion of the plant this mechanism is inserted in the robot if any insect is detected, then the mechanism will start and spray the pesticides. The water pump is used if the moisture of the soil gets low, then water pump will start by triggering the relay. If moisture level is too high, then off the water pump. Thus, all the data will be sent to on new technology of Blynk cloud to show the data in real time and a power supply is provided to all the sensors for proper working and giving the results. As in greenhouse automation [13], they used the old Blynk technology for controlling the greenhouse system including soil moisture, temperature, and humidity.

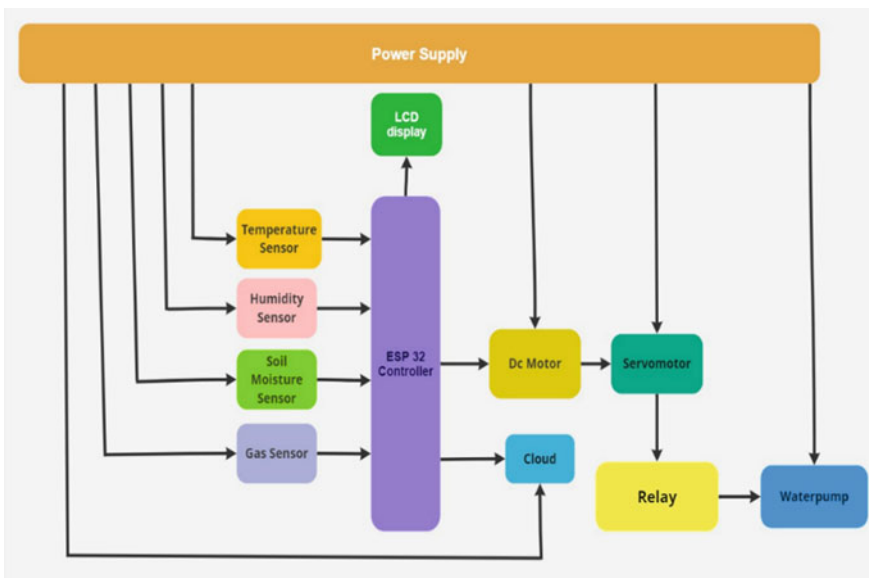


Fig. 2 Schematic diagram of observing farmland

| Disease Name         | Image Number |
|----------------------|--------------|
| Black spot of Apple  | 80           |
| Grape leaf spot      | 55           |
| Grey spot of corn    | 75           |
| Tomato mosaic virus  | 30           |
| Peach bacterial spot | 25           |

**Fig. 3** Table on plants diseases

### 3 Design Implementation

The working implementation consists of various parts, processing which is defined below:

#### A. Collection of Dataset

The analysis depends on the detection of affected leaf; [14] I have collected a dataset from an agricultural institution. This dataset has images of various disease-affected plants [15]. I organized to collect pictures of various types of infection indication. They are apple black dots, grape spot, maize gray dots, tomato mosaic virus, and peach bacterial spot [16]. One of the most frequent diseases is in apple plants which may be increased by fungi. *Podosphaera leucotricha* is the black spot as its name shows with black spots seen on the surface of the leaves. Grape leaf spot shows about fungus *Phomopsis viticola*, and maximal is determined the most critical disease of grapes [17]. Gray spot on corn results on top side. Yellow spots are viewed on another side of white disease wrapping the inner part of a leaf. Tomato mosaic virus is mostly known as plant pathogenic [18].

The number of images collected from diseases is shown in the table (Figs. 3, 4, and 5).

### 4 Future Scope

It is used in the animal shed for monitoring domestic animals. It will help the farmers to do work in any season and conditions [20, 21]. It reduces the time consumed in spraying the pesticides [22]. It works very effectively, and it will reduce the danger to farmers [23] from different breathing and physical problems. This model is used for the detection of various types of plants disease [24]. This system is used for multiple types of plants health and disease.



Image no.80



Image no.55

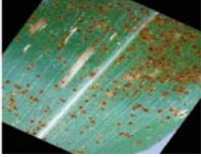


Image no. 75



Image no.30



Image no.25

**Fig. 4** Various leaves [19] affected by unwanted pesticides

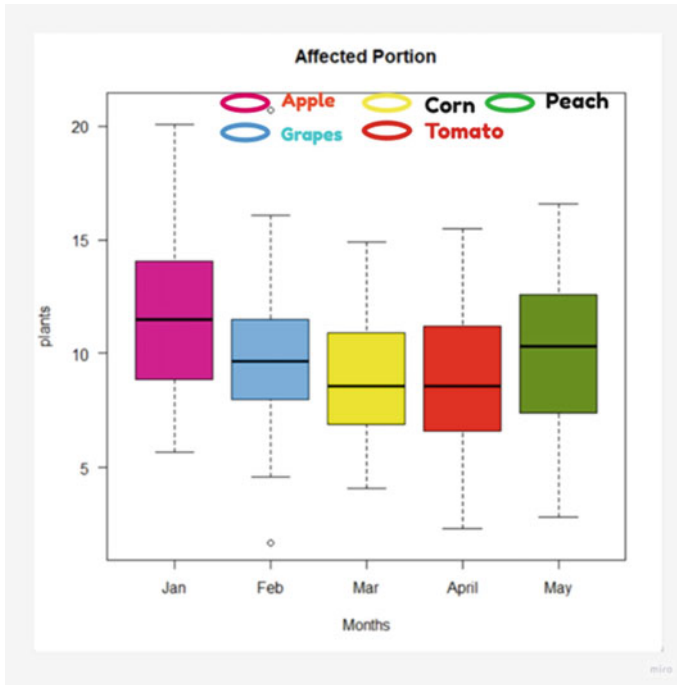


Fig. 5 Boxplot on the affected area of the plants (leaf)

## 5 Conclusion

The agriculture field needs automation in large amounts to make the human work easy, [25] and the agriculture [26] hanging robot [27] has been designed for monitoring the farm weather (temperature, humidity, and soil moisture) and also plants health; thus, system will go detection of insects [28] if any found the system will spray pesticides only on the affected portion of plants. By using this technology, there will be less time consumed and I can protect the farm as well as plants from unwanted pesticides. This proposed model is designed for the detection and quality of leaves by using different types of sensors like temperature, humidity, gas sensor, and soil moisture sensor. The purpose device is used whether the device is healthy or diseased.

## 6 Software Testing

See Figs. 6, 7, and 8.

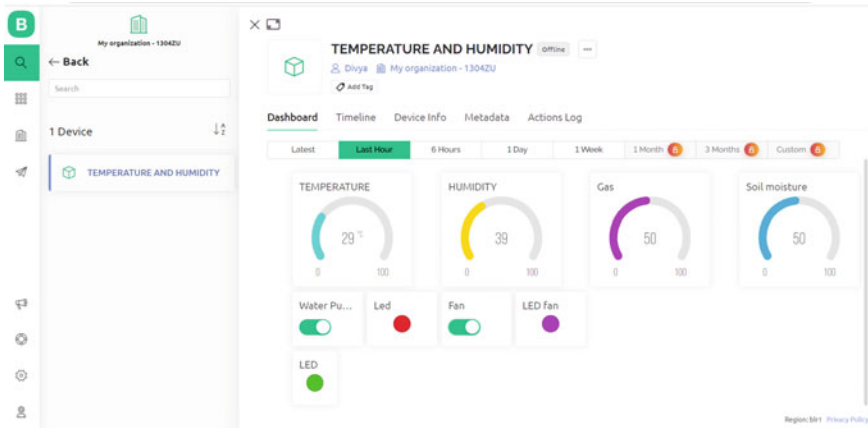
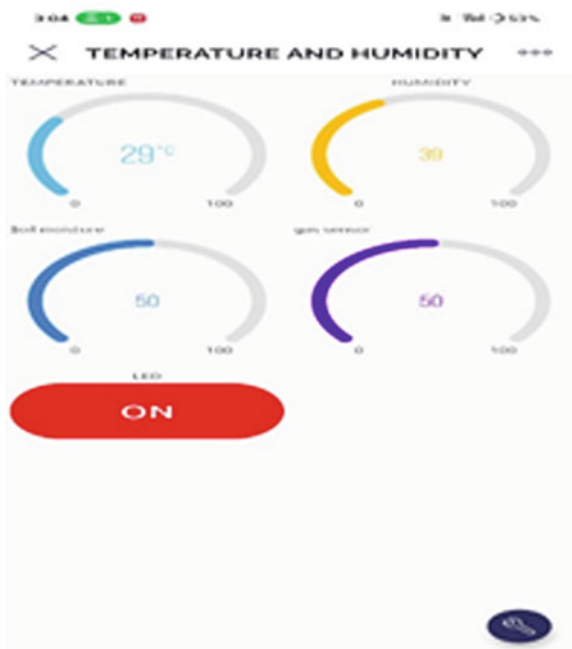


Fig. 6 Monitoring the farm by using Blynk cloud

Fig. 7 Blynk app results in real time



## 7 Hardware Testing

Figure 9 shows the output results of the farm on LCD as ESP32 is the controller module of IoT as to help the farmers and send the data on cloud. In this project, I have used various sensors like DHT11, gas sensor also soil moisture; apart from



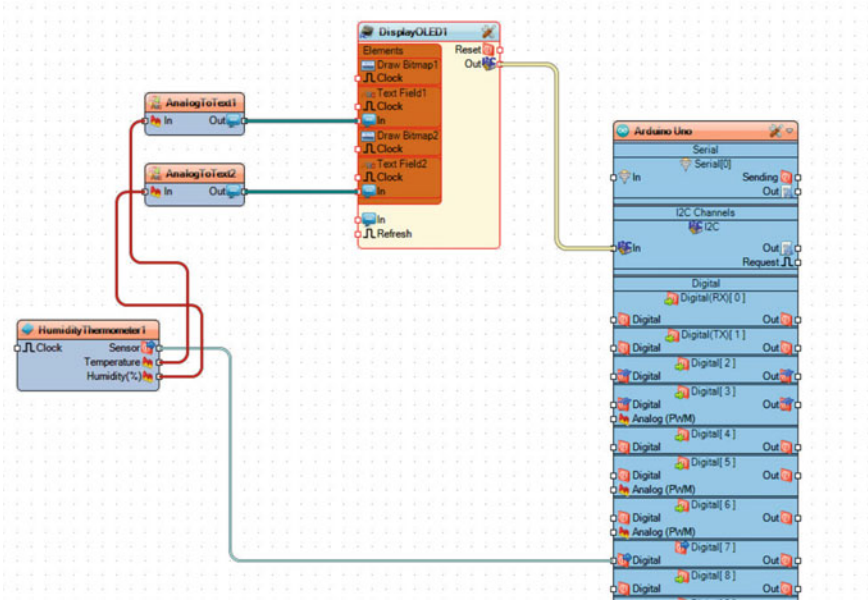


Fig. 8 Visuino results for temperature and humidity

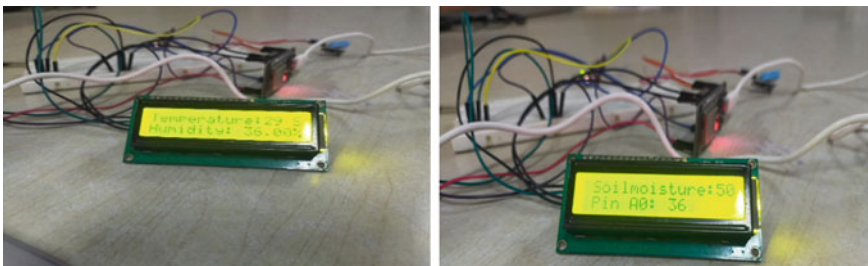


Fig. 9 Output results of the farm on LCD

these, I have also used water pumps for the proper nourishment of crops health. Although these all sensors have been used for monitoring, the farm and sensors give values on LCD in real-time mode [29, 30] . Thus, the proposed system also gives suggestion to the farmers for the betterment of farm and how to get rid of plants diseases by applying the appropriate amount of fertilizers and pesticides.

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# Contribution Unveiling Cutting-Edge Machine Learning Techniques for Image Segmentation



Nazeer Shaik, Ankur Gupta, Sunita Bhati, Jaideep Kumar, Jagendra Singh, and Ishan Budhiraja

**Abstract** Segregation of images is a critical step in processing images, computer vision, and a variety of other disciplines. The technique involves decomposing an illustration into numerous components or components, every single one that consists of an ensemble of elements with identical features for example African descent, frequency, or consistency. The most important objective of appearance, the intention of fragmentation seems to reduce complexity or customize the mathematical representation of an illustration in a way that is more readily reasonable and more straightforward for assessment. It is widely employed to locate boundaries and features in photos, and this is favorable in an assortment of industries including clinical imaging, object detection, recognition, and autonomous vehicles. Several image segmentation techniques are available, and in incorporating thresholding, zone is an area-based differentiation and corner-based recognition. A threshold segment is a simple and commonly used technique that involves setting a threshold value and dividing the pixels into two classes based on their intensity values. Region-based segmentation involves grouping pixels based on their spatial proximity and similarity in characteristics, while edge-based segmentation involves detecting edges or boundaries in an image and using them to separate different regions.

**Keywords** Vision acknowledgment · K-means clustering · Histograms · Artificial neural networks · Threshold-based segmentation · U-Net architecture

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## 1 Introduction

The analysis of pictures is an essential technology that continues to be used in a variety of industries, including imaging for medical reasons, the field of robotics, systems for managing traffic, character identification, and more. The technique involves scrutinizing and manipulating digital images using various algorithms and techniques to extract valuable information from them [1]. Segmentation of imagery is a key component in computational imaging including vision for computers, which involves assigning labels to each pixel in an image based on their characteristics. The method is commonly employed for recognizing borders and items in photos, making it an essential step in many applications. One of the main goals is the primary objective of segmentation of images seeks to consolidate as well as tweak the way a picture is represented to something that's more pertinent as well as simpler to comprehend.

Computer vision is a subfield of artificial intelligence that enables computers to identify and process objects in images and videos [2]. Object detection and image localization are some of the most popular applications of computer vision. Image localization involves drawing a bounding box around a being able to identify objects giving descriptions and boxes to surround objects, letting us estimate the position location classification of every component in a picture [3]. There are two main types of image segmentation methods: semantic segmentation and instance segmentation. Semantic segmentation involves segmenting image pixels into their respective classes and assigning them the same label or color value. On the other hand, instance segmentation is more detailed and assigns a separate label or color value to each pixel of each object in a class. Instance segmentation is commonly used in applications that require more thorough and detailed segmentation, such as medical imaging.

Deep learning models in particular have demonstrated impressive performance in picture segmentation tasks using machine learning techniques. These methods are suitable for picture segmentation jobs because they can automatically learn from vast volumes of data and extract features. Convolutional neural networks (CNNs), semantic segmentation, instance segmentation, and object recognition are a few of the frequently used machine learning approaches for picture segmentation [4, 5]. The quality and quantity of training data have a key role in how well machine learning-based picture segmentation works. A broad and representative dataset that accounts for the heterogeneity of the target pictures is essential. Additionally, network architecture design and hyperparameter tuning are crucial factors that can have a big influence on how well machine learning models for image segmentation perform. In general, machine learning methods provide promising approaches for picture segmentation problems and have the potential to dramatically develop several computer vision-based disciplines [6].

## 2 Background

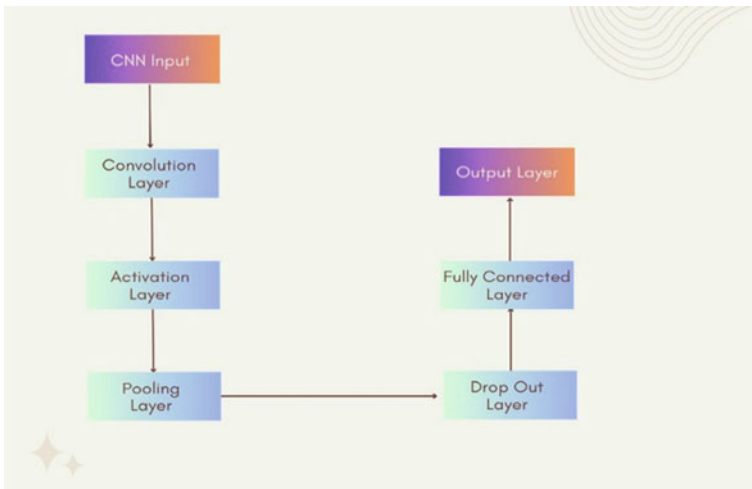
The fundamental difficulty of visual segmentation is the breakdown of a picture into accessible chunks or portions in computer vision. Numerous industries, including object detection, video surveillance, autonomous driving, medical imaging, and more, use image segmentation in a variety of ways [7].

Traditional picture segmentation methods accomplished the task using hand-crafted features and heuristics. These methods, however, frequently lacked resilience and needed a lot of human labor to adjust the settings. Deep learning models, a number of the greatest recent advances in predictive modeling approaches have shown outstanding effectiveness in picture segmentation tasks.

The capacity of convolutional neural networks (CNNs) to automatically learn characteristics from input has made them a popular choice for picture segmentation [8]. Some popular techniques for CNN-based picture segmentation include semantic segmentation, instance segmentation, and object identification (Fig. 1).

While instance segmentation focuses on identifying and segmenting certain objects within an image, semantic segmentation entails providing a semantic label to each pixel in an image. Contrarily, object identification entails spotting an object in a picture and localizing it using a bounding box [9].

The availability of large, diverse datasets that reflect the variety of the target pictures is essential for the success of machine learning-based image segmentation. Additionally, network architecture design and hyperparameter tuning are important factors that can have a big influence on how well machine learning models for image segmentation perform [10, 11]. Overall, improvements in machine learning methods



**Fig. 1** Framework of the CNN network utilized in picture segmentation is shown below

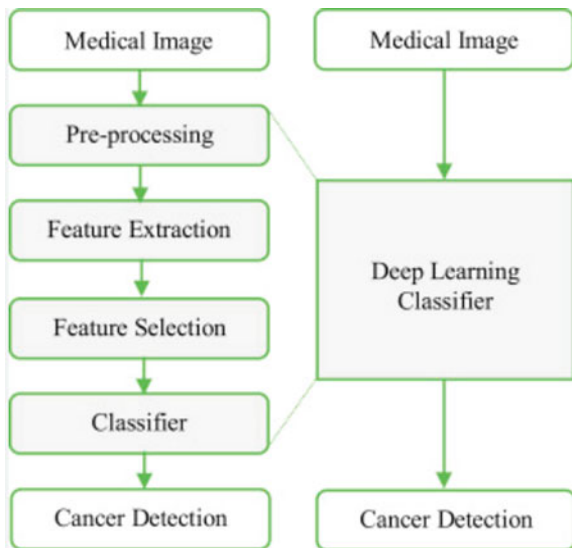
have improved picture segmentation’s accuracy and effectiveness, opening the door to a wide range of applications in diverse industries (Figs. 2 and 3).

They utilized the photograph as the initial input, subjecting it to a sequence of operations including image segmentation, followed by additional processing for extracting highlights and categorization. This sequence of steps was performed to acquire the required fragmented components.

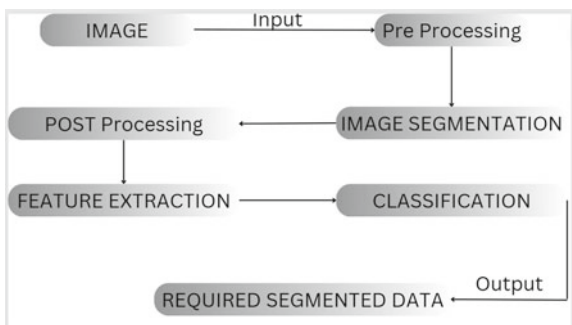
Here we are giving a textual depiction of the procedures involved in machine learning-based picture segmentation:

1. Assemble and prepare the picture dataset.
2. Create training, validation, and testing sets from the dataset.
3. Define the machine learning model’s hyperparameters and network architecture.
4. Utilize an optimization approach like stochastic gradient descent to train the model over the instructional piece.

**Fig. 2** Flow diagram of approaches to medical segmentation



**Fig. 3** Method employed to acquire the fragmented picture



5. Validate the framework's efficacy as measured by the verification collection and make any required hyperparameter adjustments.
6. To assess the model's generalizability, test its performance on the testing set.
7. Apply the learned model to each pixel in the image to segment new ones.
8. To reduce noise and enhance the visual clarity of the segmented regions, post-process the segmentation findings.
9. And then utilize measures like accuracy, recall, and  $F_1$ -score to assess the efficacy of the segmentation findings.

### 3 Features

The approach of separating one picture into numerous pixels or areas is known as the segmentation of imagery to extract meaningful information from it. Machine learning algorithms can be used to perform image segmentation by training models on labeled data. Here are some common features that can be used for image segmentation using machine learning:

- **Color:** Perhaps among the most significant aspects of visual segmentation is color. Examining the pigment ratios of individual pixels in a snapshot, a machine learning algorithm can group pixels with similar colors together to form segments.
- **Texture:** Texture refers to the visual pattern of an image. It can be used to distinguish between different regions in an image. For example, in medical imaging, different textures in an image can indicate different types of tissue.
- **Shape:** The shape of an object in an image can also be used as a feature for segmentation. By analyzing the contours of objects in an image, a machine learning algorithm can group pixels that belong to the same object.
- **Edge detection:** Edge detection algorithms can be used to identify boundaries between different regions in an image. These boundaries can be used as features for segmentation.
- **Histograms:** Histograms of pixel intensities can also be used as features for segmentation. By analyzing the distribution of pixel intensities within an image, a machine learning algorithm can group pixels with similar intensity values together to form segments.
- **CNN simulations:** CNNs are neural networks that are sophisticated machine learning algorithms that may learn features directly from raw image data. They can be used for image segmentation by training on labeled data.
- **Superpixel segmentation:** Superpixel segmentation algorithm group pixels with similar properties together to form larger segments. These segments can be used as features for further segmentation.



## 4 Proposed Methodology

The following are typical steps for machine learning-powered image segmentation: It constitutes the first level of picture evaluation. This represents the very initial phase of depict evaluation. Lacking depict the process of segmentation integrating visual recognition would turn out to be extremely challenging. Employing visual segmentation methodologies, you could separate and categorize convinced particles compared to a single image, identify those categories, and subsequently use these labels in order for categorizing other particles. You can draw lines, make limitations, and distinguish certain products (a vital component of components) for the remainder of the instances (unimportant components) in an image. The labels you created through picture segmentation can be used in machine learning for both supervised and unsupervised training. You might address a variety of business issues in this way. What are the several categories of image segmentation? There are numerous approaches to performing image segmentation, which is a fairly vast issue. Illustration splitting may be classified using this set of parameters:

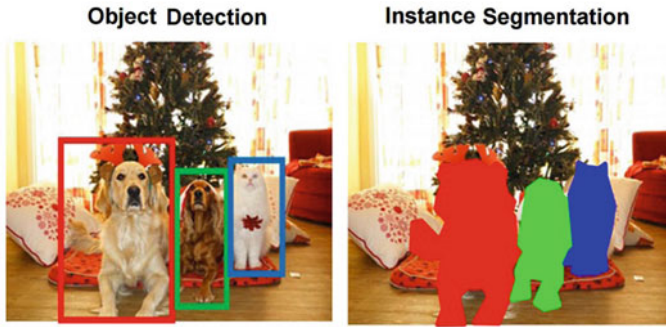
### 4.1 *Classification Hinge on Strategies*

The simplest method of object recognition is image segmentation. An algorithm is incapable of categorizing an item's pieces without first identifying the thing itself. Object identification is a prerequisite for all photo segmentation computer programs, no issue how simple or sophisticated they are to perform.

Because computers detect things by grouping like pixels and separating them from unlike pixels, we may categorize picture segmentation approaches on the hinge of this. There are a pair of techniques for doing this task.

### 4.2 *Regional Detection*

Using region merging, region spreading, and region expanding techniques, related pixels in an image are found. Clustering and related machine learning algorithms employ this method to uncover unidentified characteristics and attributes. Algorithmic procedures that do categorization make use of the aforementioned method to determine attributes in pictures and segment data based on those features.



**Fig. 4** Here we applied all of the algorithms on a dog figure and received an image with segmentation as a result

### ***4.3 Boundary-Based Approach for Discontinuity Detection***

The previously territory-based technique is the polar opposite of the demarcation-based methodology for recognizing items. In opposition to the zone is an area-based being identified, which detects pixels with equivalent qualities, the border-based technique discovers particles that are unique from other pixels. Technologies like the feature detection process, detection, line identification, and others employ this method to recognize the margins of different images and exclude those pixels from the rest of the photograph (Fig. 4).

### ***4.4 Building Techniques***

To utilize these approaches, you must obtain the architectural information for the picture. This includes pixels, which are measured payouts, histograms in graphic weight, chromatic transportation, and other relevant data. The skeletal data for the portion of the image that has to be isolated must then be accessible. You'll need that information for your machine learning system to understand the region. The algorithms we utilize for these sorts of implementations employ the region-based technique.

### ***4.5 Random Techniques***

Rather than knowing and understanding the framework of the essential picture segment, these methods need knowledge of the image's discontinuous pixel dimensions. They are useful when dealing with several photographs since they do not require a large amount of data to accomplish the segmentation task. Strategies for

machine learning are included in this area including ANN algorithms and K-means clustering.

## 4.6 *Hybrid Methods*

These algorithms utilize both randomized and compositional approaches. This suggests that these algorithms use the two forms of instantaneous pixel-level data found in the full vision and the underlying structure of the specified region in order to divide the photograph. We can start talking about the specifics now that we are aware of the many approaches and types of techniques for picture segmentation. The main categories of picture segmentation techniques are as follows:

1. Segmenting based on thresholds
2. Segmentation based on edges
3. Segmentation based on region
4. Segmenting watersheds
5. Algorithms for clustering-based segmentation
6. Segmentation using neural networks.

Data preparation: Select from the tagged learning photographs a collection of items or regions of interest that are appropriate for categorization. The labels provide the boundaries or divisions of the things or regions.

The technique of recognizing specific elements from photos, such as color, texture, and form, is known as extracting features. These characteristics will be used to train the model for segmentation.

Train the specified learning algorithm (such as neural network models like U-Net or Mask R-CNN) using the tagged data. The system will gradually learn to separate the photographs based on the extracted attributes.

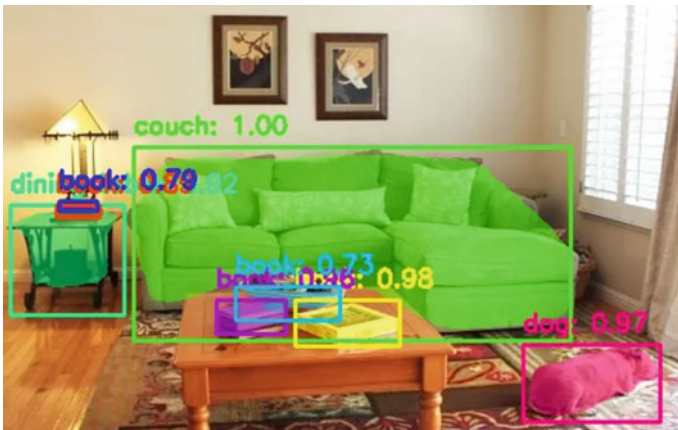
To train, CNNs need instructional information in the format of supplied input and preferred objective picture combinations, just like any other supervised machine learning technique. On the larger scheme for the present investigation, it indicates that for each three-dimensional depiction generated by CT, we require a corresponding 3D image in which the grain boundaries have already been erased. To get comparable boundaries of grains visuals, the same volume of the specimen was scrutinized by 3DXRD illumination in addition to CT measurements (Ct) at each imaging step,  $t = 0$ , CNN simulations will be trained using this paired information to predict grain boundaries from CT image data without the use of further 3DXRD imaging.

**Critique of the Approach:** Examine how well the model performed in conjunction with a set of validation data common metrics.

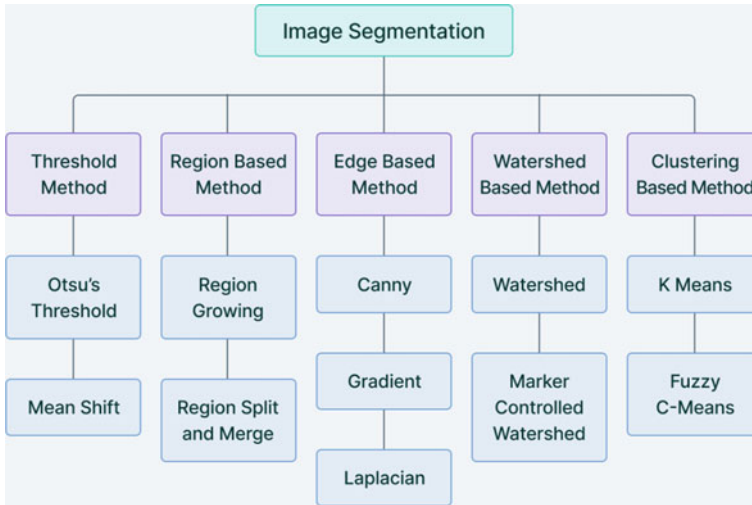
Now we are giving brief steps for image segmentation, Edge detection is the inaugural cycle in the photographic categorization technique. It distinguishes the representation of the foreground and scenery. By observing the shift in an image's intention or pixels, edge detection divides the scene. One of the most straightforward ways of splitting up an illustration is to use tipping point-based categorization, particularly based on luminosity thresholds.

The aforementioned form of differentiation incorporates clumping particles that comprise and are connected to the same object. Region-based feature extraction is connected to the thresholding technique. Close off the area that was discovered for segmentation.

The method of clustering involves arranging groups according to their characteristics. A cluster often consists of a collection of comparable pixels that are unique from other regions and belong to the same region (Figs. 5 and 6).



**Fig. 5** Image recognition scenario to separate items in the image by their measurements, indicated by different hues



**Fig. 6** In the above flow visualization, we present visual segmentation approaches such as the threshold-based procedure, Otsu's threshold, and others

## 5 Conclusion

As we've seen, segmentation entails dividing an image into a number of uniform pieces. The color, texture, characteristics, etc., of a region affect its homogeneity. Just a few of the numerous segmentation strategies have been shown to you. Active contours also referred to as "snakes," level sets, Markovian models, etc., are further options. The implementation of deep learning yielded notable advancements that enhance the results above and beyond traditional "model-based" methods. In order to recognize objects and boundaries in images (such as lines and curves), image segmentation is widely utilized. Giving each the technique of giving every molecule in the photograph an identification number to ensure that digits containing the identical description have similar properties is known as photo segmentation put another way.

In order to do an analysis of the target item, segmentation is utilized to separate it from the picture. CNN is a useful method for segmenting images, however, if the training dataset is large, it may take longer. Segmentation based on clusters requires a lot of computing time. Edge-based segmentation works well for photos with more distinct object contrast. With VGG-16, we employed a convolutional neural network. Kernel layers responsible for automated feature extraction are used in the convolutional neural network (CNN) method for the detection of the aesthetic quality and state of historic building facades. Due to the constraints and disproportionate quantity of data in delivering character representation from the assembled dataset, data training approaches are coupled with transfer learning models in an effort to expand data knowledge.

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# Empowering Elderly Safety: 1D-CNN and IoT-Enabled Fall Detection System



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**Abstract** The integration of cutting-edge technology, including deep learning, smartphone capabilities, and wearable devices, has sparked a transformative revolution in fall detection systems, offering real-time monitoring and swift response in the event of a fall. This research study presents a fall detection system that harnesses advanced deep learning techniques, particularly 1D convolutional neural networks (CNNs), to achieve remarkable accuracy scores of 91% and 92%. Rigorously evaluated using the Sisfall and UMA Fall datasets, which consist of 9 and 25 features, respectively, obtained through meticulous hand engineering, this system demonstrates its efficacy in detecting falls. The potential of this advanced fall detection system lies in its ability to significantly enhance the safety and well-being of individuals by enabling timely assistance after a fall. By leveraging the power of artificial intelligence and state-of-the-art technology, the system promises to amplify the efficiency of fall detection in real-world scenarios, providing reassurance and peace of mind for both individuals and their caregivers. Particularly beneficial for vulnerable populations like the elderly, this technology holds the promise of mitigating the risk of severe injuries and fatalities resulting from falls. The study's findings underscore the substantial progress that can be achieved in fall detection by seamlessly integrating deep learning, smartphone technology, and wearable devices. This integration paves the way for a future where prompt assistance becomes standard practice, reducing the potential consequences of falls and ultimately improving the quality of life for those at risk. As this research sheds light on the immense benefits of advanced fall detection systems, it serves as a significant step forward in ensuring the safety and welfare of individuals, fostering a safer environment for everyone.

**Keywords** Deep learning (DL) · Artificial intelligence (AI) · One-dimensional convolutional neural network (1DCNN) · Internet of Things (IoT)

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# 1 Introduction

In the ever-evolving realm of medicine, remarkable progress has been made since the turn of the millennium, leading to a notable increase in life expectancy by five years. This momentous advancement has triggered a significant demographic shift, with the elderly population now accounting for 8.5% of the global populace. Projections by the esteemed National Institutes of Health (NIH) indicate that by the year 2050, this proportion will escalate to a staggering 20%. Among the many concerns tied to the geriatric community, the prevalence of falls stands out as a substantial risk factor and the second leading cause of mortality. According to the esteemed World Health Organization (WHO), an estimated 37.3 million accidents occur annually, necessitating medical attention and leading to over 646,000 fatalities. Falls afflict around 30% of individuals aged 65 and above each year, with this percentage surging to 50% for those aged 80 and older. In response to this pressing issue, wearable healthcare applications have emerged as a promising solution, thanks to the advancements witnessed in hardware and operating systems. Particularly, automated fall detection systems (FDSs) have garnered significant interest in academic research circles due to their remarkable ability to identify and promptly report falls, consequently mitigating their impact and consequences on the elderly.

Market projections suggest that automated fall detection systems are poised to capture 60% of the fall detection systems market share between 2019 and 2020, showcasing a compound annual growth rate (CAGR) of approximately 4% from 2019 to 2029. Governments worldwide are investing in research pertaining to fall detection devices to address the substantial portion of healthcare expenditures allocated to fall-related injuries [1, 2]. In conclusion, the advancements in medicine have led to an extended life expectancy, resulting in a demographic shift with a growing elderly population. Falls, being a significant concern for the elderly, are responsible for a considerable number of accidents and fatalities each year. Wearable healthcare applications, particularly automated fall detection systems, have emerged as a promising solution to this issue. Market trends indicate a rising demand for such systems, and governments recognize the need for investing in fall detection device research to mitigate healthcare costs associated with fall-related injuries.

## 1.1 Fall Risk Factors

The act of falling occurs when an individual encounters difficulty in maintaining their balance and attempts to regain an upright position. While young people possess the physical strength to recover their balance, older individuals face greater challenges due to their weakened physical state. The causes of such collapses can be diverse, and the term “risk factors for falls” encompasses all possible circumstances that might contribute to a fall. In truth, the incidence of falls is the result of a complex interplay



of multiple factors. Therefore, understanding the likely risk factors associated with falls among the elderly is crucial. A comprehensive understanding of these risk variables enables the development of more effective strategies to prevent falls. Various factors, including biological, behavioral, demographic, and environmental elements, may contribute to falls. Extensive research has identified a range of potential hazards, which are outlined in Fig. 1. Falling from beds ranks as the second most common cause of fall-related injuries, second only to physiological issues [3]. Risk factors related to behavior are intertwined with people's thoughts, emotions, and daily activities. These factors can be addressed through strategic interventions. For example, if a person experiences trips or falls due to excessive drug or alcohol misuse, their behavior patterns can be altered through appropriate treatment strategies. Environmental risk factors stem from the immediate surroundings of an individual. Cracked sidewalks, uneven surfaces, and inadequate lighting are prominent examples of environmental risk factors. Biological risk factors include an individual's age, gender, and overall physical health. Acute and chronic diseases, diabetes, cardiovascular problems, vision impairments, balance issues, and high or low blood pressure are among the biological risk factors. While age and gender are unalterable biological characteristics, illnesses can be prevented or managed through proper medical treatment, and both physical and mental well-being can be enhanced [2]. Falls are the result of a complex interplay of factors. Risk factors for falls include biological, behavioral, demographic, and environmental elements. Understanding these factors is crucial in developing effective strategies to prevent falls among the elderly. By addressing behavior-related risks through interventions and mitigating environmental hazards, the incidence of falls can be reduced. Additionally, managing and preventing diseases and promoting overall health play a vital role in minimizing the biological risk factors associated with falls.

## 1.2 *Types of Falls Fall*

Up until the 1990s, categorizing fall was a significant problem. The largest obstacle was a lack of agreement among researchers. The majority of the classification at that time was based on the causes of falls. Depending on the position preceding a fall, there were three (other categories of falls also shown in (Fig. 2)) main categories of falls:

### a. **Fall from Bed**

- At the time of the fall, the person is lying in bed either sleeping or not.
- From bed height to floor height, the body height decreases. The body typically experiences what feels like a free fall motion at that time.
- The body is in a position on the floor that is close to the bed.
- The entire procedure occurs in a series of smaller activities over the course of 1–3 s.

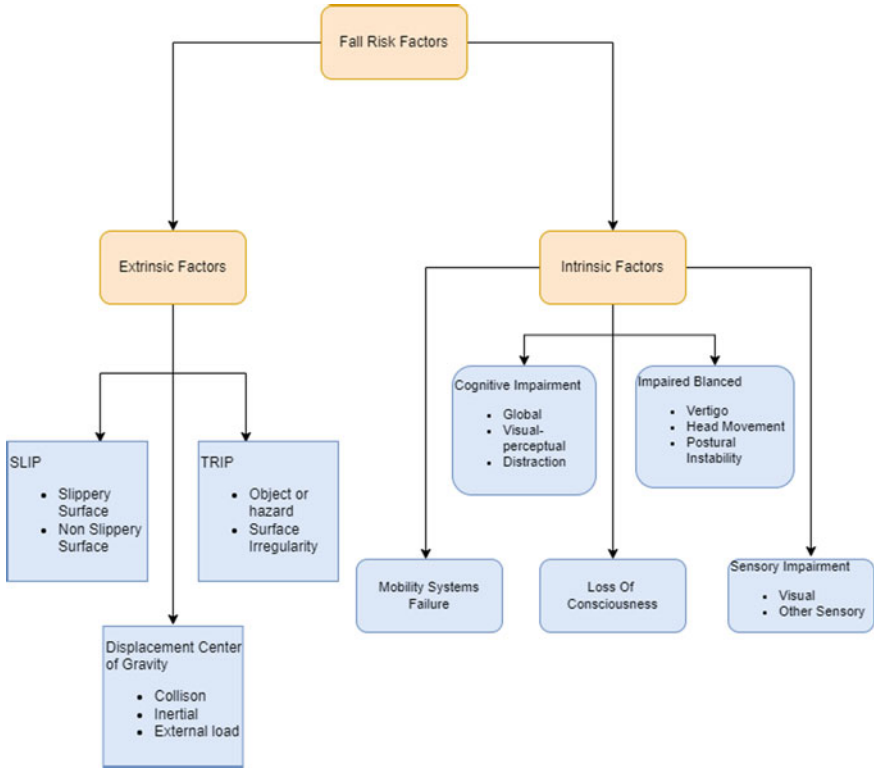


Fig. 1 Fall risk factors

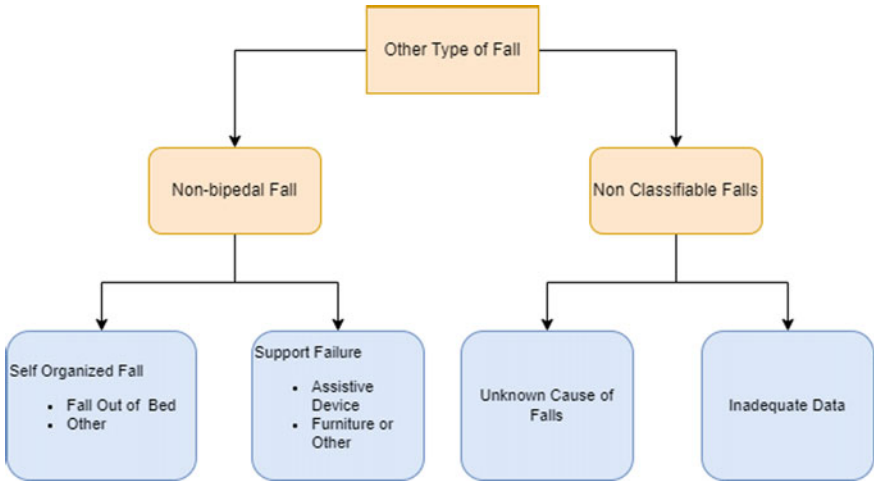


Fig. 2 Other categories of falls

**b. Fall from Sitting**

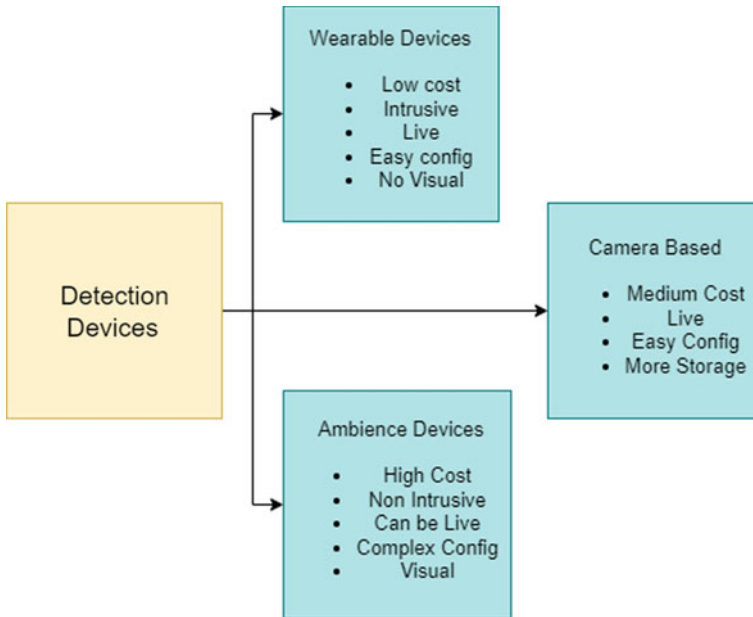
- At the start of the fall, the person is sitting on a chair or another piece of furniture approximately at the same height.
- The head descends in a free fall fashion until its height is reduced to the floor.
- The body is lying close to the chair in this position.
- The falling process is divided into 1–3 s sub-actions.

**c. Fall from Walking or Standing**

- When the fall begins, the person is either standing or walking.
- The head lowers itself to the floor while lying on it from a level that is equal to the person's height. It might move slightly while lying.
- Typically, the fall is unidirectional.

### 1.3 Fall Detection

Devices that are worn, devices that rely on cameras, and devices that measure the environment are the three primary categories that fall detection methods may be broken down into, devices that are worn, devices that rely on cameras, and devices that measure the environment which are the three primary categories that fall detection methods may be broken down into. Classification of fall detection is shown in Fig. 3. The persons who are at danger of falling are required to wear some kind of wearable gadget or apparel in the strategy that utilizes wearable technologies. The data that these sensors collect on the movement or posture of the body is then sent into a processing algorithm which determines whether or not a tumble has occurred. However, some users feel that wearable technology is excessively obtrusive and a hassle to carry about with them. They do not bother to continuously have a gadget on their person. In addition, there is an issue with the apparatus' placement. Some actions, such as dozing or moving, may displace the device from its original position, resulting in less precise results. Sleeping and moving around are examples of such activities. It would seem that the camera-based technique is successful in resolving some of these issues. The cameras are set up in strategic locations so that they may carry out unobtrusive, round-the-clock surveillance on the elderly. In contrast to sensors, cameras have the capability of evaluating and analyzing a wide variety of characteristics simultaneously. When camera prices were higher, originally fewer people wanted these kinds of devices because they were more costly. These gadgets also have the capability of saving the data they collect so that it may be analyzed and consulted at a later time. The strategy known as the ambiance device requires the installation of certain sensors in close proximity to the individuals being monitored, including on a wall, floor, or bed. These sensors are responsible for collecting data, which are then used as input by an algorithm in order to identify whether or not a fall has happened. As a direct result of this, the incidence is reported to the carers.



**Fig. 3** Fall detection devices

Because the associated individual does not have to wear a sensor, they do not have any concerns about any form of oversight [2].

In fall detection and prediction systems, camera-based sensors are widely employed. Separate cameras are utilized in such systems to monitor the routing activities of each individual. Camera-based methods are costly and necessitate a massive quantity of data storage and processing. This method of operation is extremely complex and requires a more potent GPU and CPU. In addition to their advantages, camera-based systems have disadvantages such as privacy concerns and the incapacity to track beyond the camera's field of view [2]. Because low-cost physical sensors are becoming more readily available, there has been a recent explosion in interest in wearable sensor-based computing systems. Real-time monitoring can be obtained via the employment of wearable-based devices rather than environment-based monitoring equipment. As a result, collect data that belongs to the user. In these types of systems, the devices that are used are often microcontrollers that are outfitted with inertial measurement units. This helps to reduce the overall size of the device while also extending the battery's lifespan. Wearable technology often results in reduced overall economic expenses as compared to context-aware technologies [1]. In addition to accelerometers, gyroscopes, and force sensors, the components of wearable technologies also include gyroscopes. However, it is challenging for an individual to wear multiple devices. In contrast, smartphone-based systems are inexpensive and can be utilized outside of controlled environments as the user goes about

his or her daily life. Moreover, smartphones incorporate sensors such as accelerometers, gyroscopes, and magnetometers. Thus, smartphones are frequently considered the most appropriate technology for applications in health care, security, athletics, fitness, gait analysis, and accident prediction [4]. Due to their proximity to the human body's center of gravity, the sternum and the waist have been demonstrated to be the optimal locations for a wearable accelerometer designed to detect falls accurately. Certain studies have revealed that carrying a smartphone in a pocket can hinder the effectiveness of detection systems, particularly when the device is allowed to move freely within the pocket, and the accelerometer fails to determine the user's movement accurately. Some suggested solutions propose optimal results when the smartphone is securely attached using an adjustable band around the chest, waist, or a similar fastening element. However, this rigid attachment compromises user comfort and limits their ability to access the smartphone's standard features [5]. Smart watches are wristwatches with a miniature display, integrated sensors, and Internet connectivity. Smartwatch manufacturers seek to develop a new form of wearable device capable of displaying brief communications such as SMS, RSS feeds, and Facebook notifications. Smartwatches enhance the system's ergonomics and (typically) the resolution and range of the integrated accelerometers in comparison to smartphones. In contrast, the wrist movement (where the chronometer is affixed) does not always indicate the stability of the body. Therefore, abrupt limb movements that are not inherently associated with falls can readily produce false positives. (i.e., activities that are incorrectly identified as falls) [5]. A series of ambience device approaches are installed in the immediate proximity of the associated individuals in the ambience device method, including on a wall, floor, and bed. Using the information collected from these sensors, an algorithm determines whether a fall has occurred. The incident is consequently conveyed to the attendants. As the individual is not required to wear a sensor, he or she is unconcerned about any type of surveillance [2].

#### ***1.4 Fall Prevention***

The prevention of falls is an essential aspect of providing for senior individuals, despite the impossibility of ensuring their complete prevention. There are, however, there are measures that can be taken to reduce the danger of accidents and guarantee the safety of the targeted population. This can be accomplished by routinely assessing and continuously monitoring recognized fall risk factors [6]. If these parameters' values lie within an acceptable range, it can be presumed that the individuals are in a relatively secure zone. The following exercises and practices can help prevent falls:

1. Observe their mobility pay close attention to whether they have trouble rising from a chair or walking unassisted. If they appear unsteady or cling to walls or objects frequently for balance, this may indicate an increased risk of collapsing. Encourage the use of canes and walkers, if necessary.

2. Certain medications can cause vertigo, lethargy, and other adverse effects that increase the risk of falling. Discuss their medications with their healthcare provider to ensure that the prescribed medications are suitable and do not pose a fall risk. Any concerns regarding adverse effects should be addressed immediately.
3. Consider their general health condition, including any chronic maladies, balance issues, or sensory impairments, when assessing their overall health. Regular medical examinations and communication with healthcare providers can assist in identifying and treating health conditions that may contribute to falls.
4. Examinations of the eyes and eyewear on a regular basis: Vision problems can substantially increase the risk of falling. Encourage regular eye exams to detect any changes in vision, and ensure that they have the necessary eyewear (glasses or contact lenses). Vision correction can enhance spatial awareness and reduce the likelihood of stumbling or misjudging distances.
5. Create a safe living atmosphere: Remove potential hazards from their living environment. Remove debris, secure any loose rugs or carpets, and clear all pathways. To provide additional support, install handrails along staircases and in restrooms. Ensure that there is adequate illumination in all areas, particularly at night.
6. Encourage regular physical activity, regular exercise can improve strength, balance, and flexibility, all of which are crucial for preventing falls. Encourage them to participate in senior-specific activities such as walking, tai chi, and chair exercises. Before beginning any exercise program, it is essential to consult a healthcare professional to ensure that it is appropriate for the individual's abilities and medical condition.
7. Encourage a healthful lifestyle in order to preserve an individual's overall health. This includes a healthy diet, sufficient hydration, and adequate rest. A nutrient-dense diet can support bone health and muscle stamina. Staying hydrated helps maintain proper physiological functions, and adequate rest ensures that the individual is vigilant and less likely to be involved in an accident.

These measures can substantially reduce the risk of falls, but they cannot eliminate the possibility entirely. A supportive environment, regular monitoring, and ongoing communication with healthcare professionals are essential for promoting the welfare and well-being of senior citizens.

## 2 Background

Falls are a common occurrence among people of all ages, but they are particularly prevalent among the elderly due to the gradual decline in their physical abilities. Falls can result in severe injuries such as fractures, concussions, and even fatalities. In recent years, significant research has focused on developing automated methods for detecting and analyzing falls. The use of advanced machine learning techniques for

fall detection is gaining importance, as these techniques enable systems to learn from data collected through various sensors that capture information related to different aspects of falls. By applying machine learning algorithms to this data, the system can classify and identify fall events based on specific criteria.

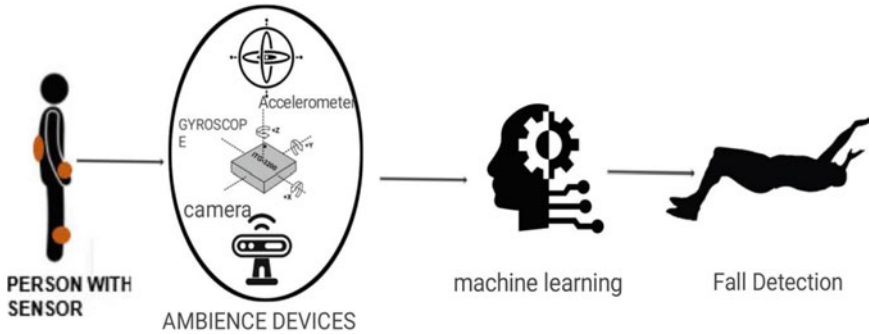
There are several machine learning and deep learning algorithms widely used for fall prevention and detection, including SVM, Artificial Neural Networks (ANNs), RF, KNN, NB, CNN, RNN, etc. These algorithms have shown promise in accurately and efficiently detecting falls. Researchers aim to leverage the capabilities of these advanced algorithms to develop highly accurate and efficient fall detection systems that can help prevent falls in a timely manner and minimize their negative consequences [1, 2, 8].

### 3 Literature Review

Important in healthcare and senior care, fall detection seeks to automatically detect accidents and alert caregivers or emergency services. By analyzing sensor data from peripheral devices or cameras, traditional ML algorithms can be used for detection of fall. A smartphone and smartwatch-based fall detection system is utilizing smartwatch and smartphones accelerometers, gyroscopes, and magnetometers. The majority of smartphones contain a GPS module that can be added to other portable devices, like smart watches and bands. It is possible to connect a smart band, watch, or other portable device lacking a GPS module to a smartphone's GPS module. In this instance, the mobile phone functions as both a monitoring device and an Internet gateway that can transmit real-time location information [9]. A variety of sensors, such as those on the wall, the floor, the bed, are installed throughout a person's residence in order to track their movements while using an ambience device (Fig. 4). These sensors capture data, which are then analyzed by an algorithm to ascertain whether a fall occurred. If these sensors detect an accident, the monitoring service will notify the caretaker [8, 10]. Researchers discovered that smartphones and ambient devices can cooperate reasonably well, so they devised a novel method for fall detection using smartphones as the master monitoring device and ambient device sensors as subordinate sensors [7].

#### 3.1 *Traditional Machine Learning Approach for Fall Detection*

Traditional machine learning methods have gained significant popularity in the domain of fall detection due to their ability to analyze intricate data patterns and make well-informed decisions based on historical data examples. In contrast to deep learning models, which often demand large volumes of data and computational



**Fig. 4** Fall detection system

resources, traditional machine learning techniques can prove to be more practical and efficient, particularly in certain fall detection scenarios. The crux of the traditional machine learning approach lies in the model training phase. A variety of classifiers, including SVM, random forests, KNN, decision trees, etc. are employed. During the training process, the classifiers are fed with a labeled dataset, where each data sample is designated as either a fall or a non-fall instance. The model endeavors to discern meaningful patterns and associations between the extracted features and their corresponding class labels. By utilizing historical data and extracting informative features, these traditional machine learning models can effectively detect falls and differentiate them from regular movements. This capability plays a pivotal role in enhancing the safety and well-being of individuals, especially the elderly or those at risk of falling. Prompt detection of falls can lead to rapid responses, such as alerting caregivers, medical professionals, or emergency services, potentially minimizing the severity of injuries and improving the overall care for vulnerable populations.

In the realm of fall detection methods, several researchers have proposed innovative approaches. Ramachandran et al. [7] introduced a method that considers both sensor measurements and the individual's biological profile. They used the UMA\_ADL\_FALL\_Dataset and employed Ordinal Logistic Regression, with KNN yielding the highest accuracy of 84.1%. Hussain et al. [8], on the other hand, utilized the Sisfall dataset and incorporated a low-pass IIR Butterworth filter and six extracted features. Remarkably, their algorithm achieved an impressive accuracy of 99.98% with SVM outperforming other methods. Toda and Shinomiya [10] took a unique approach using passive RFID (Fig. 5) sensors attached to footwear, applying the random forest algorithm. Their method achieved high accuracy with F-measure scores of 98% for person-dependent cases and 94% for person-independent cases. In a different study, Vallabh et al. [11] investigated fall detection using the "MobiFall" dataset, focusing on distinguishing between Activities of Daily Living (ADL) and fall activities. They employed various classification techniques, with KNN performing the best and achieving an accuracy of 87.5%. Chelli and Pätzold [12] evaluated KNN and ANN in identifying human activities, including falls. Both algorithms achieved high accuracies, with KNN at 81.2% and ANN at 87.8%. The researchers further



improved their results by extracting additional features from acceleration and angular velocity data. In another perspective, Miawarni et al. [13] utilized SVM and deep learning techniques on the eHomeSeniors dataset, which included thermal sensors, reaching an accuracy of 84.62% by adjusting the gamma value without normalization or standardization. Conversely, Rashid et al. [14] simulated the Sisfall dataset and tested various algorithms, such as DT, NB, SVM, KNN, and Ensemble Classifiers. Fine KNN has emerged as the top-performing algorithm, achieving accuracies of 83.76% and 84.64% in different experiments. The comparative analysis highlights that SVM, KNN, and ANN are commonly used and achieved high accuracies in fall detection tasks. Each method possesses its unique strengths and limitations, and the choice of the most suitable approach depends on factors such as dataset characteristics, computational efficiency, and specific application requirements. Overall, the advancements in fall detection research showcase diverse algorithms and techniques, ranging from logistic regression to random forest and deep learning, that contribute to improving the accuracy and reliability of fall detection systems.

Using sensor data to identify fall-related patterns and characteristics, traditional machine learning algorithms can detect falls effectively. For fall detection, decision trees and Naive Bayes are two additional machine learning algorithms that may require manual feature engineering. Both can be trained to detect falls by analyzing the features that are indicative of falls using sensor data. As with SVMs and random forests, however, traditional ML methods are used for fall detection, but they have limitations when compared to deep learning methods [3, 4, 10–12].

For fall detection using smartphones, peripheral devices, and ambient devices, deep learning models offer several advantages over conventional machine learning. These benefits include accurate detection, resistance to environmental changes,

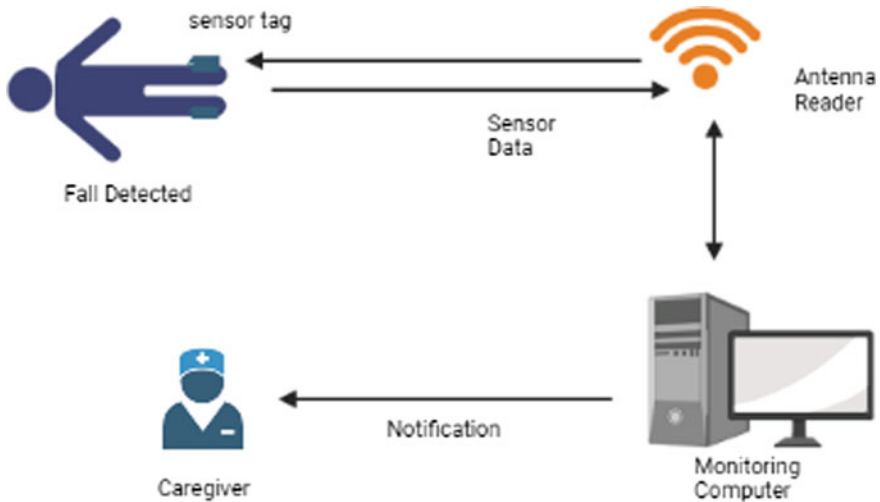


Fig. 5 Alert-based fall detection system

feature extraction from raw data, real-time processing, scalability, transfer learning, individual user adaptability, non-intrusive monitoring, context-aware detection, continuous monitoring, integration with emergency services, and evolving models. These developments contribute to the creation of more dependable and effective fall detection systems, thereby enhancing the safety and well-being of individuals, especially the elderly and vulnerable populations. The advantages are describing below.

- **Accurate Detection:**

Models employing deep learning can detect accidents with a high degree of precision. Traditional machine learning models require a substantial quantity of labeled data, and the model's accuracy is highly dependent on the labeling quality. Deep learning, on the other hand, models can learn from unprocessed data and, with the assistance of complex neural networks, can recognize patterns and make accurate predictions.

- **Robustness:**

Traditional machine learning models are more susceptible to environmental changes than deep learning models. Traditional machine learning models require consistent data with regard to quality, format, and sampling rate. However, deep learning models can adapt to changes in the environment and perform well despite chaotic or insufficient data.

- **Feature Extraction:**

The ability of DL models to extract features from unprocessed data eliminates the need for domain-specific knowledge and feature engineering. Traditional machine learning models, in contrast, require time-intensive and domain-specific feature engineering.

- **Real-Time Processing:**

Real-time data processing by deep learning models is essential for fall detection. Traditional machine learning models may require bulk processing, which may introduce latency into the system and pose a problem for applications requiring real-time processing.

- **Scalability:**

Deep learning models are highly scalable and able to manage massive data volumes. Traditional machine learning models may struggle to scale as the model's complexity and data volume increase.

- **Individual User Adaptability:**

Deep learning models can adapt to the behavior and movement patterns of individual users. By perpetually learning from data collected from a particular user, the model can customize fall detection based on the user's unique characteristics and behaviors. This adaptability increases the accuracy of fall detection systems and decreases false alarms, making them more trustworthy for individual users.

- **Monitoring Without Invasion:**

Using smartphones, wearable devices, and ubiquitous devices for fall detection provides nonintrusive monitoring, enabling individuals to maintain their privacy and independence. These devices can be incorporated into users' daily activities without causing discomfort or inconvenience. By analyzing sensor data from these devices, deep learning models enable unobtrusive fall detection without requiring individuals to wear or carry additional specialized equipment.

- **Aware of Context Detection:**

Along with movement patterns, deep learning models can capture contextual information to improve the accuracy of fall detection. By analyzing additional contextual data such as time of day, location, and environmental conditions, deep learning models can differentiate between normal activities and falls more effectively. This context-aware approach reduces false positives and improves fall detection system reliability.

- **Multimodal Data Fusion:**

Deep learning models can effectively combine data from multiple sensors to enhance the effectiveness of fall detection. Smartphones, wearable devices, and ambient devices frequently contain GPS, accelerometers, gyroscopes, barometers, and other sensors. Models employing deep learning can incorporate data from these various sensors, thereby obtaining a more complete picture of users' movements and activities. By integrating data from multiple modalities, the models can distinguish between normal activities and accidents more effectively.

- **Continuous Observation:**

Models based on deep learning enable continuous monitoring of individuals, providing fall detection capabilities around the clock. Smartphones, wearable devices, and ubiquitous devices can collect data throughout the day, allowing users' activities to be monitored in real time. This continuous stream of data can be processed by deep learning models, allowing falls to be detected promptly and appropriate actions to be taken.

- **Compatibility with Emergency Services**

Fall detection systems based on deep learning can integrate seamlessly with emergency services and caregiver notifications. When a fall is detected, the system can autonomously send alerts to designated caregivers or emergency services, ensuring that the individual in need receives immediate assistance. This integration expedites response times and improves the safety and well-being of all users.

- **Evolving Models:**

As more data becomes available, deep learning models can evolve and develop continuously. By retraining the model with new labeled data, fall detection accuracy can be improved. This adaptability enables fall detection systems to remain current and enhance their performance by learning from new examples.

- **Computing Capabilities at the Edge:**

The optimization of deep learning models for edge computing enables fall detection to be performed directly on smartphones, wearable devices, and ambient devices. Computing at the network's edge reduces the need for cloud-based processing, which can enhance response times and privacy. By executing deep learning models locally on the devices, fall detection can be conducted in real-time without the need for a constant Internet connection. This capability is especially advantageous in instances where network connectivity is limited or unreliable.

### ***3.2 Deep Learning Approach for Fall Detection***

Fall detection is a critical area of research aimed at ensuring the safety and well-being of vulnerable populations, particularly the elderly. Deep learning (DL) techniques have gained significant attention in recent years due to their ability to automatically learn intricate patterns and representations from raw data, often outperforming traditional machine learning approaches in various domains. In the context of fall detection, DL methods offer promising avenues for more accurate and robust detection systems.

In the domain of fall detection and activity recognition, numerous studies have explored the effectiveness of various machine learning techniques and deep learning methods. Syed et al. [15] introduced an innovative system that combines fall detection with the recognition of daily activities using data from the IMU accelerometer and gyroscope. Their CNN achieved an unweighted average recall rate of 88%, demonstrating its superior performance compared to other methods. In a separate study, Luna-Perejon et al. [16] investigated the use of Gated Recurrent Neural Networks (RNNs) based on LSTM and GRU for real-time fall detection using wearable devices with accelerometers. The selected architecture achieved impressive F1-scores of above 0.98 for falls and 0.85 for background activities, showcasing the effectiveness of RNN-based models. Likewise et al. [17] examined three datasets containing falls and activities of daily living. They applied Singular Value Decomposition (SVD) and 1D convolutional neural networks (CNNs) for feature extraction and recognition. The combination of dimension reduction features like SMV + SVD improved the accuracy to 75.65%, demonstrating the effectiveness of the proposed approach. Moreover, Garg, Sankalp, Bijaya Ketan Panigrahi, and Deepak Joshi [18] proposed a Deep Neural Network (DNN) for fall detection, showcasing its robustness to noise and achieving high accuracy, sensitivity, specificity, precision, and F-Score. The DNN performed well even in noisy environments, making it a valuable tool for real-time fall detection applications. Additionally, Kumar, H. Senthil, et al. [19] presented a comprehensive fall detection and activity identification system that utilized a CNN for feature extraction and XGB for categorization. The gradient-boosted CNN achieved an unweighted average recall of 89%, surpassing previous approaches. Overall, these studies demonstrate the effectiveness of deep learning methods, such as CNNs and RNNs, in fall detection and activity recognition tasks. The combination of deep

learning models with other techniques, like XGB, enhances the accuracy and robustness of the systems. The proposed methods offer promising results for real-world fall detection applications, holding potential benefits in healthcare and elderly care settings. However, the choice of the most suitable method should consider factors such as dataset characteristics, computational resources, and specific application requirements. Wisesa, I. Wayan Wiprayoga, and Genggam Mahardika [20] utilized RNNs to analyze sensor data for fall detection and activity recognition. They used the UMA FALL ADL dataset, employing a one-layer LSTM architecture with 100 hidden neurons. The best performance was achieved using X-axis accelerometer data, with good overall classification on falls. Combining all sensor data yielded lower performance.

### 3.3 *Observation and Findings*

- Camera-based methods are expensive and require a powerful GPU and CPU, which makes them difficult to use and necessitates storing and processing an enormous quantity of data.
- The disadvantages of camera-based systems include privacy concerns and the incapacity to observe beyond the camera's field of view.
- Smartphones are not compatible with wearable fall detection devices. A fall detection system must measure four to six g (one g = 9.8 m/s<sup>2</sup>), but smartphone accelerometer sensors may measure up to 2 g. Software adjustment can modify that.
- Using smartphone sensors like the accelerometer and gyroscope depletes the battery, which is a disadvantage for mobile devices. Optimization of software can extend the battery life of mobile devices.
- It may be difficult for medical professionals to comprehend technical terms such as energy consumption, battery backup, response time, and sensor installation.
- The use of wearable and ambient devices can provide users with greater privacy than camera-based fall detection systems, which pose significant privacy risks.
- In addition to detecting falls, wearable devices can monitor pulse rate, blood pressure, and sleep patterns.
- According to this study, KNN and SVM have the highest accuracy for mobile-based approaches, while CNN and RNN have the highest accuracy for ambience-based approaches.
- Deep learning models offer superior performance, reduced need for feature engineering, increased scalability and adaptability.
- As a solution, a hybrid approach combining smartphones and ambient devices with a model of deep learning is employed. A hybrid approach that incorporates inexpensive wearable and ambient devices can assist in problem resolution.
- In addition to detecting injuries, wearable devices can provide alerts and notifications for medication reminders, appointment reminders, and other vital information to elderly.

- The Sisfall dataset and the UMA Fall dataset are widely utilized in the field of fall detection research and are regarded as significant assets for the development and evaluation of fall detection algorithms and systems.

### 4 Proposed Model

One-dimensional CNN networks have emerged as prominent deep learning models in fall detection systems. They are utilized to extract meaningful features from input signals, which are then employed for classification. In the context of fall detection, 1D CNNs can analyze sensor data from peripheral devices or cameras to identify patterns related to falls. They are particularly effective at detecting temporal patterns in sequential data, which is often the case in fall detection applications [4, 15, 19].

IoT and cloud technologies have become integral components of fall detection system development and implementation. By placing Internet of Things devices, such as sensors, on the body or in the environment, falls or changes in motion indicative of falls can be detected. The data collected by these sensors can then be transmitted to the cloud for processing and analysis using machine (Fig. 6) learning algorithms like 1D CNN. Leveraging cloud technology enables remote monitoring and real-time alerts in the event of a fall. Caregivers or medical professionals can receive alerts on their mobile devices or computers and respond promptly to provide assistance. The cloud also facilitates the storage and analysis of large volumes of data, which can be utilized to improve the accuracy and effectiveness of fall detection systems over time. Moreover, the integration of IoT and cloud technologies enables the development of more sophisticated fall detection systems with additional capabilities such as predictive analytics and personalized feedback.

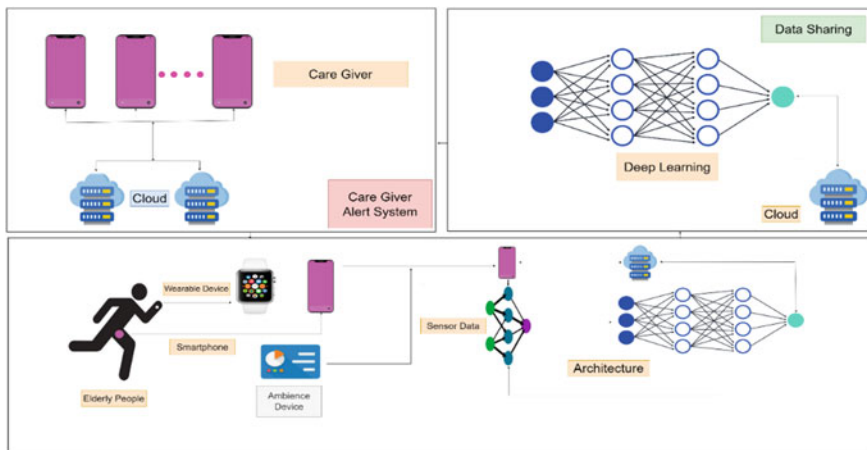


Fig. 6 Proposed model

To address fall detection among the elderly, we are currently designing a revolutionary system that combines smartphone and ambient device technology. Our proposed system utilizes deep learning to create a highly accurate fall detection model capable of distinguishing between falls and non-falls. This model forms the basis of an IoT-based alert system that incorporates both a smartphone and an ambient device, enabling the detection of falls both indoors and outdoors. If a fall occurs indoors, the model sends an alert to a family member inside the house, whereas it notifies a nearby caretaker about the user’s location in the case of an outdoor fall. For falls occurring outside, the system automatically alerts a nearby caregiver. Wearable devices such as smartwatches and smart bands are connected (Fig. 7) to the system via Bluetooth and WiFi. However, even in instances where a person is not wearing any wearable devices while at home or does not own a smartphone, the system can still detect falls using ambient sensors. When a person falls outside, the system utilizes their smartphone and peripheral devices to detect the fall. The system remains connected to a cloud server, allowing the alert system to reach all nearby caregivers within the same network. Furthermore, the system prioritizes the fatality rate and issues alerts accordingly.

Our fall detection system represents an innovative solution aimed at improving the quality of life for the elderly. By harnessing advanced technology, we can detect falls with greater accuracy, ensuring prompt medical attention and potentially saving lives. The deep learning-based model can distinguish between falls and other movements, providing precise alerts only when necessary. The IoT-based alert system is a crucial feature that ensures that caregivers are promptly notified, irrespective of whether the user is indoors or outdoors. This feature is particularly vital in emergency situations

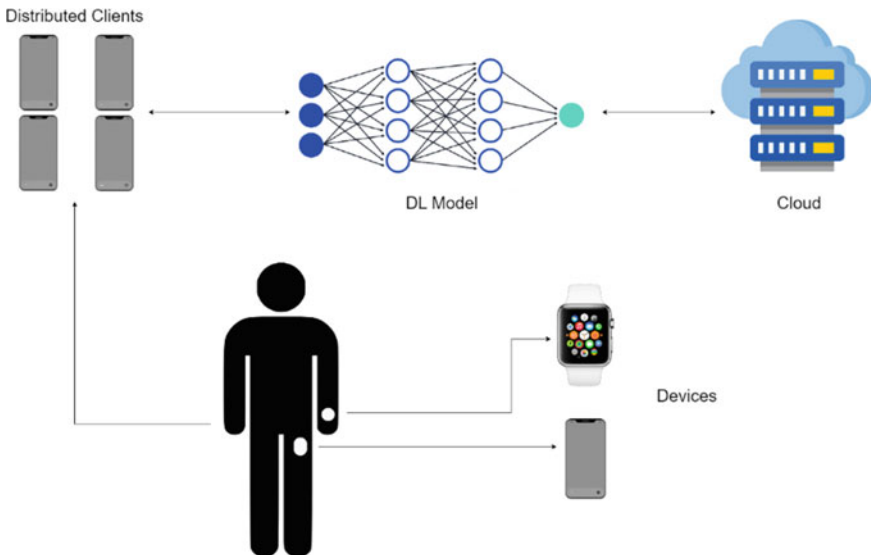


Fig. 7 Proposed model scheme

where every second counts. Additionally, the system's ability to prioritize high-risk falls ensures immediate attention from caregivers. The flexibility of our system is also noteworthy, as it can detect falls even without wearable devices or smartphones. This capability is especially valuable for individuals who may forget to wear their devices or do not own a smartphone. Through our groundbreaking technology, we believe that our fall detection system has the potential to revolutionize the elderly care industry. Accurate and timely fall detection can significantly enhance the quality of life for the elderly and their caregivers [3, 4, 9, 19].

#### ***4.1 Proposed Model Architecture***

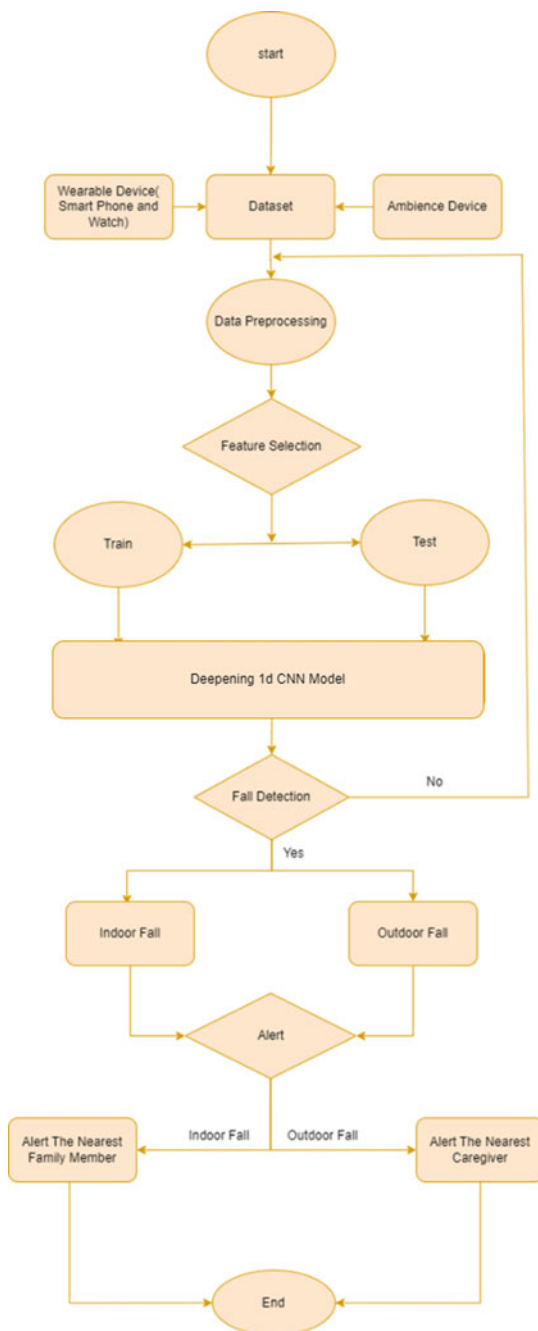
The proposed model architecture starts by collecting data from two sources: a wearable device and an ambient device. The wearable device records data from sensors like accelerometers and gyroscopes, while the ambient device captures audio or video recordings. These two sets of data are combined to create a comprehensive dataset. The data then goes through preprocessing and feature extraction steps. This involves cleaning the data to remove any noise or outliers and performing sensor fusion to integrate information from the different sensors (Fig. 8). Relevant features, such as statistical measures or frequency-domain features, are extracted from the preprocessed data. After preprocessing, the dataset is divided into two groups: the training data and the test data. The training data is used to train two deep learning models: a 1D CNN. The 1D CNN model learns spatial patterns from the data using multiple convolutional layers and pooling layers for down-sampling. The output of the CNN is then flattened and connected to fully connected layers for classification. This allows the model to learn temporal dependencies in the data. Finally, the output from the fully connected layers is used for classification tasks [4, 15, 18, 19].

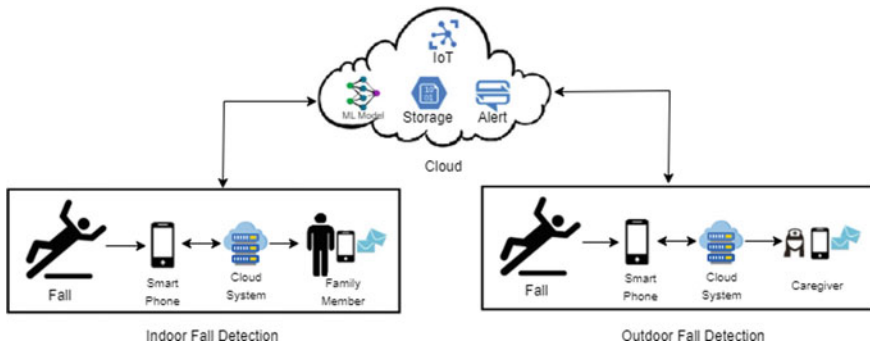
Once the models are trained, the preprocessed data is inputted into both models to detect fall events. The models produce probabilities indicating the likelihood of a fall event occurring. These probabilities are compared against a predetermined threshold to determine whether a fall has happened or not. In the case of an indoor fall, the alert system is triggered to notify the nearest family member. For outdoor falls, the system alerts the nearest caregiver.

To facilitate the alert system, the models are integrated into a cloud system. This cloud system enables real-time processing and analysis of the data, ensuring prompt detection of fall events. Once a fall is detected, the cloud system sends notifications to the designated recipients, such as the nearest family member or caregiver. These notifications can be delivered through various means, such as mobile applications, email, or SMS (Fig. 9). The integration with the cloud system allows for scalability, remote access, and efficient management of the alert system. The process loops back to the data processing step after triggering the alert system, allowing continuous monitoring and analysis. The process continues until no fall events are detected [3, 4, 18, 19].



**Fig. 8** Proposed model architecture



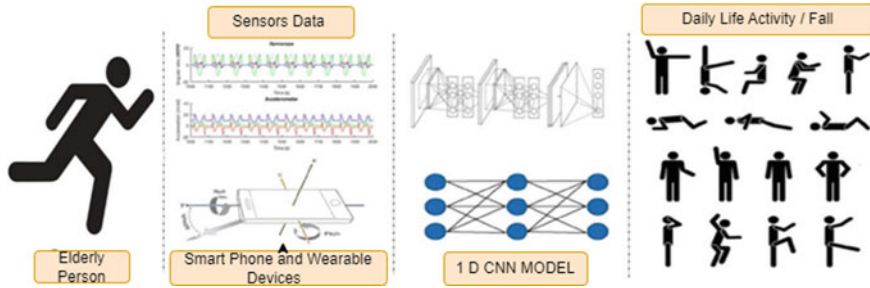


**Fig. 9** Alert system scheme

## 4.2 Methodology

### Data Collection

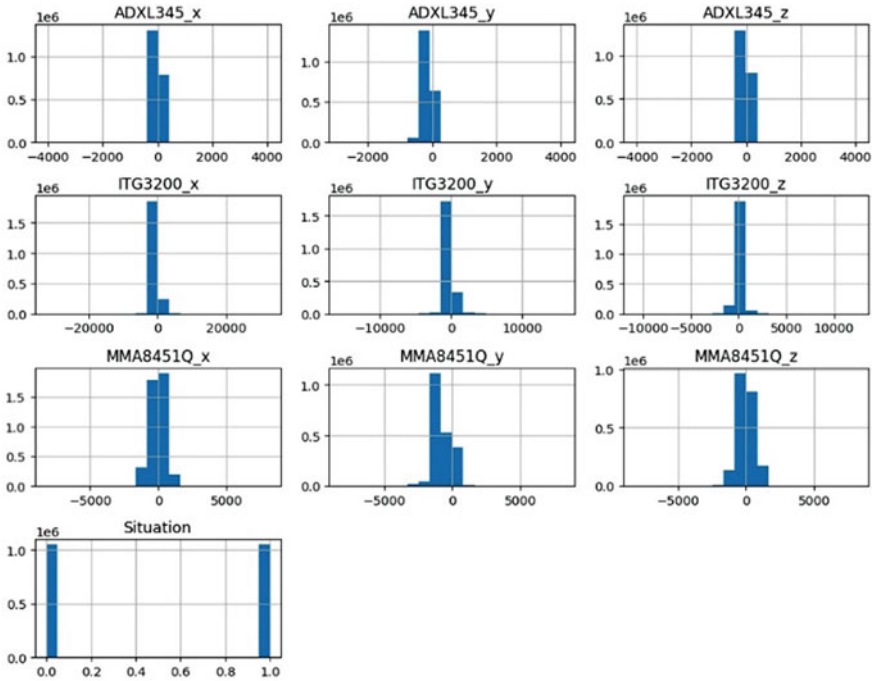
In this study, two datasets were used: the Sisfall dataset [21] and the UMA Fall dataset [22]. The Sisfall dataset was collected with the participation of 38 volunteers, who were divided into two categories: elderly and young adults. The geriatric group consisted of 15 participants (8 males and 7 females), while the young adults group consisted of 23 participants (11 males and 12 females). All participants were retirees from the Universidad de Antioquia and parents of active employees. It is important to note that all participants were in good health, without any gait problems (Fig. 10). The young adults performed activities of daily living (ADLs) and simulated falls, while the elderly individuals were advised not to perform falls and certain activities due to physical limitations or medical advice. Notably, a 60-year-old Judo expert, who was one of the participants, simulated both accidents and ADLs. Prior to their involvement in the study, all participants provided informed consent. The study protocol was approved by the Bio-Ethics Committee of the Medicine Faculty at the Universidad de Antioquia UDEA (Medellin, Colombia) in accordance with the principles outlined in the Declaration of Helsinki. The dataset was collected using a custom-built embedded device that included a Kinets MKL25Z128VLK4 microcontroller (NPX, Austin, Texas, USA), an Analog Devices ADXL345 accelerometer (16 g, 13 bits ADC), a Freescale MMA8451Q accelerometer (8 g, 14 bits ADC), and an ITG3200 gyro. The device was attached to the participants' waists, allowing accurate differentiation between activities using a single accelerometer system. For this study, only the acceleration data captured by the ADXL345 sensor was utilized due to its energy efficiency and wider range. However, the data collected by the second accelerometer and the gyroscope is also available for future research purposes. The sensor orientation was established with the positive z-axis facing forward, the positive y-axis aligned with gravity, and the positive x-axis positioned on the participant's right side. All experiments were conducted with a sampling frequency of 200 Hz from the beginning of the recording.



**Fig. 10** Data collection technique

The UMA Fall dataset [22] was created by Santoyo-Ramón, José Antonio, Eduardo Casilari, and José Manuel Cano-García. The main objective of this dataset was to track the movements of participants during falls. In the initial experimental setup, 17 participants were equipped with smartphones connected wirelessly to four sensing nodes, or “motest,” which were placed on their chest, waist, wrist, and ankle. Texas Instruments CC2650 SimpleLink™ Bluetooth low energy/multi-standard Sensor Tag modules were used as the sensing nodes. Each Sensor Tag module comprised an ARM CC2650 microcontroller, MEMS sensors, and an InveSense MPU-9250 Inertial Measurement Unit (IMU) with triaxial sensors for accelerometer, gyroscope, and magnetometer readings. The Sensor Tags were powered by a CR2032-type battery, allowing for wireless communication and full mobility. These sensing motest used a 2.4 GHz wireless MCU with ultra-low power consumption, supporting communication via BLE, 6LowPAN, or ZigBee. In the experimental setup, a smartphone has served as the central device of a Bluetooth Low Energy (BLE) piconet, acting as the master, while the four Sensor Tags has functioned as slaves. The smartphone received packets containing readings from the Sensor Tags. To assess fall detection algorithms, the researchers compared their performance using various sampling frequencies ranging from 5 to 256 Hz. To avoid Bluetooth network saturation, the Sensor Tags were set to transmit data at 20 Hz. The firmware of the Sensor Tags was modified to transmit the readings from the three IMU triaxial sensors via BLE at a rate of 50 ms. Furthermore, a smartphone, equipped with its own IMU, acted as a fifth sensor and was consistently placed in the subject’s trouser pocket to capture thigh movement. The smartphone measurements were recorded at a sampling frequency of 200 Hz. This comprehensive dataset provides valuable information for evaluating fall detection algorithms and understanding human movements during falls in real-world scenarios.

After the original signal has undergone preprocessing, the next stage is featuring extraction for classification purposes. Typically, two types of feature extraction methods are used [8]; one employs nine features (Figs. 11 and 12) comprised data from all sensors, and the other employs 25 features (Figs. 13 and 14). These extracted

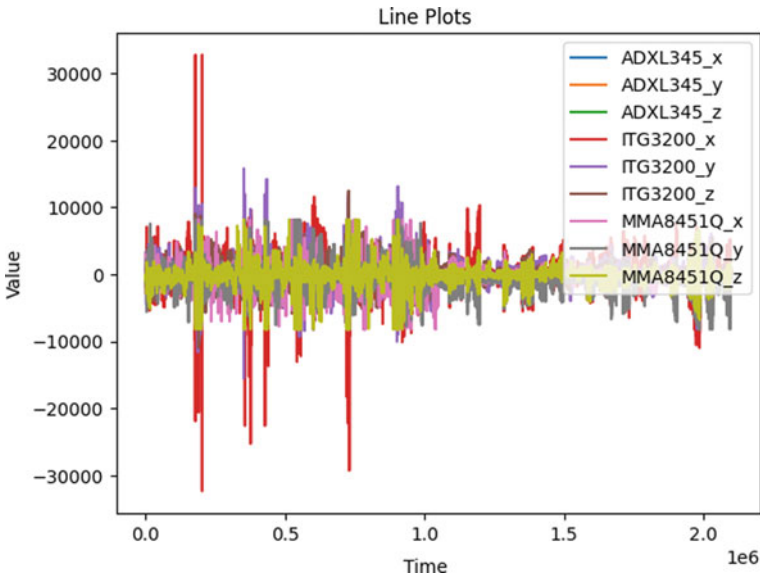


**Fig. 11** Sisfall dataset with nine features

features include the signal’s maximum amplitude, minimum amplitude, mean amplitude, variance, kurtosis, skewness, angular velocity, acceleration. These characteristics provide valuable information that can be used to distinguish and classify distinct patterns or signal characteristics. By taking into account these distinct characteristics, machine learning algorithms can effectively analyze and classify signal data for subsequent analysis or decision-making processes.

For an accelerometer signal: Let us assume that the accelerometer signal is denoted by  $a(i)$ , where  $i$  ranges from 1 to  $N$  (total number of samples).

- Maximum amplitude:  $\text{Max\_Acceleration} = \max(a(i))$ .
  - This formula calculates the maximum value of the acceleration signal. It finds the highest recorded acceleration value in the signal.
- Minimum amplitude:  $\text{Min\_Acceleration} = \min(a(i))$ .
  - This formula calculates the minimum value of the acceleration signal. It finds the lowest recorded acceleration value in the signal.
- Mean amplitude:  $\text{Mean\_Acceleration} = (1/N) * \text{sum}(a(i))$ .
  - This formula calculates the mean (average) value of the acceleration signal. It sums up all the acceleration values in the signal and divides the sum by the total number of samples.



**Fig. 12** Sisfall dataset with nine features (Line Plots)

- Variance:  $\text{Variance\_Acceleration} = (1/N) * \sum((a(i) - \text{Mean\_Acceleration})^2)$ .
  - This formula calculates the variance of the acceleration signal. It measures the spread or dispersion of the acceleration values around the mean. It sums up the squared differences between each acceleration value and the mean and then divides that sum by the total number of samples.
- Kurtosis:  $\text{Kurtosis\_Acceleration} = (1/N) * \sum(((a(i) - \text{Mean\_Acceleration})/\sqrt{\text{Variance\_Acceleration}})^4)$ .
  - This formula calculates the kurtosis of the acceleration signal. Kurtosis is a measure of the "tailedness" or the presence of outliers in the distribution of the signal. It normalizes the fourth moment of the acceleration signal by dividing it by the variance.
- Skewness:  $\text{Skewness\_Acceleration} = (1/N) * \sum(((a(i) - \text{Mean\_Acceleration})/\sqrt{\text{Variance\_Acceleration}})^3)$ .
  - This formula calculates the skewness of the acceleration signal. Skewness measures the asymmetry of the signal's distribution. It normalizes the third moment of the acceleration signal by dividing it by the variance.

For a gyroscope signal: Let us assume that the gyroscope signal is denoted by  $g(i)$ , where  $i$  ranges from 1 to  $N$  (total number of samples).

- Maximum amplitude:  $\text{Max\_AngularVelocity} = \max(g(i))$ .
- Minimum amplitude:  $\text{Min\_AngularVelocity} = \min(g(i))$ .

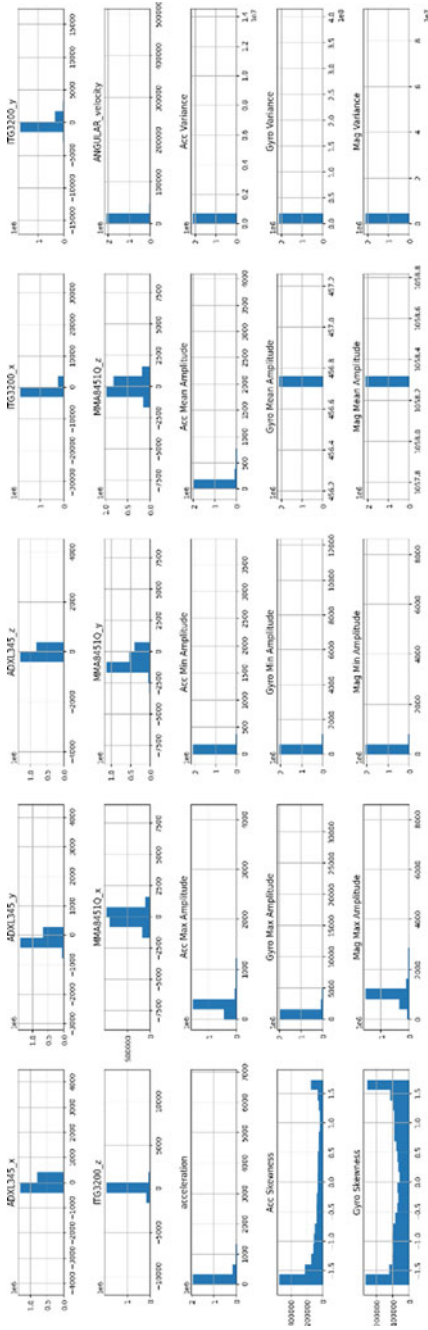


Fig. 13 Sisfall dataset with 25 features

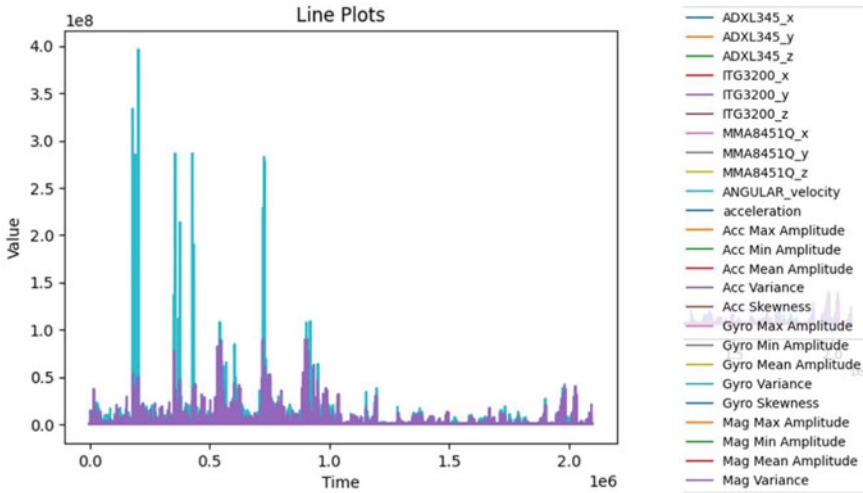


Fig. 14 Sisfall dataset with 25 features (Line Plots)

- Mean amplitude:  $\text{Mean\_AngularVelocity} = (1/N) * \text{sum}(g(i))$ .
- Variance:  $\text{Variance\_AngularVelocity} = (1/N) * \text{sum}((g(i) - \text{Mean\_AngularVelocity})^2)$ .
- Kurtosis:  $\text{Kurtosis\_AngularVelocity} = (1/N) * \text{sum}(((g(i) - \text{Mean\_AngularVelocity})/\text{sqrt}(\text{Variance\_AngularVelocity}))^4)$ .
- Skewness:  $\text{Skewness\_AngularVelocity} = (1/N) * \text{sum}(((g(i) - \text{Mean\_AngularVelocity})/\text{sqrt}(\text{Variance\_AngularVelocity}))^3)$ .

For a magnetometer signal: Let us assume that the magnetometer signal is denoted by  $m(i)$ , where  $i$  ranges from 1 to  $N$  (total number of samples).

- Maximum amplitude:  $\text{Max\_MagneticField} = \text{max}(m(i))$ .
- Minimum amplitude:  $\text{Min\_MagneticField} = \text{min}(m(i))$ .
- Mean amplitude:  $\text{Mean\_MagneticField} = (1/N) * \text{sum}(m(i))$ .
- Variance:  $\text{Variance\_MagneticField} = (1/N) * \text{sum}((m(i) - \text{Mean\_MagneticField})^2)$ .
- Angular Velocity:  $\text{Angular Velocity } (\omega) = \Delta\theta/\Delta t$ .
  - In a three-dimensional scenario, where an object can rotate around multiple axes, the formula for angular velocity ( $\omega$ ) is represented as a vector:

$$\omega = (\omega_x, \omega_y, \omega_z),$$

where  $\omega_x$  represents the angular velocity around the  $x$ -axis,  $\omega_y$  represents the angular velocity around the  $y$ -axis, and  $\omega_z$  represents the angular velocity around the  $z$ -axis. The values of  $\omega_x$ ,  $\omega_y$ , and  $\omega_z$  can be calculated using differentiation

(taking the rate of change) of the respective angular displacement with respect to time.

A low-pass filter is applied to the angular velocity signals to remove high-frequency noise or vibrations. The cutoff frequency determines the point at which the filter starts attenuating the high-frequency components. A Butterworth filter is used, which provides a maximally flat response in the passband. The 'filtfilt' function is used to apply the filter to the angular velocity signals and ensure zero-phase filtering. The 'b' and 'a' coefficients of the filter are obtained from the [8] 'butter' function. The filtered angular velocity signals for each axis are concatenated into a single array 'w' using the np.concatenate function. The Euclidean norm (magnitude) of the vector is computed and assigned to a new feature called 'ANGULAR\_velocity'.

Using the aforementioned formulas, we were able to identify the top 25 hand-engineered features (Fig. 12). These include the accelerometer (ADXL345) axes: 'ADXL345\_x', 'ADXL345\_y', 'ADXL345\_z', the gyroscope (ITG3200) axes: 'ITG3200\_x', 'ITG3200\_y', 'ITG3200\_z', and the magnetometer (MMA8451Q) axes: 'MMA8451Q\_x'. Additionally, the following features (Fig. 13) were also included: Accelerometer Maximum Amplitude: 'Acc Max Amplitude', Accelerometer Minimum Amplitude: 'Acc Min Amplitude', Accelerometer Mean Amplitude: 'Acc Mean Amplitude', Accelerometer Variance: 'Acc Variance', Accelerometer Skewness: 'Acc Skewness', Gyroscope Maximum Amplitude: 'Gyro Max Amplitude', Gyroscope Minimum Amplitude: 'Gyro Min Amplitude', Gyroscope Mean Amplitude: 'Gyro Mean Amplitude', Gyroscope Variance: 'Gyro Variance', Gyroscope Skewness: 'Gyro Skewness', Magnetometer Maximum Amplitude: 'Mag Max Amplitude', Magnetometer Minimum Amplitude: 'Mag Min Amplitude', Magnetometer Mean Amplitude: 'Mag Mean Amplitude', and Magnetometer Variance: 'Mag Variance'. The same feature extraction technique was utilized for the UMA Fall dataset.

### Proposed Deep Learning Model

In our proposed method for detecting falls using the Sisfall dataset and UMA Fall dataset, we utilize a 1D convolutional neural network (1DCNN) model. 1DCNN (convolutional neural network): This model utilizes convolutional layers to extract relevant features from the input data. By applying filters and aggregation operations, the CNN learns spatial patterns and captures crucial data for fall detection [4, 15, 17, 19].

#### *One-Dimensional Convolutional Neural Network (1DCNN)*

1D CNNs operate on sequential data with a single dimension, such as time series or text. They use convolutional layers to extract features from the input data, similar to other CNNs. In 1D CNNs, the convolutional operation is performed along the temporal or spatial axis of the data, as opposed to across two-dimensional spatial dimensions, as in image data. In a 1D CNN, an input sequence is convolved with a filter of a fixed size by gliding over the sequence and computing a dot product between the filter weights and the values in the current window. This procedure generates a



feature map that emphasizes the presence of particular patterns or features in the input sequence. A 1D CNN can capture various levels of granularity in the input data by employing multiple filters of varying sizes. Typically, the resultant feature maps are transmitted through activation functions and aggregating layers to further process the features and reduce the data's dimension. On the extracted features, one or more fully connected layers may be used to accomplish classification or regression [4, 17–19].

One-dimensional convolutional neural networks (1DCNNs) can be used for fall detection. The input signal is first passed through a convolutional layer, which performs feature extraction. The output of the convolutional layer is then passed through a max-pooling layer, which down samples the feature map. Finally, the output of the pooling layer is passed through a fully connected layer for classification.

The output of the convolutional layer can be computed using the following equation:

$$y[i] = b + \sum_{(j = 0 \text{ to } m - 1)} w[j] x[i + j], \quad (1)$$

where  $y[i]$  is the output at position  $i$ ,  $b$  is the bias term,  $w[j]$  is the weights of the filter,  $x[i + j]$  is the input values, and  $m$  is the size of the filter.

The output of the max-pooling layer can be computed using the following equation:

$$y[i] = \max(x[is : is + k]), \quad (2)$$

where  $y[i]$  is the output at position  $i$ ,  $x[is : is + k]$  is the input segment of length  $k$  starting at position  $i*s$ , and  $s$  is the stride.

The output of the fully connected layer can be computed using the following equation:

$$y = f\left(b + \sum_{(i = 0 \text{ to } n - 1)} w[i] x[i]\right), \quad (3)$$

where  $y$  is the output,  $b$  is the bias term,  $w[i]$  is the weights,  $x[i]$  is the inputs,  $n$  is the number of inputs, and  $f$  is the activation function. In this study, we employ a 1D convolutional neural network (CNN) model that is well-suited for extracting unique features from datasets with present window lengths. The size of the testing set is 20% of the total dataset. StandardAero is utilized to normalize the input features so that the data have a mean of zero and a standard deviation of one. We transform the input data into a 3D tensor so that it can be processed by the 1D CNN. The tensor has three dimensions, which include sample count, time increments, and characteristics.

### *Algorithm*

This algorithm describes the steps taken in the provided code to train a CNN model for fall detection and evaluate its efficacy.

- Import required libraries: pandas, numpy, sklearn, keras, matplotlib.
- Load the dataset and split it into input (X) and output (y) variables.
- Split the data into training and testing sets using `train_test_split()` from sklearn.
- Scale the input features using `StandardScaler` from sklearn.
- Reshape the input data to a 3D tensor for use with 1D CNN.
- Build a 1D CNN model using `Sequential()` from keras.
- Add `Conv1D` and `MaxPooling1D` layers to the model.
- Flatten the output from the `Conv1D` layer and add `Dense` layers to the model.
- Compile the model using `binary_crossentropy` loss function, `adam` optimizer, and `accuracy` metric.
- Train the model using `fit()` from keras.
- Plot the training and validation accuracy and loss using `matplotlib`.
- Make predictions on the testing data using `predict()` from keras.
- Convert the probabilities to class labels.
- Print the classification report using `classification_report()` from sklearn.
- Plot the confusion matrix using `confusion_matrix()` from sklearn and `matplotlib`.

### *Explanation of the algorithm*

#### *Data Preparation:*

Imports required libraries such as Pandas, NumPy, Sklearn, and Keras. This is the initial step. The next step in the data preparation process is the import of the data. Following that, the data are separated into the two variables that were input.

#### *Data Preprocessing:*

The next stage is to preprocess the data, where the data is divided into training and testing sets with the help of the `train test split` function from sklearn. Eighty % of the data will be used for training, while the remaining 20% will be used for testing. `StandardScaler`, which is included in sklearn, is used to do the scaling on the input features. In this stage, the features are standardized by first calculating the mean and then scaling the mean down to the unit variance. The input data is reformatted into a three-dimensional tensor so that it can be processed by the one-dimensional CNN model.

#### *Building the 1D CNN Model:*

In order to construct the 1D CNN model (Fig. 15), the model architecture is specified by utilizing the `Sequential` API that is provided by Keras. Two convolutional layers have been added, each with 128 and 256 filters correspondingly. After each convolutional layer comes a max-pooling layer, which helps minimize the spatial dimensions of the data. The output is then flattened by the model, and it is run through a dense layer that has 64 units and a dropout layer in order to prevent overfitting. In the end, a dense layer that only contains a single unit and uses sigmoid activation is added in order to do binary classification. The Adam optimizer is used in the compilation process, along with binary cross-entropy loss.

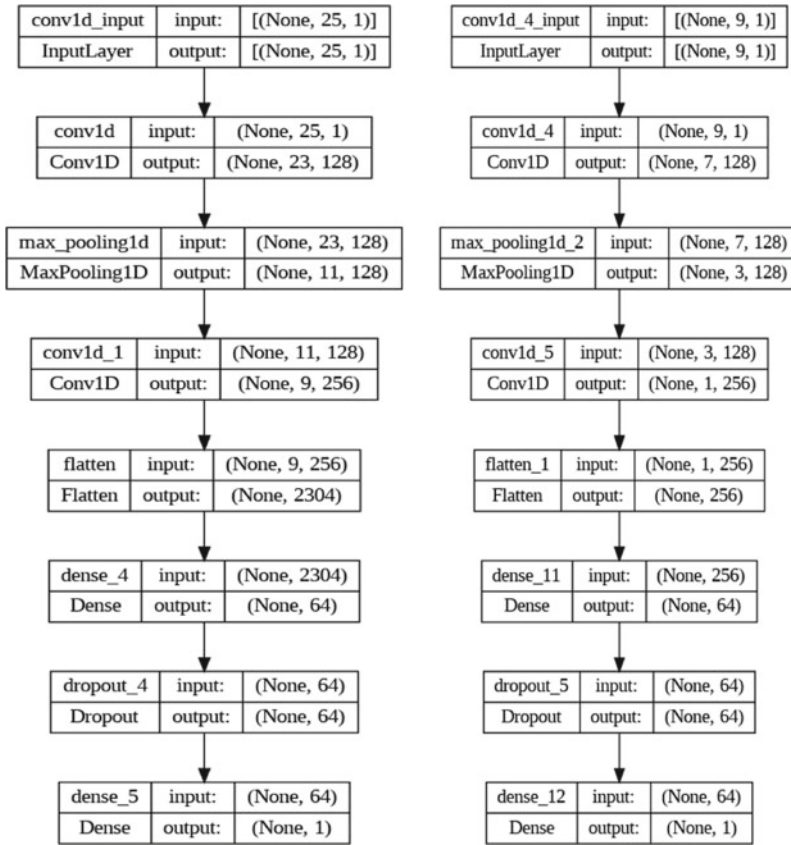


Fig. 15 CNN model building

*Training and Testing the Model:*

The training of the model is carried out using the fit technique with a batch size of 32 and a total of 10 epochs. Matplotlib is used to create plots of the training and validation accuracies as well as the losses.

**Evaluation and Performance Analysis:**

*Model Analysis Matrix*

A classification model’s efficacy is evaluated using the metrics True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN). These metrics provide granular insight into the model’s ability to correctly classify instances into their respective classifications.

- True Positive (TP): This metric represents the number of instances correctly classified by the model as positive (class 1) instances. It measures the number of instances in which the model correctly predicted the positive class.
- False Positive (FP): This metric indicates the number of instances incorrectly classified as positive (class 1) by the model. It measures the number of instances in which the model predicted the positive class, but the actual class was class 0 (negative).
- True Negative (TN): This metric represents the number of instances correctly classified by the model as negative (class 0). It measures the number of times the model correctly predicted the negative class.
- False Negative (FN): This metric represents the number of instances improperly classified by the model as negative (class 0). It quantifies the number of situations in which the model predicted a negative class, but the actual class was positive (class 1).
- These metrics are used to calculate additional performance metrics, including accuracy, precision, recall, and  $F_1$ -score.
- Precision: Precision is the ratio of true positives (TP) to the sum of true positives (TP) and false positives (FP). It measures the proportion of correctly identified positive instances among all predicted positive instances.
- Recall: Recall is the ratio of true positives (TP) to the sum of true positives (TP) and false negatives (FN). It measures the proportion of correctly identified positive instances among all actual positive instances.
- $F_1$ -score: The  $F_1$ -score is the harmonic mean of precision and recall. It provides a balanced measure of the model's performance by considering both precision and recall.  $F_1$ -score is calculated as  $(2 * \text{Precision} * \text{Recall}) / (\text{Precision} + \text{Recall})$ .
- Support: Support refers to the number of instances for each class in the dataset. It can be represented by the sum of true positives (TP) and false negatives (FN) for a specific class.
- Accuracy: Accuracy is the ratio of correct predictions (sum of true positives and true negatives) to the total number of predictions. It measures the overall correctness of the model's predictions.
- Macro avg: Macro average calculates the average precision, recall, and  $F_1$ -score across all classes. It treats each class equally, regardless of its support. To calculate macro average precision, recall, and  $F_1$ -score, you would take the average of the respective metric values for each class.
- Weighted avg: Weighted average calculates the average precision, recall, and  $F_1$ -score, taking into account the support of each class. It gives more weight to the metrics of the class with higher support.

### *1DCNN Model for Sisfall Dataset*

After applying the trained model to the testing data of the Sisfall dataset and generating predictions, a threshold of 0.5 is used to transform the projected probabilities into class labels.

The 1DCNN model demonstrated an accuracy score of 89% for the normal Sisfall dataset and 91% for the Sisfall dataset with 25 features. This suggests that the model accurately predicted 89% of outcomes in the Sisfall dataset with nine features and 91% of outcomes in the Sisfall dataset with nine features. In (Fig. 16) is a plot of training loss and validation loss over epoch, training accuracy and validation accuracy over epoch, and a confusion matrix of 0, 1 for Not fall and fall situations for Sisfall Dataset with 9 features, also (Fig. 17) show for Sisfall dataset with 25 features.

*Comparing 1DCNN Models with 9 Features and 25 Features Using the Sisfall Dataset*

Model 2, the 1DCNN with 25 features, demonstrates slightly superior performance compared to Model 1, the 1DCNN with 9 features, in terms of precision, recall, and F1-score for both classes. It accomplishes greater precision and recall, resulting in a higher F1-score. Both models exhibit high accuracy, with Model 2 obtaining a slightly higher accuracy of 0.91 than Model 1, which achieves an accuracy of 0.89. The macro and weighted average metrics for Model 2 are also greater, indicating a superior performance across all classifications. On the basis of these results, it can be

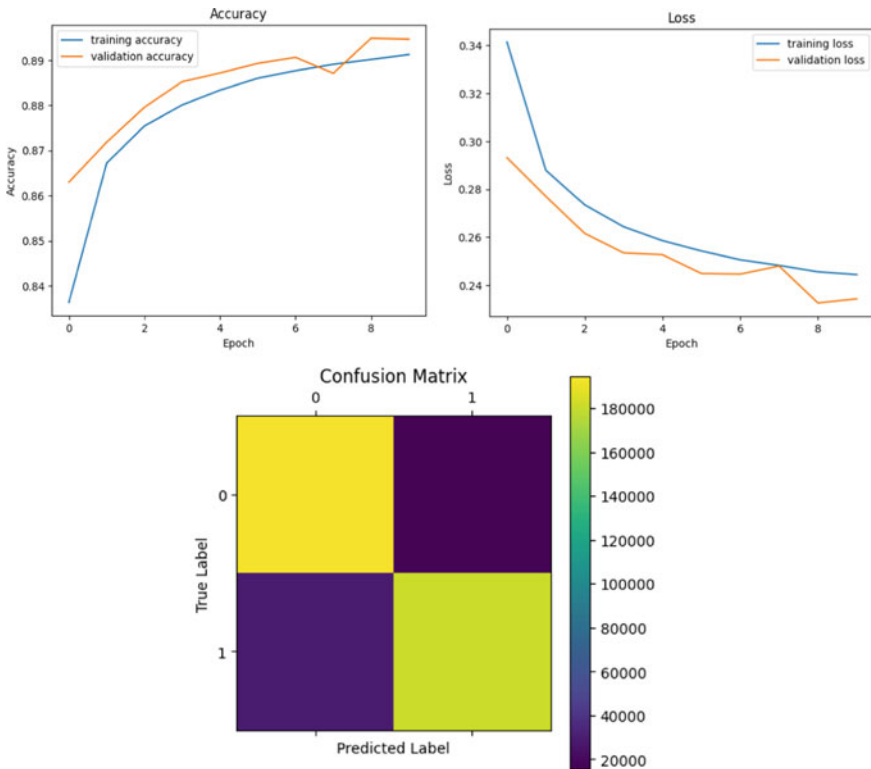
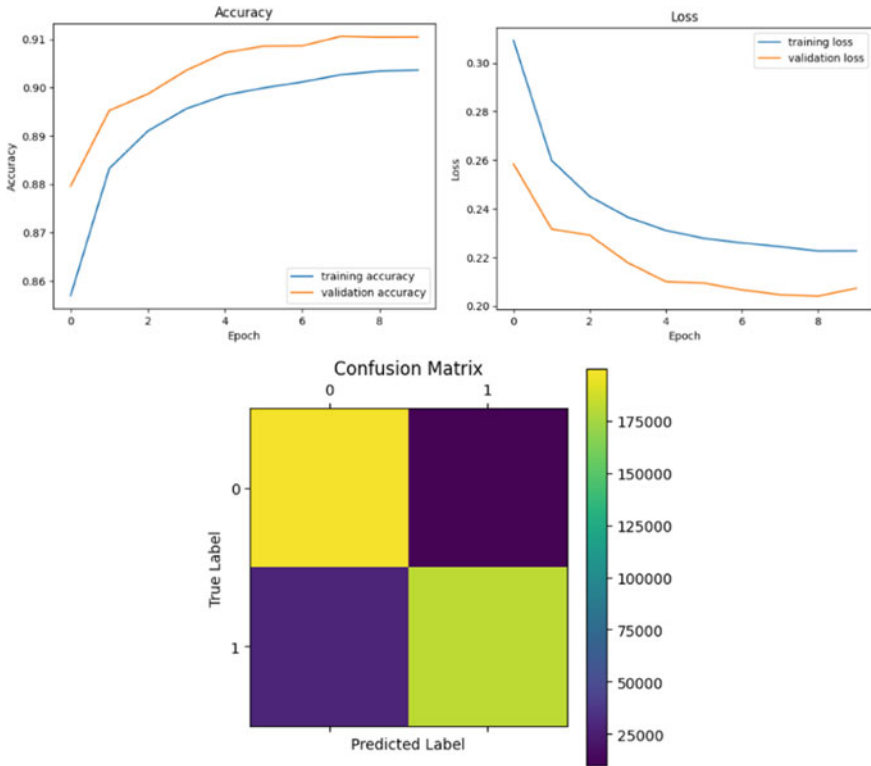


Fig. 16 1DCNN Model Matrix Sisfall with nine features



**Fig. 17** CNN model matrix Sisfall dataset with 25 features

concluded that the CNN model with 25 features outperforms the CNN model with nine features on the Sisfall dataset.

*Model 1: 1DCNN with Sisfall Dataset 9 Features*

- Class 0 has a precision of 0.87 and class 1 has a precision of 0.92.
- Class 0 has a recall  $F_1$  rate of 0.93, while class 1 has a recall  $F_1$  rate of 0.86.
- Class 0 has an  $F_1$ -score of 0.90, whereas class 1 has an  $F_1$ -score of 0.89.
- Accuracy: 0.89 is the model’s accuracy.
- The average precision, recall  $F_1$ , and  $F_1$ -score at the macro level are 0.90, 0.89, and 0.89, respectively.
- The weighted average precision is 0.90, recall  $F_1$  is 0.89, and the  $F_1$ -score is also 0.89 (Table 1).

*Model 2: 1DCNN with Sisfall Dataset 25 Features*

- Class 0 has a precision of 0.88, whereas class 1 has a precision of 0.95.
- Class 0 has a recall  $F_1$  rate of 0.95, while class 1 has a recall  $F_1$  rate of 0.87.
- Class 0 has an  $F_1$ -score of 0.91, while class 1 has an  $F_1$ -score of 0.91.

**Table 1** 1DCNN with nine features Sisfall dataset

|               | Precision | Recall $F_1$ | $F_1$ -score | Support |
|---------------|-----------|--------------|--------------|---------|
| 0             | 0.87      | 0.93         | 0.90         | 209,768 |
| 1             | 0.92      | 0.86         | 0.89         | 209,662 |
| Accuracy      |           |              | 0.89         | 419,430 |
| Macro avg.    | 0.90      | 0.89         | 0.89         | 419,430 |
| Weighted avg. | 0.90      | 0.89         | 0.89         | 419,430 |

- The model is accurate to 0.91 degrees.
- The average precision, recall  $F_1$ , and  $F_1$ -score at the macro level are 0.91, 0.91, and 0.91, respectively.
- The weighted average precision is 0.91, the recall  $F_1$  is 0.91, and the  $F_1$ -score is 0.91 (Table 2).

#### *1DCNN Model for UMA Fall Dataset*

For the UMA Fall dataset with nine features and for the UMA Fall dataset with 25 features, the 1DCNN model exhibited an accuracy score of 90% and 92%, respectively.

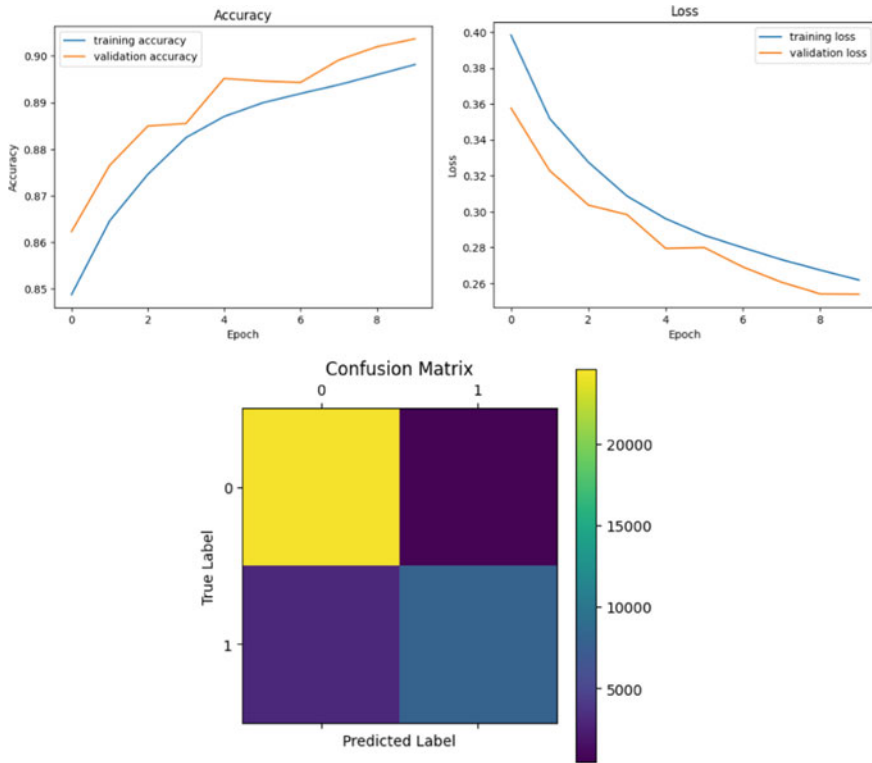
This indicates that 90% of outcomes in the UMA Fall dataset with 9 features and 91% of outcomes in the UMA Fall dataset with 25 characteristics were correctly predicted by the model. For the UMA Fall dataset with nine features, a plot of training loss and validation loss over epoch, training accuracy and validation accuracy over epoch, and a confusion matrix of 0, 1 for Not fall and fall circumstances are shown in (Fig. 18). UMA fall with 25 features is shown in (Fig. 19).

#### *Comparison of 1D CNN Models with 9 Features on the UMA Fall Dataset*

Model 2, the 1D CNN with 25 features, outperforms Model 1, the 1D CNN with 9 features, in terms of precision, recall, and F1-score for both classes. It achieves higher precision, recall, and F1-score values for both classes. Both models show high accuracy, with Model 2 achieving a slightly higher accuracy of 0.92 compared to Model 1 with an accuracy of 0.90. The macro and weighted average metrics for Model 2 are also higher, indicating better overall performance across all classes.

**Table 2** 1DCNN with 25 features' Sisfall dataset

|               | Precision | Recall $F_1$ | $F_1$ -score | Support |
|---------------|-----------|--------------|--------------|---------|
| 0             | 0.88      | 0.95         | 0.91         | 209,768 |
| 1             | 0.95      | 0.87         | 0.91         | 209,662 |
| Accuracy      |           |              | 0.91         | 419,430 |
| Macro avg.    | 0.91      | 0.91         | 0.91         | 419,430 |
| Weighted avg. | 0.91      | 0.91         | 0.91         | 419,430 |



**Fig. 18** 1DCNN model matrix UMA fall with nine features

Based on these results, it can be concluded that the 1D CNN model with 25 features performs better than the 1D CNN model with nine features on the UMA Fall dataset.

*Model 1: 1D CNN with nine Features*

- Precision: For class 0, the precision is 0.89, and for class 1, it is 0.94.
- Recall: For class 0, the recall  $F_1$  is 0.90, and for class 1, it is 0.73.
- F1-score: For class 0, the  $F_1$ -score is 0.93, and for class 1, it is 0.82.
- Accuracy: The accuracy of the model is 0.90.
- Macro average: The macro average precision is 0.92, recall  $F_1$  is 0.85, and  $F_1$ -score is 0.88.
- Weighted average: The weighted average precision is 0.91, recall  $F_1$  is 0.90, and  $F_1$ -score is 0.90 (Table 3).

*Model 2: 1D CNN with 25 Features*

- Precision: For class 0, the precision is 0.90, and for class 1, it is 0.95.
- Recall: For class 0, the recall  $F_1$  is 0.98, and for class 1, it is 0.76.
- F1-score: For class 0, the  $F_1$ -score is 0.94, and for class 1, it is 0.85.



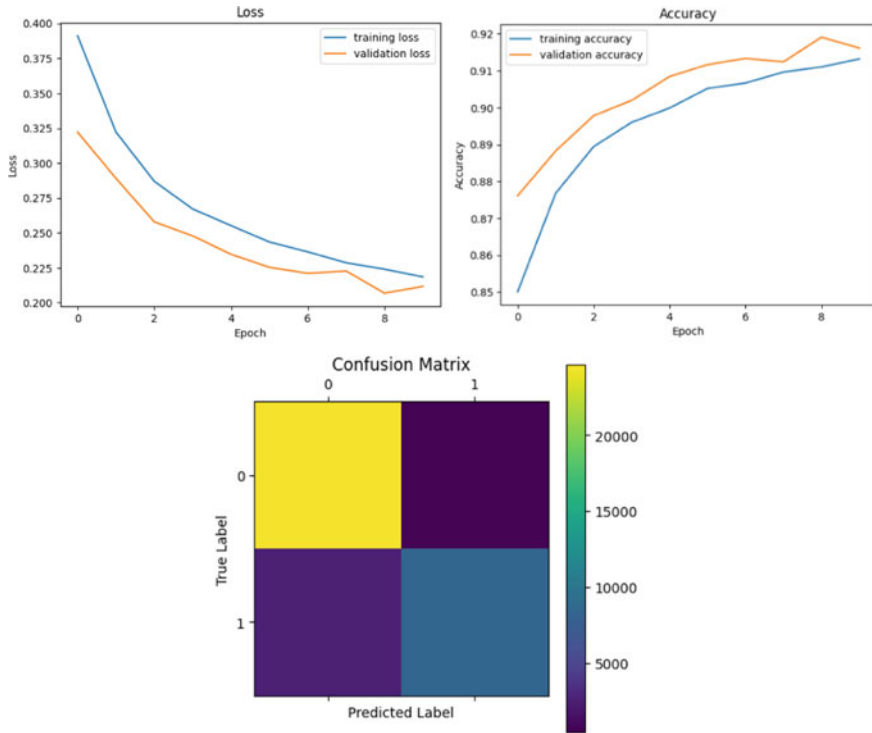


Fig. 19 1DCNN model matrix UMA Fall with 25 features

Table 3 1DCNN with 9 features UMA Fall dataset

|              | Precision | Recall $F_1$ | $F_1$ -score | Support |
|--------------|-----------|--------------|--------------|---------|
| 0            | 0.89      | 0.90         | 0.93         | 25,066  |
| 1            | 0.94      | 0.73         | 0.82         | 10,990  |
| Accuracy     |           |              | 0.90         | 36,056  |
| Macro avg    | 0.92      | 0.85         | 0.88         | 36,056  |
| Weighted avg | 0.91      | 0.90         | 0.90         | 36,056  |

- Accuracy: The accuracy of the model is 0.92.
- Macro average: The macro average precision is 0.93, recall  $F_1$  is 0.87, and  $F_1$ -score is 0.89.
- Weighted average: The weighted average precision is 0.92, recall  $F_1$  is 0.92, and  $F_1$ -score is 0.91 (Table 4).

**Table 4** IDCNN with 25 features UMA Fall dataset

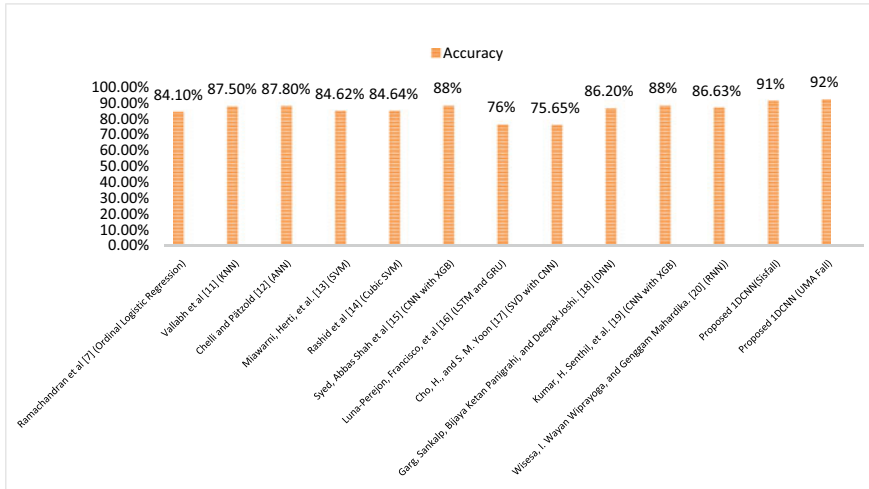
|               | Precision | Recall $F_1$ | $F_1$ -score | Support |
|---------------|-----------|--------------|--------------|---------|
| 0             | 0.90      | 0.98         | 0.94         | 25,066  |
| 1             | 0.95      | 0.76         | 0.85         | 10,990  |
| Accuracy      |           |              | 0.92         | 36,056  |
| Macro avg.    | 0.93      | 0.87         | 0.89         | 36,056  |
| Weighted avg. | 0.92      | 0.92         | 0.91         | 36,056  |

### 4.3 Experiment Setup

In this study, machine learning experiments were conducted using Google Colab and an HP laptop. The HP laptop featured a ninth-generation i7 processor, 16 gigabytes of RAM, and a one-terabyte solid-state drive. Our development environment for executing machine learning tasks was Jupyter Notebook. Cloud-based platform Google Colab gave us access to potent computational resources. It allowed us to utilize Google’s high-performance GPUs and TPUs to expedite our machine learning experiments. We utilized Colab’s collaborative features to readily share and collaborate with other researchers on our code and findings. We utilized the HP laptop’s local computational capability and storage capacity for specific experiments. The i7 ninth-generation CPU ensured the efficient processing of our machine learning algorithms, while the 16 gigabytes of RAM enabled us to manage large datasets and intricate models. The one terabyte SSD was sufficient for storing our datasets, models, and intermediate results. Our primary development environment was Jupyter Notebook, which allowed us to write and execute code in an interactive and reproducible manner. To implement and evaluate our models, we utilized numerous machine learning libraries and frameworks, such as TensorFlow and Keras. The adaptability and extensive data visualization support of Jupyter Notebook assisted us in analyzing and interpreting our experimental results. By combining Google Colab and our HP laptop, we obtained a comprehensive experimental configuration that enabled us to conduct effective machine learning research. This configuration provided us with the flexibility to utilize both cloud-based resources and local computational capacity, allowing us to address a variety of research challenges and gain insightful knowledge.

### 4.4 Result Analysis

In this detailed comparison of various models (Fig. 20), their respective accuracies are examined in a classification task. Ramachandran et al. [7] employed Ordinal Logistic Regression, achieving an accuracy of 84.1%. Vallabh et al. [11] used KNN, reaching an accuracy of 87.5%. Chelli and Pätzold [12] utilized ANN, obtaining a higher accuracy of 87.8%. Miawarni, Herti, et al. [13] applied SVM, resulting in an accuracy of 84.62%. Rashid et al. [14] introduced Cubic SVM with an accuracy



**Fig. 20** Comparison with others

of 84.64%. Syed, Abbas Shah et al. [15] combined CNN with XGBoost, achieving an accuracy of 88%. Luna-Perejon et al. [16] used LSTM and GRU, obtaining an accuracy of 76%. Cho and Yoon [17] combined SVD with CNN, reaching an accuracy of 75.65%. Garg et al. [18] employed DNN, achieving an accuracy of 86.2%. Kumar et al. [19] also combined CNN with XGBoost, resulting in an accuracy of 88%. Wisesa et al. [20] used RNN, achieving an accuracy of 86.63%. Additionally, the proposed 1DCNN (Sisfall) model demonstrated an accuracy of 91%, showcasing its ability to accurately detect falls. The 1DCNN (UMA Fall) model achieved an even higher accuracy of 92%, indicating its superior performance compared to the other models (Table 5).

## 4.5 Limitations

**Limited Resources:** The development and maintenance of an efficient Fall Detection System (FDS) requires considerable resources. Obtaining extensive and diverse datasets, undertaking field trials, and ensuring data privacy and security all require financial investments. Additionally, expertise and personnel are required for data acquisition, model development, and system deployment. These aspects may not be fully realized due to limited resources, which may have an effect on the system's overall performance and scalability.

**Limited Computational Power:** Implementing sophisticated deep learning models, such as 1DCNNs, often demands significant computational power. Training and executing these models efficiently can be computationally costly and may necessitate high-performance hardware, such as GPUs or specialized processors. The inability

**Table 5** Comparative result table

| Name of Model   | Accuracy (%) |
|---|--------------|
| Ramachandran et al. [7] (Ordinal Logistic Regression) | 84.1         |
| Vallabh et al. [11] (KNN)                             | 87.5         |
| Chelli and Pätzold [12] (ANN)                         | 87.8         |
| Miawarni et al. [13] (SVM)                            | 84.62        |
| Rashid et al. [14] (Cubic SVM)                        | 84.64        |
| Syed et al. [15] (CNN with XGB)                       | 88           |
| Luna-Perejon et al. [16] (LSTM and GRU)               | 76           |
| Cho and Yoon [17] (SVD with CNN)                      | 75.65        |
| Garg et al. [18] (DNN)                                | 86.2         |
| Kumar et al. [19] (CNN with XGB)                      | 88           |
| Wisesa et al. [20] (RNN))                             | 86.63        |
| Proposed 1DCNN (Sisfall)                              | 91           |
| Proposed 1DCNN (UMA Fall)                             | 92           |

to investigate and utilize more complex models can be hampered by a system's limited computational capacity, thereby compromising its potential accuracy and performance.

To address these constraints, resource management and strategic planning are required. Effectively allocating resources, such as prioritizing data collection efforts based on available funding, can mitigate the effect of limited resources. Exploring optimization techniques, model compression methods, or utilizing cloud computing resources can assist in circumventing computational power limitations. Although these constraints present challenges, it is essential to acknowledge them and pursue solutions that maximize the system's potential within the constraints available. Even with limited resources and computational capacity, it is possible to develop an alert system with effective performance and usability by maximizing available resources and investigating alternative approaches.

## 5 Future Scope

Future emphasis should be placed on the following areas to improve the effectiveness and usability of the Fall Detection System (FDS):

Integrating the alert system with a cloud infrastructure is a necessary and logical step in developing a scalable and effective solution. The advantages of cloud connectivity include scalability, dependability, and accessibility. The system can achieve real-time monitoring, seamless integration with other systems, and remote access from a variety of devices and locations by utilizing cloud hosting. This permits the

generation of timely alerts and improves the system's overall functionality. To facilitate cloud integration, a comprehensive system for applications that can connect with smartphone wearable devices like smart watches and smart bands must be developed. Moreover, integration with ambient devices is necessary. This integrated system enables the transmission of location data to caregivers via IoT technology in the event of an outdoor fall. In such situations, the alert system can quickly identify the nearest caregiver and notify them of the exact location, allowing for immediate intervention. Additionally, if a fall occurs inside the home, the system should be able to alert family members or other individuals who are present. This ensures that the individual in need can receive immediate assistance. By leveraging cloud infrastructure and integrating multiple devices and systems, the proposed solution improves the alert system's effectiveness and efficiency. The ability to seamlessly connect wearable devices, utilize IoT technology for outdoor fall detection, and notify caregivers and family members in real time greatly enhances the system's overall safety and response capabilities.

Expand and diversify the dataset to enhance the model's ability to generalize, it is essential to acquire a more extensive and diverse dataset. By collecting information from a variety of sources, environments, and demographics, the model will be able to manage a wider variety of real-world scenarios. This can include information from various sensors, locations, and user profiles, taking into account age, gender, and physical abilities. Moreover, data augmentation techniques can be utilized to artificially increase the dataset's size and diversity, emulating various scenarios and enhancing the models generalizability.

Utilize advanced deep learning models, the efficacy of the system can be improved by incorporating more complex and sophisticated deep learning models. Recurrent neural networks (RNNs), attention-based models, and transformer models have demonstrated superior performance in time series analysis and sequential data processing domains. Exploring these models enables the identification of intricate patterns and long-term dependencies within the data, resulting in enhanced accuracy and predictive abilities.

Real-World testing and field trials to assure the alert system's practical applicability, it is essential to conduct exhaustive real-world testing and field trials. Evaluating the model's performance under real-world conditions provides invaluable insight into its usefulness and efficacy. Field evaluations can help identify any limitations or enhancement areas that must be addressed, ensuring that the system performs accurately and reliably in real-world situations.

Security and Privacy Considerations, it is of the utmost necessity to ensure the security and privacy of the collected data. Implementing comprehensive data anonymization techniques and adhering to applicable privacy regulations will increase stakeholder and user confidence. Prioritizing data security and privacy protects the integrity and secrecy of personal information, thereby enhancing user confidence in the system.

## 6 Conclusion

In conclusion, the study focuses on enhancing elderly fall detection systems through the integration of deep learning and IoT technologies. The results demonstrate the impressive effectiveness of the proposed 1DCNN models, accurately detecting falls in different datasets with accuracies of 91% and 92% on the Sisfall and UMA Fall datasets, respectively.

A significant aspect highlighted in the study is the incorporation of fatality rates into the alert system. This consideration enables caregivers and family members to be promptly notified in critical situations, allowing for timely assistance and potentially saving lives. This proactive approach adds an extra layer of safety and support to the fall detection system, making it more effective in real-world scenarios. The thesis provides valuable insights into the field of fall detection by introducing novel models that outperform existing approaches in terms of accuracy. Future research and development should focus on further refining deep learning algorithms, incorporating diverse datasets, integrating advanced sensor technologies, and considering fatality rates to further enhance the system's accuracy, applicability, and reliability.

Continued efforts in research and development are essential to optimize the proposed fall detection models and address any limitations. Successfully integrating these technologies into healthcare and assisted living environments will significantly improve the safety and well-being of individuals at risk of falls. By incorporating fatality rates into the alert system, the fall detection technology can promptly notify caregivers or family members in critical situations, ensuring timely assistance and potentially saving lives. This crucial feature reinforces the system's overall effectiveness and its potential positive impact on vulnerable individuals' lives. Ultimately, advancements in fall detection technology, along with the integration of fatality rates, have the potential to enhance the overall quality of life for at-risk individuals by providing timely assistance and minimizing the risks associated with falls. The findings of this research contribute to the ongoing development of reliable and effective fall detection systems, further improving the safety and well-being of vulnerable individuals in real-world settings.

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# Anticipating Graduate Program Admission Through Implementation of Deep Learning Models



Nazeer Shaik, Jagendra Singh, Ankur Gupta, Dler Salih Hasan, N. Manikandan, and Radha Raman Chandan

**Abstract** Acceptance into a graduate program must be part of a student's academic journey. Every year, a huge number of people apply to schools and universities, and the admissions process may be tough and time-consuming. Many factors are considered while evaluating a student's application, including academic achievement, test scores, LOR, and extracurricular activities. However, selecting the best choices can still be arbitrary and prone to mistakes. As a result, it is required to develop a more efficient and objective technique of evaluating an applicant's chances of admission to a graduate course based on their application materials. The purpose of this study is to develop a ML model that can predict a student's prospects of acceptance into a graduate school. The model will be trained using a dataset containing different characteristics, such as GRE scores, GPA, and letters of recommendation. The dataset will be preprocessed to cope with missing values, outliers, and categorical data. A variety of ML methods, including LR, DT, and SVM, will be used to build the model. The algorithm's efficacy will be measured using a variety of measures, including accuracy, precision, recall, and F1 score. The best-performing model will then be picked and used to evaluate the admissions outcomes of fresh applicants.

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**Keywords** Statement of purpose · Machine learning · Letter of recommendation · False positive rate · Test of English as a Foreign Language (TOEFL) · Logistic regression · Support vector machine · K-nearest neighbors · Random forest · Gradient boosting classifier

## 1 Introduction

Graduate admission is a highly competitive and sought-after procedure that shapes an individual's professional future. Given the number of factors involved, predicting the chance of admission may be a difficult undertaking. However, with the introduction of machine learning algorithms, the admission prediction process has become more accurate and efficient [1].

In this paper, we will use five different ML models to estimate a candidate's chance of admission: SVM, gradient boosting classifier, random forest classifier, K-nearest neighbor, and logistic regression. We employed a dataset that included information on a candidate's academic history, test results, and research experience [2, 3]. As extra factors, we analyzed the candidate's SOP and LOR. The initial stage in our investigation was to preprocess the data. We began by cleansing the data and dealing with any missing or erroneous numbers. Following that, we used feature scaling to guarantee that all variables were on the same scale. After that, the dataset was separated into training and testing sets, with 80% used for training and 20% for testing. The five machine learning models were then trained on the training data before being tested on the testing data [4]. The precision, recall, and F1 scores of each model were used to calculate its accuracy. With an F1 score of 0.91, we discovered that the random forest classifier has the maximum accuracy. The other models performed well as well, with SVM and gradient boosting classifier having F1 scores of 0.89 and 0.88, respectively.

It is well-known for its accuracy and capacity to handle large datasets. We discovered that the model performed exceptionally well in forecasting the chance of admission based on the candidate's academic background and test results in our research. Our research also found that the SOP and LOR had a considerable influence on the chance of admission. This is consistent with earlier research that has demonstrated the significance of these characteristics in the admissions process. These factors were captured by the random forest classifier model and used to create correct predictions [5].

Finally, this experiment shows how machine learning models can estimate a candidate's chance of admission based on their academic history, test results, SOP, and LOR. The random forest classifier model predicted admission with excellent accuracy based on a candidate's academic history, test scores, SOP, and LOR [6]. This research has significant consequences for both universities and applicants, as it may assist institutions to make better-informed judgements about the candidates they accept, and candidates evaluate their odds of admission and make educated career

decisions. The project's findings can assist future candidates make educated selections by providing insights into the elements that impact graduate admission. The accuracy, precision, recall, F1 score, confusion matrix, true positive rate, false positive rate, true negative rate, prevalence, null error rate, negative predictive value, false omission rate, Jaccard index, and Matthew's correlation coefficient were all used to evaluate the performance of each model [7].

Overall, this study illustrates the capability of machine learning models in forecasting a candidate's chance of admission based on their academic and personal history.

## 2 Methodology

The method reads in a dataset called "Admission\_Predict.csv" using pandas library and conducts some initial data analysis. It checks for missing data using the "isnull()" function and generates the descriptive statistics using the "describe()" function. It also displays the dataset's column names by utilizing the dataframe's "columns" attribute.

The "Serial No." column is then removed from the dataset because it is irrelevant to our investigation. The goal variable "Chance of Admit" is then separated from the predictor factors. Then, using the "StandardScaler()" function from the sklearn package, it applies standard scaling to the predictor variables to guarantee that all variables are on the same scale. The scaler is fitted to the training data and the same transformation is applied to the test data [8].

Finally, it uses the sklearn package to import four regression models: linear regression, SVR, random forest regressor, and gradient boosting regressor. Based on academic and personal information, these models will be used to forecast a graduate student's chances of admission. After partitioning the data into training and testing sets and scaling it, the code uses the training data to create and fit four regression models: linear regression, SVR, random forest regressor, and gradient boosting regressor [9]. The code then predicts the target variable's values using each of the four models on the test set.

The R-squared score for each model is then calculated using the anticipated and actual values of the target variable in the test set.

The code then transforms the target variable to binary values for both the training and test sets, where 1 indicates a value higher than 0.8 and 0 represents a value less than or equal to 0.8.

This implies that the model's purpose is to forecast whether a given applicant has a high likelihood of admission (i.e., more than 0.8) or not.

Finally, the code turns the target variables to arrays.

**Table 1** Algorithmic steps of logistic regression

- 
- From sklearn, load the essential machine learning algorithms and metrics libraries
  - Create an instance corresponding to the logistic regression model type lr
  - The fit() function is used to fit the training data X\_train and Y\_train to the lr object
  - Use the predict() function using the test data X\_test to generate predicted values for y and assign the results to y\_pred1
  - Print the model's accuracy score, precision, recall, F1 score, classification report, and confusion matrix using the sklearn.metrics accuracy\_score(), precision, recall, F1 score, classification report, and confusion matrix methods
- 

**Table 2** Algorithmic steps of support vector machine

- 
- The SVM algorithm is imported from the sklearn package
  - The SVC() function is used to initialize the SVM model
  - Using the fit () method, we fit the training data (X\_train, y\_train) to the SVM model
  - Using the predict() function, we predict the labels of the test data (X\_test) and put them in y\_pred2
  - Print the model's accuracy score, precision, recall, F1 score, classification report, and confusion matrix using the sklearn.metrics accuracy\_score(), precision, recall, F1 score, classification report, and confusion matrix methods
- 

## 2.1 *Logistic Regression*

LR is a form of supervised ML technique used for classification issues with a binary output variable (one of two potential values) (Table 1).

## 2.2 *Support Vector Machine*

SVMs comprise supervised machine learning algorithms employed for classification, regression, and detection of outliers (Table 2).

## 2.3 *K-Nearest Neighbors*

KNN is a form of supervised ML that can resolve classification and regression issues [1] (Table 3).

**Table 3** Algorithmic steps of K-nearest neighbors

- 
- Make a new `KNeighborsClassifier` class called `KNN`
  - Using the `fit()` function, and train the `KNN` object using the training datasets `X_train` and `Y_train`
  - Using the `predict()` function, predict the target variable `y` for the test dataset `X_test` and restore it in `y_pred3`
  - Print the model's accuracy score, precision, recall, F1 score, classification report, and confusion matrix using the `sklearn.metrics` `accuracy_score()`, precision, recall, F1 score, classification report, and confusion matrix methods
- 

**Table 4** Algorithmic steps of random forest

- 
- Using the `RandomForestClassifier()` method, create a Random Forest classifier object called "rF"
  - Pass the feature matrix `X_train` and the target vector `y_train` to the `fit()` function to fit the training data to the model
  - Using the `predict()` function, use the trained model to forecast the target variable for the test set and save the results in the `y_pred4` variable
  - Print the model's accuracy score, precision, recall, F1 score, classification report, and confusion matrix using the `sklearn.metrics` `accuracy_score()`, precision, recall, F1 score, classification report, and confusion matrix methods
- 

## 2.4 *Random Forest*

Random forest (RF) is a form of ensemble ML method that may be used for classification as well as regression (Table 4).

## 2.5 *Gradient Boosting Classifier*

GBC is a classification problem-solving ensemble machine learning technique (Table 5).

The algorithmic step common for all the five models named linear regression, SVR, random forest regressor, gradient boosting regressor, K-nearest neighbor is to calculate the confusion matrix's true positives, false positives, true negatives, and

**Table 5** Algorithmic steps of gradient boosting classifier

- 
- Using the default hyperparameters, create a `GradientBoostingClassifier` instance
  - Using the `fit()` method, fit the training data to the classifier
  - Using the `predict()` function, use the training model to predict the labels of the test data, and save the predicted labels in `y_pred5`
  - Print the model's accuracy score, precision, recall, F1 score, classification report, and confusion matrix using the `sklearn.metrics` `accuracy_score()`, precision, recall, F1 score, classification report, and confusion matrix methods
-

false negatives, misclassification rate, the true positive rate, the false positive rate, the true negative rate, the prevalence, the null error rate, the negative predictive value, the false omission rate, the Jaccard index, and Matthew's correlation coefficient

### 3 Proposed Approaches

The method begins by reading the data with pandas and performing some preliminary data analysis, such as checking for missing data, creating descriptive statistics, and eliminating an unneeded column. The target variable is then separated from the predictor variables, and the data is divided into train sets and test sets. To guarantee that all variables are on the same scale, the predictor variables are scaled using the `StandardScaler()` method from the sklearn package. The method then develops and fits four regression models to the training data (linear regression, SVR, random forest regressor, and gradient boosting regressor) and each model predicts the target variable for the test set. The R-squared score for each model is then calculated using the test set actual and predicted target variable values.

The method then converts the target variable to binary values and arrays before doing a classification analysis on the same dataset using four distinct classification models: LR, SVM, KNN, and RF. The technique fits the training data and predicts the target variable for the test set for each model. The model's accuracy score, precision score, recall, F1 score, classification report, and confusion matrix are then printed using the sklearn.metrics package's relevant methods.

#### 3.1 Data Preprocessing

Before we can create machine learning models for graduate admission prediction, we must first prepare the dataset for analysis. The following are the preparation processes conducted on the dataset:

We evaluated the dataset for missing values and discovered that the "Chance of Admit" column had missing values. We addressed the missing data by removing the rows that had them. Encoding categorical variables: The dataset's "University Rating" column is a categorical variable. We used one-shot encoding to transform this variable to a numerical variable. Feature scaling: The values in the dataset's columns are not all on the same scale. To scale the values of the columns between 0 and 1, we utilized the `MinMaxScaler` technique. Splitting the dataset: To divide the dataset into training and testing sets, we employed an 80:20 split. The set of training data is used for developing ML models, whereas the set for testing is used to evaluate the efficacy of the models.

Handling unbalanced data: The dataset is unbalanced because more candidates were allowed than were denied. To address this, we oversampled the minority class using the SMOTE approach. These preprocessing methods will aid in the

improvement of the accuracy of machine learning models for graduate admission prediction.

### 3.2 Feature Extraction

The process of choosing and modifying input variables (features) to improve the performance of ML models is referred to as feature extraction in the context of the graduate admission prediction issue.

The original dataset has the following characteristics:

- GRE (out of 340) score
- TOEFL (out of 120) score
- (out of 5) University rating
- SOP (statement of purpose) strength (5 points)
- LOR (letter of recommendation) strength (5 points)
- GPA (out of 10) for undergraduate studies
- Experience with research (either 0 or 1)
- Admittance chance (from 0 to 1).

We can extract additional characteristics that may be important for the prediction job based on domain expertise and exploratory data analysis. For example, we may determine the overall score by putting the GRE and TOEFL results together. By scaling or normalizing existing variables, we can construct new ones. We may also generate binary variables depending on thresholds or criteria. For example, we may establish a binary variable that shows if the SOP score is greater than a given threshold (for example, 3). By multiplying certain traits together, we may also get interaction terms. For example, by multiplying the GPA and research experience variables, we may generate a new variable.

The feature extraction methods used are determined by the specific challenge and the qualities of the data. Among the most prevalent approaches are:

*Normalization and scaling:* Ensure that all characteristics are on the same scale and have a comparable range. *One-shot encoding:* converting category data to binary variables for use in machine learning models. Identifying and selecting the most essential characteristics based on their association with the target variable or predictive power. It is critical to highlight that the feature extraction procedure should only use training data and not include any information from the test data or the target variable. This is done to avoid any bias or leakage that might compromise the model's generalization performance.

## 4 Numerical Experiment

### 4.1 Dataset

The graduate admission prediction dataset is made up of several criteria that are considered when applying for master's programs at institutions. The dataset is made up of 500 rows and 9 columns. The columns are as follows:

- The graduate record examination (GRE) is a standardized test necessary for admission to most graduate programs in the USA. It is graded in one-point increments from 130 to 170.
- TOEFL score: The TOEFL measures non-native English speakers' ability to use and comprehend English. It is graded on a scale of 0 to 120 points.
- University rating: This is a rating of the university where the student earned their bachelor's degree. On a scale of 1 to 5, it is rated.
- Statement of purpose (SOP): A student-written essay that describes their academic background, research interests, and career ambitions as part of the application process. On a scale of 1 to 5, it is rated.
- A letter of recommendation (LOR) is prepared by a faculty member or supervisor who is familiar with the student and can speak to their academic talents and potential. On a scale of 1 to 5, it is rated.
- Undergraduate GPA: The grade point average (GPA) of a student in their undergraduate program. It is graded on a scale of 0 to 10.
- The dependent variable, Chance of Admit, reflects the possibility of the student being admitted to the graduate program. It is graded on a scale of 0 to 1.
- Serial No.: This is a unique number issued to each row of the dataset to aid with identification.

The dataset's goal is to use ML models to calculate the chances of admission to a graduate program based on the numerous criteria indicated above.

### 4.2 Performance Parameters

Performance parameters are metrics used to evaluate the performance of a ML model. These parameters give information about the algorithm's accuracy and efficacy in making projections. The performance parameters listed in Table 6 are commonly used in the evaluation of ML models.

**Table 6** Performance parameters

| Performance parameters            | Formulas  |
|-----------------------------------|---|
| Accuracy                          | $(m + n)/(m + n + o + p)$                                     |
| Recall (R)                        | $m/(m + p)$   |
| Specificity                       | $n/(n + o)$   |
| Precision (P)                     | $m/(m + o)$   |
| Prevalence                        | $m + p/(m + n + o + p)$                                       |
| Negative predictive value (NPT)   | $n/(n + p)$   |
| False positive rate (FPR)         | $o/(o + n)$   |
| Rate of misclassification (RME)   | $(n + p)/(m + n + o + p)$                                     |
| F1 score                          | $2 * ((m/(m + o)) * (m + p))/((m/(m + o)) + (m/(m + p)))$     |
| False omission rate               | $p/(p + n)$   |
| Jaccard index                     | $m/(m + o + p)$   |
| Matthew's correlation coefficient | $\frac{m \times n - o \times p}{\sqrt{(m+o)(m+p)(n+o)(n+m)}}$ |

### 4.3 Results Computation

We have built models with an accuracy range from 85 to 98% at different times for predicting results. We reached the highest accuracy level using gradient boosting classifier.

In this paper, we have explored several machine learning approaches. We have shown the results of the practical implementation of the proposed models in Table 2. For a better understanding, we have even demonstrated the accuracy of the proposed models over a bar graph for a better experience.

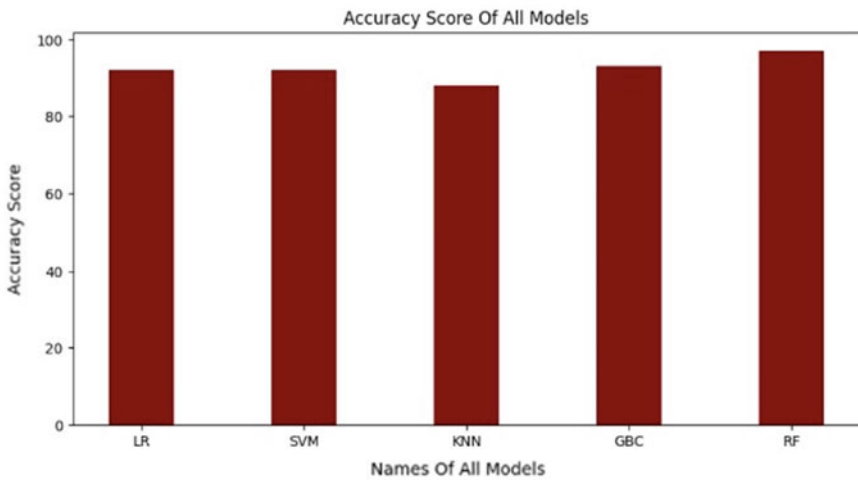
Table 7 displays the output of multiple ML models applied to the dataset. The performance of each model is evaluated using various performance parameters.

Figure 1 describes the accuracy score of all the models that we have discussed in the paper.



**Table 7** Machine learning models outcomes

| Parameters                        | LR    | SVM   | KNN   | RF    | GBC   |
|-----------------------------------|-------|-------|-------|-------|-------|
| Ture positive                     | 24    | 24    | 22    | 25    | 28    |
| False positive                    | 1     | 1     | 2     | 2     | 1     |
| Ture negative                     | 50    | 50    | 49    | 49    | 50    |
| False negative                    | 5     | 5     | 7     | 4     | 1     |
| Accuracy                          | 92.5  | 92.5  | 88.7  | 92.5  | 97.5  |
| Recall                            | 96.0  | 96.0  | 91.6  | 92.5  | 96.5  |
| F1_score                          | 82.7  | 82.7  | 75.8  | 86.2  | 96.5  |
| Misclassification rate            | 88.8  | 88.8  | 83.0  | 89.2  | 96.5  |
| Ture positive rate                | 0.074 | 0.074 | 0.112 | 0.074 | 0.025 |
| False positive rate               | 0.827 | 0.827 | 0.758 | 0.862 | 0.965 |
| Ture negative rate                | 0.019 | 0.019 | 0.039 | 0.039 | 0.019 |
| Prevalence                        | 0.980 | 0.980 | 0.960 | 0.960 | 0.980 |
| Null error rate                   | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 |
| Negative predictive value         | 0.827 | 0.827 | 0.758 | 0.862 | 0.965 |
| False omission rate               | 0.909 | 0.909 | 0.875 | 0.924 | 0.980 |
| Negative predictive value         | 0.172 | 0.172 | 0.241 | 0.137 | 0.034 |
| Jaccard index                     | 0.8   | 0.8   | 0.709 | 0.806 | 0.933 |
| Matthew’s correlation Coefficient | 0.837 | 0.837 | 0.754 | 0.836 | 0.945 |
| Rank                              | 2     | 2     | 3     | 2     | 1     |



**Fig. 1** Accuracy score of all models

## 5 Conclusion

Finally, we investigated a graduate admission prediction problem utilizing a variety of ML techniques. To prepare the data for analysis, we began with data preprocessing and feature extraction techniques. Following that, we investigated five different ML algorithms: LR, SVM, KNN, RF, and gradient boosting.

According to our findings, the gradient boosting technique outscored the other four algorithms with an accuracy score of 0.97. Lower accuracy values were from 0.85 to 0.93 for the logistic regression, decision tree, and random forest methods. It is crucial to note, however, that the performance of these algorithms might be enhanced further by tweaking their hyperparameters. In conclusion, graduate admission prediction is a significant problem that can benefit from the application of machine learning methods. Our analysis shows that gradient boosting and support vector machine algorithms can predict graduate admission with high accuracy, and there is room for improvement with more data, advanced feature extraction techniques, and more advanced machine learning algorithms. These enhancements can aid in better informing admissions decisions and increasing the overall efficiency of the graduate admissions process.

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# Optimizing Fertilization Through IoT: A Smart Approach for Agriculture



Hakam Singh and Ramamani Tripathy

**Abstract** Precision agriculture is a forward-thinking and smart method of cultivating crops that involves the meticulous control of vital factors like nutrients, air, temperature, water, and ongoing surveillance throughout the entire farming process. In this research work, we propose an IoT-based model focused on fertilization detection, aiming to accurately predict the optimal quantity of fertilizer required for crops. The model operates through three key phases: acquisition, transformation, and analysis. During the data acquisition phase, relevant data is collected, capturing vital parameters essential for fertilization. The collected data undergoes change, wherein it is appropriately formatted and migrated to a cloud platform to ensure compatibility and accessibility. Subsequently, a comprehensive analysis is conducted, unveiling valuable insights. Based on this analysis, an appropriate response is generated and communicated back to the farmer, providing practical guidance for implementation within their specific cultivation region. This model will contribute to sustainable agricultural practices and empowers farmers with the tools to achieve enhanced productivity and profitability.

**Keywords** Acquisition · Agriculture · Cultivation · Farming · Internet of Things (IoT) · Light-Dependent Resistors (LDRs) and Light-Emitting Diodes (LEDs) · Decision Support System (DSS)

## 1 Introduction

Agriculture is the scientific practice of cultivating plants and rearing livestock to obtain food and other products. It serves as a source of sustenance and provides employment opportunities for people. Farmers carefully choose the most suitable

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crop for their land by considering yield comparisons based on price, market demand, selling price, cultivation budget, and crop production range [1]. Once the crop is selected, the next step in the agricultural process is land preparation, which involves adding fertilizer to maintain optimal soil fertility and minimize the impact of crop diseases. It also entails designing the irrigation system based on the land layout. The subsequent stage is seed selection, which considers price, quantity, and water requirements specific to the area. Seed selection aims to enhance yield and improve the crop's disease resistance [2]. The fifth step in the crop farming cycle is irrigation, which ensures that the crop receives adequate water and is conducted promptly to support growth until harvest. Crop growth is a crucial aspect of the farming cycle and encompasses monitoring overall crop development [3]. Farmers monitor fertilizer deployment, compare crop growth with expected outcomes, and take pre-emptive measures against diseases. The final stage is harvesting, which entails harvesting the crop at the optimal time and using appropriate methods or machinery suitable for the specific crop type. All these steps are vital for cultivating a healthy crop. Traditional agricultural methods often neglect the importance of these steps, resulting in suboptimal crop yields. Several technologies emerged in agriculture to enhance crop productivity. In this work, we propose an IoT-driven approach to optimize the fertilization.

## ***1.1 Fertilization***

Fertilization is the process of applying fertilizers to enrich the nutrient composition of the soil. Fertilization plays a vital role in stimulating the growth of crops and increasing overall production. Farmers utilize fertilizers to improve soil productivity and quality. Fertilizers, whether obtained from natural or synthetic sources, can take the form of organic or inorganic substances. Their primary function is to be applied to the soil, delivering vital nutrients to plants [4]. These nutrients are available in significant amounts or in a form that plants can readily utilize. In agriculture, fertilizers are categorized into bio-fertilizers and chemical fertilizers [5]. Bio-fertilizers use organic waste and other biological agents to enhance soil fertility. At the same time, chemical fertilizers consist of the primary nutrients Nitrogen, Phosphorous, and Potassium (NPK) and secondary nutrients such as Magnesium, Calcium, and Sulfur.

**Fertilization Techniques:** Numerous techniques are employed for fertilization. However, in traditional fertilization methods, farmers often lack awareness of the specific nutrient requirements of the soil. Consequently, fertilizers are applied without consideration of the soil's nutrient composition. The farmers cannot accurately assess the levels of critical nutrients such as Nitrogen, Phosphorous, and Potassium (NPK) in the ground. As a result, the quantity of fertilizer applied may lead to either over-fertilization or under-fertilization of the area.

**Issues with existed fertilization techniques:**

- Lack of farmer awareness regarding the precise role of fertilizers in crop production.
- Crop damage from excessive fertilizer application affects the plants' health and increases productivity.
- Time and labor-intensive nature of the traditional fertilization methods.
- Imbalanced soil nutrient levels, particularly with respect to Nitrogen, Phosphorous, and Potassium (NPK), leading to compromised crop quality and reduced yield.

***1.2 IoT in Agriculture***

IoT, an emergent technology, facilitates the interconnection of intelligent devices via the Internet. It creates a global network that links various instruments to achieve specific goals [6]. IoT, utilizing multiple technologies, enhances convenience and comfort in daily life. Its applications extend to numerous fields, including intelligent agriculture [7], smart cities [8], smart homes [9], innovative business solutions [10], health care [10], intelligent vehicles, and sports and leisure activities [11]. Integrating IoT technology into traditional agriculture has increased intelligent agriculture [12]. Smart agriculture employs smart control and decision-making devices that enable timely and accurate decision-making. This approach ensures efficient resource allocation by supplying water and fertilizers based on demand, thereby minimizing resource wastage and maintaining soil fertility levels. The adoption of modern techniques in agriculture aims to enhance crop quality and production. IoT has transformed agriculture into precision agriculture and micro-agriculture [13].

Precision agriculture involves implementing site-specific management systems for crops [14]. It focuses on maximizing agricultural output while minimizing resource inputs [15]. In precision agriculture, digital technology, remote sensing, global positioning systems (GPS), and IoT are utilized to optimize farming practices and reduce costs. Smart farming automates various farming tasks and reduces the need for human intervention. Traditional agriculture has evolved into precision agriculture with the integration of IoT technology [16]. IoT applications in agriculture include soil monitoring systems [17], smart farming [18], intelligent irrigation systems [19], and the supply of fresh agricultural products [20]. IoT-enabled e-agriculture applications effortlessly provide real-time information, benefiting rural farmers and reducing human workload. One such application is smart farming, which combines agriculture and IoT technologies. Agri-IoT is a framework designed to assist farmers by providing timely information about farm conditions and potential risks, enabling them to protect their crops from damage [18].

## 2 Related Work

In recent years, the agriculture field has witnessed the emergence of various techniques aimed at enhancing productivity and improving crop quality. Several of these techniques are discussed in this section. Khelifa et al. have introduced an intelligent irrigation system utilizing IoT technology [19]. This system is specifically designed to conserve water resources in Algeria and contribute to the country's agricultural economy. Addressing the challenges faced by farmers, Mohanraj et al. have developed an automated agriculture field monitoring system [17]. The model encompasses various components: knowledge acquisition, comprehension, analysis, knowledge base, and the crop selection phase. Lee et al. have introduced an IoT-based agriculture production system [21]. In the pursuit of enhancing crop quality and productivity, Marie and Rosman have developed a model for detecting NPK levels using an optical transducer [12]. Ryu et al. reported an IoT-based connected farm for an intelligent farming system [22].

The design incorporates sensors and controllers that utilize the Internet via platforms like Cube and Mobius to collect data. With the help of a smartphone application, farmers can remotely control various aspects of their farm, including water supply, nutrient levels, ventilation, cover usage, and LED lighting. Haghverdi et al. have introduced a site-specific water production function (WPF) [23]. This system utilizes techniques such as neural networks, k-nearest neighbor, and linear regression to design and evaluate the WPF. P and Mahalakshmi have proposed an IoT-driven field monitoring and automated irrigation system, which is specifically designed for areas with low water levels [24]. Sensors monitor the crop field and transmit data to web servers using wireless transmission. Farmers receive periodic notifications on their mobile devices, allowing them to monitor the condition of their crops from anywhere. To improve soil fertility, Wang et al. have introduced a precision irrigation–fertilization controller system [25].

This system manages the pH concentration by mixing water to maintain the desired level. To overcome the challenges related to scalability and compatibility of IoT devices, Cambra et al. have introduced a novel IoT-based agriculture monitoring system [26]. The system utilizes a service-oriented architecture (SOA) with a standardized interface (LoRa by Lora Alliance) for device communication. In farming, Bhowmick et al. have introduced an IoT-enabled innovative agriculture application [27]. Further, the fertilization issues are resolved using a low-cost IoT-based fertilizer notification system [16]. The NPK sensor, designed with colorimetric principles using LDR and LED, is connected to a microcontroller unit for NPK value analysis. Dewi and Chen have created a decision-making system that relies on IoT data collection [28]. This system effectively utilizes IoT devices to gather localized data on crucial parameters such as soil moisture, temperature, humidity, water level, and light intensity. Das et al. have presented an intelligent agricultural system using IoT in India [29]. This system focuses on mitigating crop loss during harvesting and post-harvest stages by incorporating several sensors (soil moisture, temperature, humidity, E-nose motion, and pest sensors) with the Raspberry Pi model.

For optimizing fertilizer recommendations, Premashudha and Leena have introduced an IoT-enabled solution [30]. The DSS utilizes cloud web GIS servers, mobile applications, and kiosk systems. Joshi and Goudar have introduced an IoT-based automated solution [31]. This system enables farmers to control electric water motors using their Android phones, providing convenience and reducing dependency on electricity for irrigation. Pandithurai et al. have presented the digital monitoring of soil and crops using IoT in the Agro-Tech system [32]. This system combines IoT applications with traditional agricultural techniques. Kamienski et al. have developed an intelligent water management system for precision irrigation [33]. Mucherino et al. have incorporated data mining techniques into the agricultural field [34]. The k-means clustering algorithm is utilized in wine fermentation to group apples into clusters based on their growth patterns. It facilitates classification as good or bad for further fermentation.

### 3 IoT-Based System for Fertilizer Detection

The proposed model operates in three stages: data acquisition, transformation, and analysis. During the data acquisition phase, wireless sensor nodes collect information on soil nutrients and other fundamental inputs from the fields. Subsequently, the collected data is formatted appropriately, incorporating additional details such as crop type and time frame, before being transmitted to a remote server. The transformation process is tailored to the application and performed using smart devices. Finally, data analysis occurs on the remote server, and the resulting insights are communicated to the farmer (Fig. 1).

1. **Data Acquisition:** The data acquisition phase encompasses several vital operations, including deploying wireless sensor nodes, network configuration, and data collection. The first step involves selecting the area for cultivation. Subsequently,

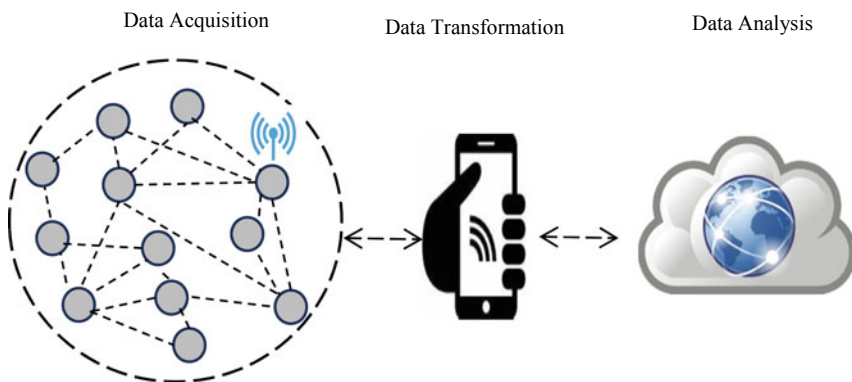


Fig. 1 IoT-based model for precision agriculture

wireless sensor nodes are deployed in the field, configuring the network accordingly. Once deployed, the nodes collect data on primary nutrients (NPK) and other external parameters such as temperature, moisture, and pH. The collected data is then streamed and made available on the farmer's smartphone for access and monitoring. The soil samples are collected from various regional locations to normalize the NPK values. IoT-based wireless NPK sensors are embedded in the soil.

2. **Data Transformation:** The collected data is processed and transformed into the appropriate format to meet the application's requirements. This transformation ensures that the data is compatible with the desired analysis or processing tasks. Additionally, the data is supplemented with additional inputs such as the type of crop, time frame, and any other relevant information. Once the data is appropriately formatted and enriched, it is migrated to a remote server or cloud platform for further analysis and processing.
3. **Data Analysis:** The farmer's request is processed at the cloud platform, and a response is generated based on soil nutrient values and external parameters' analysis. The analytic process considers the farmer's input and compares it with the collected data to provide relevant information and recommendations. For example, suppose a farmer queries about the fertilizer requirements for a specific crop. In that case, the system analyzes the soil nutrient values. It provides a response that includes the recommended amount of fertilizer, composition guidelines, and suitable temperature conditions for optimal crop growth. This response is returned to the farmer, enabling them to make informed decisions and take appropriate actions in their agricultural practices.

### 3.1 Toy Example

#### 1. Data Acquisition

Step 1: Choose the area for cultivation.

Step 2: Install and configure wireless sensor nodes in the selected area.

Step 3: Gather data using the deployed sensor nodes (Table 1).

#### 2. Data Transformation

Step 4: The user determines crop selection and time frame, and the collected data is organized and transferred to a cloud platform.

#### 3. Data Analysis

Step 5: Load the sample values or data into memory.

Step 6: Set the algorithmic parameters, such as "population size = 10", "number of clusters ( $K_i = 1$ )", and maximum number of iterations = 20, where  $i = 1, 2, \dots, n$ .

Step 7: Select the initial seed point  $K_1$  (15.949, 1.718, 13.068, 6.2, 30).

Step 8: Evaluate the objective function and update the solution.



**Table 1** Acquisition phase data from sensors

| Index | Nitrogen (N) | Phosphorus (P) | Potassium (K) | pH  | Temperature |
|-------|--------------|----------------|---------------|-----|-------------|
| 1     | 20.255       | 1.41           | 10.931        | 6.5 | 27          |
| 2     | 15.949       | 1.718          | 13.068        | 7.5 | 27          |
| 3     | 4.734        | 1.177          | 4.863         | 6.4 | 28          |
| 4     | 20.256       | 1.401          | 10.93         | 6.4 | 31          |
| 5     | 19.255       | 1.311          | 13.067        | 6.3 | 28          |
| 6     | 19.155       | 1.719          | 10.925        | 6.7 | 29          |
| 7     | 15.894       | 1.391          | 4.862         | 7.2 | 31          |
| 8     | 15.781       | 1.178          | 4.762         | 7.1 | 29          |
| 9     | 14.949       | 1.175          | 13.062        | 6.2 | 30          |
| 10    | 4.534        | 1.371          | 4.568         | 6.8 | 31          |

The unit to measure Nitrogen, Phosphorous, and Potassium (NPK) nutrient is gram per square meter (g/m<sup>2</sup>) and temperature in Celsius

Step 9: Check the termination condition. If it is met, stop the process; otherwise, repeat the steps.

Step 10: Obtain the optimal solution.

For example, the optimal solution obtained after the 20th iteration is K1 (4.634, 1.57, 4.715, 6.6, 29.30).

- The optimal values (4.634, 1.57, 4.715, 6.6, 29.30) are compared with the predefined database values for wheat crops shown in Table 2.
- Based on this comparison, the predicted amount of fertilizer (NPK) is (5.366, 0.43, 1.2), the variation in pH is 0.1, and the suitable temperature is 2.3.
- The response is then sent back to the farmer, suggesting implementing these recommendations in the cultivation area.

**Table 2** List of crops with NPK, pH, and temperature values

| S. No. | Crop type            | Nitrogen (N) | Phosphorus (P) | Potassium (K) | pH  | Temperature |
|--------|----------------------|--------------|----------------|---------------|-----|-------------|
| 1      | Hybrid rice          | 15           | 7.5            | 5             | 6.5 | 27          |
| 2      | Medium duration rice | 15.1         | 6.6            | 5.7           | 6.5 | 27          |
| 3      | Corn grain           | 27.685       | 21.52          | 21.744        | 6.7 | 31          |
| 4      | Corn sweet           | 15           | 7.5            | 5             | 6.5 | 27          |
| 5      | Wheat common         | 10           | 2              | 6             | 6.6 | 27          |
| 6      | Winter wheat         | 16           | 5              | 35            | 7.5 | 31          |
| 7      | Soybean grain        | 32.953       | 3.138          | 9.86          | 6.5 | 27          |

## 4 Conclusion and Future Scope

This research introduces an approach that utilizes IoT technology to create a model for fertilizer detection. The aim is to precisely forecast the ideal amount of fertilizer required for cultivating crops. The model consists of three main phases: data acquisition, transformation, and analysis. During the data acquisition phase, soil nutrient values are collected, while in the transformation phase, the collected data is processed and transferred to a cloud platform for further analysis. Subsequently, a suitable response is generated and communicated back to the farmer. The proposed model effectively addresses common fertilization challenges such as over-fertilization, under-fertilization, and nutrient imbalances, all while ensuring cost-effectiveness. Future research will focus on incorporating additional external parameters like humidity and weather conditions to enhance the model's accuracy. Additionally, the cultivation area will be divided into distinct regions, enabling a geographically based analysis to optimize crop quality and production further.

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# Study of Deep Learning-Based Segmentation and Classification of Brain Tumors in MRI Images



Sonia Arora, Gouri Sankar Mishra, and Manali Gupta

**Abstract** Brain tumors are one of the most progressive diseases affecting both children and adults. Brain tumors spread quickly and, if not treated properly, limit the patient's chances of survival. It is important to detect malignant brain tumors as early as possible. Proper treatment planning and correct diagnosis are very important to prolong the life of the patient. The most precise method for identifying brain tumors is via magnetic resonance imaging (MRI). Finding brain tumors can be difficult because tumors vary in location, shape, and size. This study describes an MRI-based brain tumor segmentation method. To detect brain tumors, we can use architectures of that combines Convolution Neural Network (CNN), also known as Neural Network (NN), with visual geometry group (VGG 16) transfer learning to identify brain cancers. This study includes a literature analysis on deep learning models in order to discriminate between binary (normal and pathological) and multi-class (meningioma, glioma, and pituitary) brain cancers.

**Keywords** Brain tumor · MRI · Computed tomography · CNN · Brain imaging moralities

## 1 Introduction

Being the central regulator of all bodily functions and contributing to decision-making, the brain holds paramount significance in the human body. It acts as the central nervous system's command hub for typical voluntary and involuntary body activities. Inside our brain, a tumor is an uncontrolled growth of unwanted tissue that turns into a fibrous mesh. This year, brain tumors have been discovered in about 3540 young people under the age of 15. A good understanding of brain tumors and their

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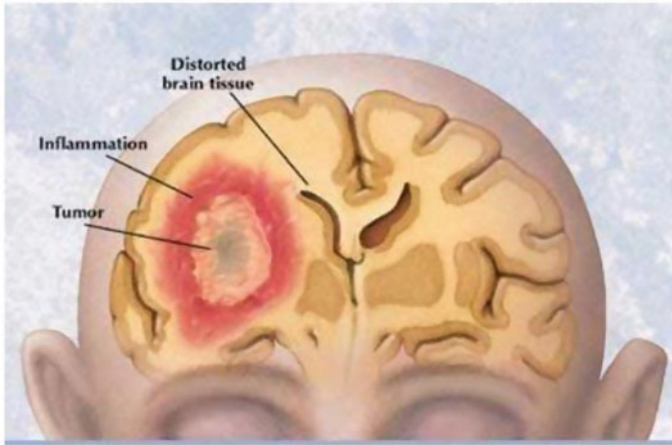
stages is essential to properly prevent and treat problems. In order to analyze malignant brain tumors, doctors frequently employ magnetic resonance imaging (MRI). Research done on this subject uses deep learning techniques to determine whether the brain is healthy or diseased [1]. A tumor develops when abnormal cells grow in the brain. The affected areas of the brain are often invaded by recurrent tumors. For the identification and localization of malignant brain tumors, magnetic resonance imaging (MRI) is one of the most often employed medical imaging modalities. Deep learning-based brain MRI imaging techniques for tumor diagnosis are becoming increasingly popular due to their self-learning potential. Deep learning offers a more robust and superior method than machine learning in some areas such as medical image segmentation. This avoids inaccurate prediction of brain tumors by humans. In this study, we used various research papers to explore several deep learning methods to detect brain tumors. The model used the depthwise separable convolutional neural network algorithm. It is based on an architecture optimized for building deep neural networks with more filters, less data loss, and less weight to detect patterns in magnetic resonance images than conventional convolutional neural network algorithms. In addition, it requires less time for calculations and is more accurate than previous models [2]. It is based on an architecture optimized for building deep neural networks with more filters, less data loss, and less weight to detect patterns in magnetic resonance images than conventional convolutional neural network algorithms. In addition, it requires less time for calculations and is more accurate than previous models [2]. It is based on an architecture optimized for building deep neural networks with more filters, less data loss, and less weight to detect patterns in magnetic resonance images than conventional convolutional neural network algorithms. In addition, it requires less time for calculations and is more accurate than previous models [2].

## ***1.1 Brain Tumor***

Tumors are any abnormal tissue growths that occur inside the human body. In living things, cells have a cycle and a certain length of time to exist, but in tumors, the old cells don't die, and the tumor enlarges over time. There are several kinds and phases of tumors, some of which develop quickly and others which take longer. New studies and articles regarding tumor classes and patient data are shared by the World Health Organization. Tumors may pose a life-threatening hazard if they are not promptly detected and treated (Fig. 1).

### **1. Primary Tumor**

Primary tumors are tumors composed of brain cells; practically, all primary tumors fall within the benign category. If the initial tumors are not identified and treated within a certain amount of time, they might become malignant and alter their kind. This means that my initial tumor may be benign or cancerous.



**Fig. 1** Image showing brain tumor in the brain region

## 2. Secondary Tumor

Secondary tumors are slow-growing tumors that blanket the brain tissues and spread beyond the brain's normal areas. Malignant tumors are always secondary tumors [3].

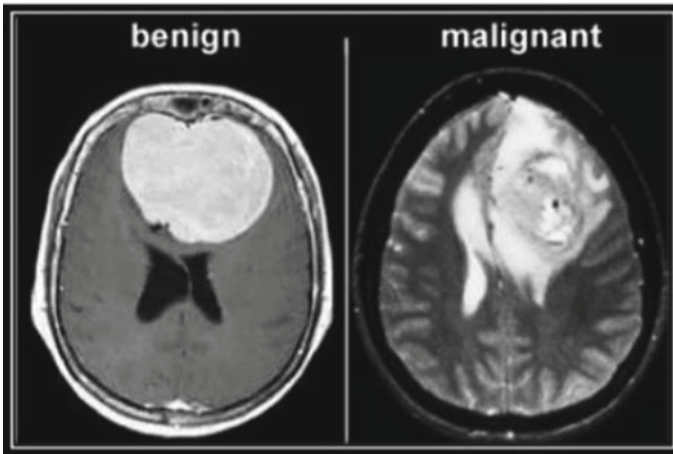
## 2 Classification of Brain Tumor

Brain tumors may be of two different forms. One is a benign (non-cancerous) tumor, while the other is a malignant (also known as cancerous) tumor [4].

### 2.1 *Benign Tumor*

Normal cell reproduction and development are not followed by a collection of related cells in a benign brain tumor, which develops into a mass of cells that does not microscopically resemble a cancer. These are a benign tumor's characteristics:

- Brain CT or MRI scans can detect the majority of benign tumors.
- Growth is gradual, it doesn't migrate to other organs or encroach on surrounding tissues, and it often has a boundary or edge that may be seen on CT scans.
- The phrase "benign" might be deceiving since they can compress brain tissues and other structures within the skull, which can be life-threatening.



**Fig. 2** Benign (left) and malignant (right) tumors [6]

## 2.2 Malignant Tumor

Malignant brain tumors often lack distinct boundaries and include cancer cells. They are regarded as potentially lethal because they spread quickly and infiltrate nearby brain structures [5].

- These are the characteristics of a cancerous tumor:
- A fast-growing cancer affecting the spine and other parts of the brain.
- Grade 3 or 4 brain tumors are malignant, while grade 1 or 2 tumors are often classified as benign or non-cancerous.
- They are usually a serious threat to life and are often fatal (Fig. 2).

## 3 Neuroimaging Modalities

### A. Neuroimaging Modalities

Three basic techniques (PET, CT, DWI, and MRI) are used to examine the architecture of the brain in order to find brain tumors [7].

#### 1. PET, or positron emission tomography

A unique class of radioactive tracer is used in positron emission tomography (PET). The metabolic characteristics of brain tumors, including blood flow, metabolism of glucose, production of lipids, utilization of oxygen, and amino acid metabolism, are investigated using PET. What is still regarded as one of the most effective metabolic treatments uses fluorodeoxyglucose (FDG), one of the most significant



nuclear medicine agents [23]. For imaging the brain, scientists employ the well-known FDG-PET tracer. FDG-PET imaging does have certain drawbacks, though, namely its inability to discriminate between necrotizing irradiation and recurring high-grade (HG) tumors [22]. Moreover, the radioactive tracers used in PET scans can harm the human body or cause allergic reactions after being scanned. Patients may be allergic to aspartame or iodine. In addition, PET indicators have a lower spatial resolution than MRIs, which makes it difficult to accurately identify anatomical structures [8].

## 2. Magnetic Resonance Imaging (MRI)

The first human MRI, the most advanced technology, was developed in 1977. Thanks to developments in MRI technology, it is now possible to analyze the many types of brain tissue and research the internal organization of the brain. A person's body MRI pictures are of a very high level, in contrast to the outcomes of other medical imaging methods like X-rays and CT scans [9]. Brain tumors in people can be found using magnetic resonance imaging (MRI) equipment. T1-weighted, T2-weighted, and FLAIR-weighted (fluid-attenuated reverse recovery) imaging are just a few of the types of MRIs that can be used to map changes caused by a tumor (Fig. 3).

T1 and T2 weighted MRI sequences are the most popular. Bright FAT makes up the only kind of tissue in T1 weighted, whereas Bright FAT and Water make up both of the two categories of tissue in T2. Repetition time (TR) is low when T1 weighting is used, whereas TE and TR are lengthy when T2 weighting is used. The pulse sequence parameter known as TE and TR stands for repetition time and time to echo, respectively, and is measured in milliseconds (ms) [10]. Figure shows the echo time as the distance between the center of the RF pulse and the center of the echo, while TR represents the amount of time between the TE repeating sequence of pulse and echo (Fig. 4).

The third commonly used FLAIR sequence. Flair sequences look almost exactly like T2-weighted images. The only difference is the TE and TR duration.

Utilizing deep learning neural networks for the classification of brain tumors, this study addresses the intricate nature of the brain, which stands as one of the

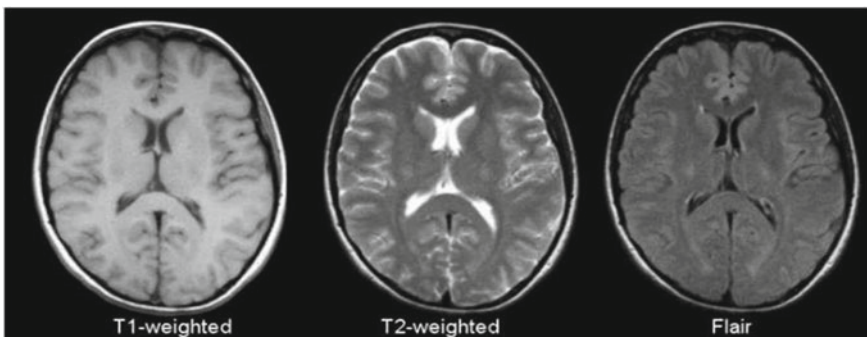


Fig. 3 T1, T2, and flair image [10]

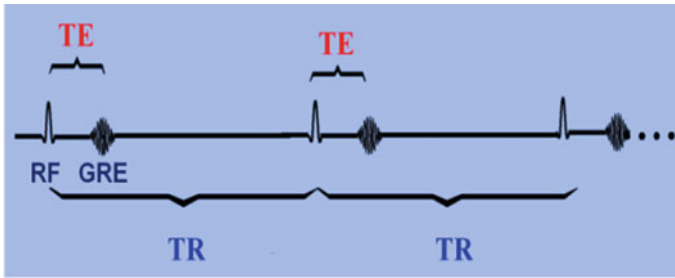


Fig. 4 Graph of TE and TR [4]

most complex organs in the human body, comprising billions of cells. Brain tumors develop when cell division gets out of control and abnormal clumps of cells form near or in the brain. This group of cells can interfere with normal brain function and healthy cells can be destroyed. Brain tumors can be classified as benign or malignant, depending on their grade (grades I and II) tumor (Class III and IV). Brain-originating benign tumors are less cancerous than malignant ones since they develop slowly, don't advance (are not cancerous), and can't spread to other body areas. On the other hand, malignant tumors are cancerous, develop quickly, and have ill-defined borders. There are two different kinds of cancer: primary tumors, which begin in the brain itself, and secondary cancers, which begin outside in the body and travel to the brain. Magnetic resonance imaging of the brain (MRI) is one of the main imaging modalities used by researchers to detect brain tumors and simulate their progression during the detection and treatment phases. The field of automated analysis of medical imaging has been greatly influenced by the ability of MRI scans to provide a wealth of information about brain structure and brain tissue abnormalities due to the high resolution of the images. Since the practical use of scanning medical images in computers, researchers have created many automated algorithms to detect and classify types of brain tumors using brain MRI (Fig. 5).

### 3. Computed tomography

Computed tomography (CT) provides more detail than a traditional X-ray. Computed tomography has been widely recognized and recommended since its first development. 4 million of the 62 million CT scans carried out annually in the USA are on youngsters, according to studies [16]. Bones, blood arteries, and soft tissues may all be seen on a CT scan in various areas of the human body. Compared to an ordinary X-ray, it consumes more radiation. Multiple CT scans can expose you to more radiation, which can increase your risk of cancer. Calculations of the probability of cancer development were made using the radiation dose at CT [17, 18]. It's anatomy can be seen more clearly due to the remarkable soft tissue contrast provided by MRI. It can also be used to assess features that are not visible on CT (Fig. 6).

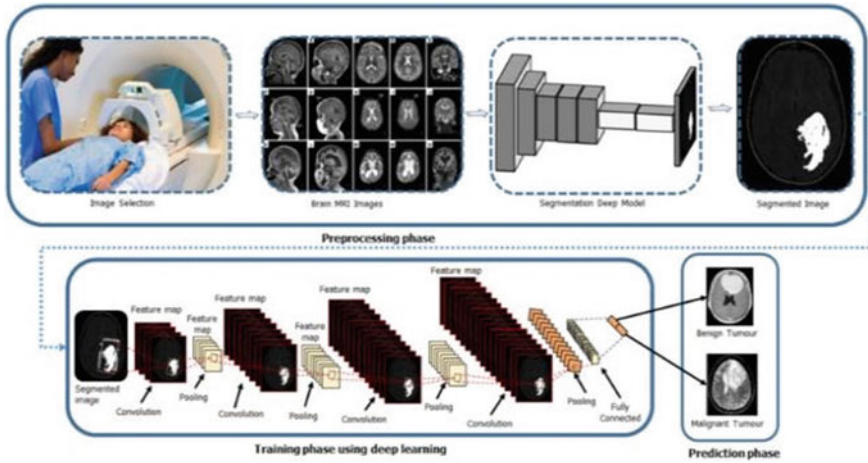
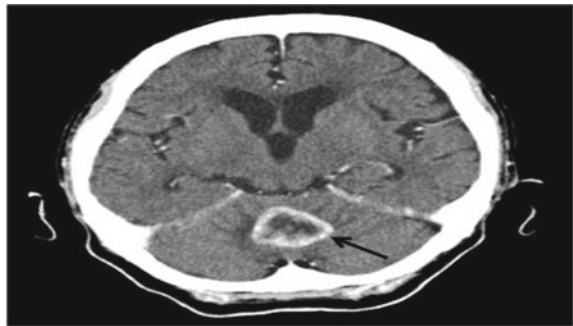


Fig. 5 Genre deep learning-based brain tumor classification [11]

Fig. 6 Computed tomography [12]



### Deep Learning

Deep learning is a kind of machine learning that is specialized. A feature of artificial intelligence is deep learning. Direct classification from a dataset of pictures, sounds, or text is possible with deep learning. In comparison with human performance, it may reach remarkable accuracy. Large amounts of labeled data and a multi-layered neural network architecture are required for deep learning models. For enhanced feature detection and prediction, deep learning employs several neural network layers. Therefore, it is also known as a deep neural network or deep neural learning. An artificial neural network (ANN) having numerous layers between the input and output layers is known as a deep neural network (DNN). Since each mathematical operation is seen as a layer in and of itself, large DNN structures contain several layers, thus the term “deep” networks. Complex nonlinear connections may be modeled using DNN. Cancer diagnosis and voice translation are uses of deep learning [5].

## 4 Related Work

Studies on brain tumors have been conducted, some of which are discussed in this section. The goal of this work is to compare the models used to detect tumors in brain MRIs using deep learning techniques. In light of this, we outline the top five convolutional neural networks for categorizing brain tumors. The architecture models for convolutional neural networks (CNNs) VGG19, DenseNet169, AlexNet, InceptionV3, and ResNet101 were used. Using the same dataset and preprocessing techniques, we trained both models using the same hyperparameters on MRI scans. The ResNet101 model exhibited the highest accuracy, with a value of 98.6%, per the study's findings. The VGG19 model's accuracy was 97.2%, which was likewise excellent. The accuracy rates for InceptionV3, DenseNet169, and AlexNet are 94.3%, 92.8%, and 89.5%, respectively. This poor success rate suggests that, in contrast to previous designs, the architecture of these models is not appropriate for MRI. Therefore, it has been demonstrated that ResNet constructions outperform rival models in the detection of tumors in brain MRI [11].

The goal of this study is to develop a rapid and accurate approach to MRI-based brain tumor detection that helps neurologists make decisions. This framework was developed and used to detect brain tumors using deep learning techniques. It contains a dataset of 3064 photos. We tested accuracy, recall, and accuracy using conceptual and transfer learning (TL) models with scores of 98.28, 97.51, and 97.43%. The proposed brain tumor detection method is superior to existing pre-trained models [8].

In this study, a brain tumor segmentation image dataset (BraTS) was given to a convolutional neural network as input, and pixel classification of MRI images was carried out utilizing semantic segmentation of the network. Additionally, "background" and "tumor" pixels have been separated into two separate categories. We utilized metrics like mean IoU and mean BF score. Analyze the semantic segmentation's output. On the other side, the outcomes of the dice were used to contrast the truth labels discovered in the original picture data with the anticipated labels gathered on the network's final layer. Using anticipated truth labeling, 3D imaging of the brain and tumors was the last stage. In conclusion, semantic segmentation of test pictures enabled the highly precise prediction of tumors. One may claim that brain tumor's 3D pictures help surgeons more efficiently plan their breadth, height, and depth. Calculating the tumor volume might offer crucial information in addition to the ophthalmological examination. Advantage in numbers for tumor size, location, and therapy [13]. Specifically, this study uses X-ray images to detect brain tumors. Convolutional neural networks (CNNs) are the subject of this study, which describes how to find brain tumors on X-rays and MRIs. This facilitates therapy and increases consistency. Several articles have already been devoted to the subject of "detection of brain tumors." The primary goal of the proposal is to employ transfer learning in convolutional neural network (CNN) models to enhance accuracy. Python

and Jupyter notebooks were used for this study. Here, deep feature extraction was performed using a pre-trained deep CNN model. Three measures are used to assess job performance: classification, accuracy, F1 score, and validation accuracy. The model was developed using CNN with test accuracy and F1 score of 98.4% and 98.5%, respectively. This precision helps detect tumors at an early stage and prevent bodily harm such as stroke, paralysis, and other disorders [14].

The Bat method and a convolutional neural network (CNN) were applied. The purpose of this study is to create a hybrid brain tumor detection system. This method makes use of medical imaging, such as magnetic resonance imaging (MRI) or computed tomography (CT), to identify and categorize brain tumors. Age extraction is the process of erasing all of the past and its negative influences from various pixels. You may be able to find out more about the tumor to help diagnose it. With this method, the size, shape, and function of the tumor can be determined. Health care using different colors to represent different height steam and patients determine the severity of the tumor. Medical staff can provide information to graphical user interface structure and boundaries. The Bat method is used to tune CNN parameters to improve performance. CNN is learned to recognize model and Suggestive Photo Features tumors. This method can improve the accuracy. The speed of diagnosis of brain tumors [15] the present investigation, five advanced deep learning (DL) models and convolutional neural network (CNN) techniques were utilized to classify brain tumors. The ResNet50 and DenseNet121 models' accuracy was 93.23%. However, the DenseNet121 model (92.86%) had the lowest accuracy, and the MobileNetV2 (97.02) model (97.02) had the best accuracy (97.08%) [16].

The aim of these efforts is to find a solution to the problem of intensive data collection. The cornerstone of this work was to build a framework for a convolutional neural network (CNN) model, select parameters to train the model on this problem, and use the visual geometry group (VGG 16) as a tumor diagnostic tool. Our technique can be used to assess MRI images to detect brain tumors. The system has demonstrated an exceptional accuracy of 92% in all tests, exceeding current industry standard approaches for brain tumor detection [17].

This article provides a framework for identifying the exact location and morphology of brain tumors using a segmentation model. This approach also uses a multi-level ensemble learning model to classify brain tumors in an MRI dataset. The geometric characteristics of the tumor are determined by the method of statistical measurements based on regional characteristics. Unlike many other models, the classification model is trained on the normal brain and the three main types of malignant brain tumors MRI. The use of a multi-level assembly and the process of improving the weakest base model improve the accuracy of the final assembly model. In this article, we also demonstrate how deep learning networks can be used to demystify

tumor spurious segmentation in typical brain MRI images [18]. Finding a solution to the issue of centralized data collection is the aim of this effort. The goals of this study were developing a convolutional neural network (CNN) model framework, selecting the parameters to train the model for this issue, and using the visual geometry group (VGG 16) as a tool for diagnosing brain tumors. Our technique might be used to evaluate the MR pictures and find brain tumors. The system demonstrated outstanding accuracy of 92% throughout testing, outperforming the existing industry standard approaches for brain tumor detection [17].

This paper suggests a framework for determining the precise location and morphology of brain tumors using a segmentation model. A multi-level ensemble learning model is also used by the framework to categorize brain tumors in an MRI data set. A statistical measuring method based on region attributes is used to determine a tumor's geometrical characteristics. Three base learners, two main ensemble learners, and a final ensemble model make up the categorization model. In contrast to many other models, the classification model is trained on three primary kinds of MRI brain cancers as well as a normal brain. The accuracy of the final ensemble model is increased by using a multi-level ensemble and the method of fine-tuning the weakest base model. This paper also illustrates how a deep learning network may be used to debunk incorrect tumor segmentation in a typical MRI brain picture [18] (Table 1).

**Table 1** Comparison table of different literature review

| Author                                | Title  | Dataset                                     | Used techniques  | Performance measure  | Year |
|---------------------------------------|--|---|--|--|------|
| Soumia and Hemdani et al. [19]        | Deep learning with efficient NetB1 to detect brain tumors from MRI images                        | MRI images dataset                          | CNN  | They achieved 98% performance and 97% accuracy on a dataset of 3064 brain MRI images   | 2023 |
| Tummala et al. [10]                   | Classification of brain tumors by magnetic resonance imaging using a set of vision transducers   | Figshare                                    | ImageNet-based ViT   | 98.7%  | 2022 |
| Saif Ahmad and Choudhury et al. [20]  | Performance of deep transfer learning network for brain tumor detection using MRI images         | Brain image                                 | VGG-16, VGG-19, ResNet50, InceptionV3, Xception, and DenseNet201                     | The results show that the best model has a 10 × cross-validation accuracy of 99.39%  | 2022 |
| Srikanth and Suryanarayana et al. [9] | Multi-class classification of brain tumor images using data augmentation by deep neural networks | Hospitals' dataset from 2010 to 2015, China | 16-layer VGG-16 deep NN  | 98%  | 2021 |
| Dipu, Shohan et al. [21]              | Brain tumor identification using various deep learning algorithms                                | Brain tumor progression                     | YOLO V3 Pytorch, YOLO V4 Darknet, Scaled YOLO V4, YOLO V4 Tiny, YOLO V5, Faster-RCNN | After evaluating the experimental results of these models, we determined that the YOLO V5 model provided the best performance, achieving a mAP@0.5 of 95.07%. In contrast, the YOLO V3 Pytorch | 2021 |

## 5 Conclusion

Early detection of brain tumors has the potential to drastically lower global mortality rates. Because of the tumor's form, changeable size, and structure, reliable detection of brain tumors remains challenging. The classification of MR images influences clinical diagnostic and treatment decisions for patients with brain malignancies. In these papers, we looked at several types of brain tumor research. In conclusion, we proposed a CNN-based approach for segmenting brain tumors in an MRI investigation. The goal of this research is to reliably identify the many models used to detect brain cancers using MRI data. Brain tumors are the most fatal and life-threatening kind of cancer, impacting millions of people worldwide. A variety of brain tumor segmentation and classification approaches have been presented to enhance medical image analysis. However, these algorithms have several flaws, including low contrast images, incorrect tumor region segmentation caused by certain artifacts, a computationally complex method that requires more treatment time to correctly identify the tumor region, and existing deep learning methods that require a large amount of training data to overcome overfitting.

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# Ubiquitous Computing: A Comprehensive Review



Manoj Wadhwa and Utpal Shrivastava

**Abstract** Ubiquitous computing, also known as pervasive computing or ambient intelligence, has emerged as a prominent field of research and development in recent years. This review aims to provide a comprehensive overview of ubiquitous computing, covering its key concepts, historical development, enabling technologies, applications, challenges, and future directions. The review synthesizes a wide range of literature from academic research papers, conference proceedings, and industry publications. It highlights the evolution of ubiquitous computing, explores its various components, discusses notable applications in different domains, and examines the challenges and ethical considerations associated with its adoption. The review concludes by discussing potential future developments and emphasizing the transformative potential of ubiquitous computing in shaping our future technological landscape.

**Keywords** Ubiquitous computing · Pervasive computing · Ambient intelligence

## 1 Introduction

Ubiquitous computing refers to integrating computing technology seamlessly into the environment and everyday objects, making it pervasive and invisible to the users. The vision behind ubiquitous computing is to create an environment where devices and systems are interconnected and work together to enhance human activities and experiences [1]. Ubiquitous computing aims to enable information and communication technology to be seamlessly integrated into our daily lives, making it more efficient, convenient, and unobtrusive [2]. Rather than relying on traditional desktop computers

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or mobile devices, computing capabilities are embedded in various objects, from household appliances and furniture to wearable devices and even the surrounding environment.

### ***1.1 Key Features and Principles of Ubiquitous Computing***

Following are the features and principles of ubiquitous computing [3].

**Embeddedness:** Computing capabilities are integrated into everyday objects, making them capable of processing, sensing, and communicating data.

**Connectivity:** Ubiquitous computing systems are interconnected, allowing devices to communicate with each other and share data seamlessly. This connectivity can be achieved through wired or wireless networks.

**Context awareness:** Ubiquitous computing systems are designed to be aware of their surroundings and the context in which they operate. They can sense and gather information from the environment, such as location, temperature, or user preferences, to adapt and provide personalized experiences.

**Adaptability:** Ubiquitous computing systems are flexible and adaptable to changing conditions. They can adjust their behavior and functionality based on user needs and preferences.

**Transparency:** The technology in ubiquitous computing is meant to be invisible and unobtrusive, seamlessly integrated into the environment and everyday objects. Users should not have to focus on the technology itself but rather on the tasks and activities they want to accomplish.

## **2 Historical Background and Evolution**

The concept of ubiquitous computing was first introduced by Mark Weiser, a computer scientist at Xerox PARC, in the early 1990s. In his influential paper titled “The Computer of the twenty-first century,” published in 1991, Weiser envisioned a future where computing technology would disappear into the fabric of everyday life [4]. He proposed the notion of “calm technology” that would seamlessly support human activities without demanding attention. Since Weiser’s initial ideas, ubiquitous computing has evolved and expanded significantly. In the early stages, research focused on developing and refining the underlying technologies and infrastructure needed to support ubiquitous computing, such as wireless communication, sensor networks, and miniaturized computing devices [5]. Over time, the field has witnessed the emergence of numerous applications and prototypes that demonstrate the potential of ubiquitous computing in various domains. Smart homes, healthcare monitoring systems, intelligent transportation systems, and smart cities are just a few examples of the areas where ubiquitous computing has made notable progress.

## 2.1 Importance and Motivation for Studying Ubiquitous Computing

There are several reasons for studying ubiquitous computing.

**Enhancing User Experience:** Ubiquitous computing aims to seamlessly integrate technology into our lives, providing enhanced user experiences by making technology intuitive, personalized, and contextually aware. Understanding the principles and concepts behind ubiquitous computing can lead to the design of more user-friendly and efficient systems.

**Enabling Technological Advancements:** Ubiquitous computing requires advancements in various areas, including networking, sensor technologies, data processing, and artificial intelligence. By studying ubiquitous computing, researchers can drive innovation and contribute to developing new technologies and techniques.

**Addressing Societal Challenges:** Ubiquitous computing has the potential to address societal challenges in areas like healthcare, transportation, and energy management. By studying and implementing ubiquitous computing solutions, researchers can contribute to improving the efficiency, accessibility, and sustainability of these domains.

**Shaping the Future:** Ubiquitous computing is integral to digital transformation, shaping the future of technology and society. By studying ubiquitous computing, researchers can actively participate in defining the direction of technological advancements, ethical considerations, and policy frameworks related to its adoption.

## 3 Models of Ubiquitous Computing

Several models and frameworks have been proposed in ubiquitous computing to conceptualize and guide the design and implementation of ubiquitous computing systems. These models provide a structured approach to understanding the different components, interactions, and principles involved in creating successful ubiquitous computing environments [1, 6]. Here are some prominent models:

**Mark Weiser's Three Waves Model:** Mark Weiser, one of the pioneers of ubiquitous computing, proposed a model that describes the evolution of computing technology in three waves:

The first wave involved mainframe computers and batch processing.

The second wave focused on personal computers and human-computer interaction.

The third wave, the era of ubiquitous computing, aims to integrate computing technology seamlessly into the environment and everyday objects.

**Context-Awareness Model:** Context awareness is a key aspect of ubiquitous computing. This model emphasizes the importance of context in understanding and adapting to the user's environment. It involves sensing and gathering contextual

information, such as location, time, activity, and user preferences, and using this information to provide personalized and contextually relevant services.

**The CALM Model:** The CALM (Computing as a Utility) model views computing as a utility, similar to electricity or water. It suggests that ubiquitous computing resources should be readily available and accessible on demand, allowing users to use computing power and services whenever and wherever they need them.

**The Smart Environment Model:** This model focuses on creating intelligent and responsive environments that can sense and interpret user behavior and adapt accordingly. Smart environments are equipped with sensors, actuators, and communication capabilities to collect and process data, enabling personalized and context-aware interactions.

**The Centralized Versus Distributed Model:** This model explores the distribution of computational resources in ubiquitous computing systems. It considers whether computing power and intelligence should be centralized in a central server or distributed across different devices and objects. It highlights the trade-offs between centralized control and distributed decision-making in terms of efficiency, scalability, and autonomy.

**The Person-Action-Context (PAC) Model:** The PAC model emphasizes the importance of understanding the relationships between the person, their actions, and the context in which they occur. It recognizes that the behavior and requirements of the user, the actions they perform, and the context in which those actions occur are all critical factors in designing effective ubiquitous computing systems.

**The Ambient Intelligence Model:** Ambient intelligence focuses on creating intelligent environments that are sensitive, adaptive, and responsive to the needs and preferences of individuals. It aims to create environments that can anticipate and fulfill users' needs by using embedded intelligence and context awareness.

**The Augmented Reality (AR) Model:** This model combines the real and virtual worlds by overlaying digital information onto the user's perception of the physical environment. AR models in ubiquitous computing involve the integration of digital content, such as text, images, and 3D objects, into the user's view, enhancing their understanding and interaction with the environment.

These models provide different perspectives and frameworks for understanding and designing ubiquitous computing systems. They help researchers and practitioners identify the key components, principles, and interactions necessary for creating successful ubiquitous computing environments. It is important to note that these models are not mutually exclusive and can be combined and adapted based on the specific requirements and goals of the ubiquitous computing system being developed.

## 4 Enabling Technologies in Ubiquitous Computing

**Internet of Things (IoT) and Sensor Networks:** Integrating IoT devices and sensor networks continue to be a prominent area of research. Researchers are exploring ways to improve IoT systems' connectivity, energy efficiency, and data management. They

also investigate novel sensor technologies and protocols for various applications, such as smart cities, healthcare monitoring, and environmental sensing [6].

**Edge and Fog Computing:** With the exponential growth of data generated by IoT devices, there is an increasing focus on edge and fog computing paradigms. These approaches involve processing and analyzing data closer to the data source at the network edge to reduce latency, bandwidth usage, and dependency on cloud infrastructure. Researchers are working on optimizing resource allocation, data caching, and task offloading techniques in edge and fog computing environments.

**Context-Aware Computing:** Context awareness remains a crucial research area within ubiquitous computing. Researchers are developing algorithms and techniques to enable systems to understand and adapt to contextual information, such as user location, preferences, and activities. Context-aware applications are being explored in personalized health care, smart homes, and intelligent transportation systems.

**Human-Computer Interaction (HCI):** HCI research in ubiquitous computing focuses on designing intuitive and seamless interfaces for interacting with smart environments and everyday objects. This includes exploring novel input methods, gesture recognition, voice interfaces, and augmented reality (AR) and virtual reality (VR) technologies. Researchers are also investigating novel interaction techniques to address privacy, security, and trust challenges in ubiquitous computing systems.

**Artificial Intelligence and Machine Learning:** Ubiquitous computing benefits from AI and machine learning advances. Researchers are applying these techniques to improve smart systems' data analysis, prediction, and decision-making capabilities. In ubiquitous computing environments, machine learning algorithms are used for activity recognition, anomaly detection, predictive maintenance, and intelligent resource management.

**Security and Privacy:** As ubiquitous computing involves collecting and processing sensitive data, ensuring security and privacy is a critical area of research. Researchers are developing robust authentication and encryption mechanisms and privacy-preserving techniques to protect user data in IoT and ubiquitous computing systems.

## 5 Present Challenges of Ubiquitous Computing

Despite its numerous advantages and potential benefits, ubiquitous computing faces several challenges that need to be addressed for its successful deployment and widespread adoption.

**Privacy and Security:** Ubiquitous computing involves the collection, storage, and processing of vast amounts of personal data, raising significant privacy concerns. The pervasive nature of ubiquitous computing systems can lead to the unintentional exposure of sensitive information. Establishing robust privacy protection mechanisms and secure data transmission and storage practices is essential to mitigate privacy risks. Additionally, ensuring the security of ubiquitous computing systems against unauthorized access, data breaches, and malicious attacks is crucial.

**Data Management and Ownership:** Ubiquitous computing generates massive data from sensors, devices, and user interactions. Managing and analyzing this data poses storage, processing, and scalability challenges. Moreover, clarifying the ownership and control of the generated data is critical. Clear guidelines and regulations are needed to address data ownership, sharing, and user consent issues to protect individual rights and prevent misuse.

**Interoperability and Standards:** Ubiquitous computing involves diverse devices, platforms, and protocols. The lack of interoperability and standardization across these systems creates compatibility issues, limiting seamless communication and integration between devices and services. Establishing common standards and protocols for data exchange, communication, and interoperability is essential to enable seamless interactions and interoperability between different ubiquitous computing systems.

**Energy Efficiency:** Ubiquitous computing systems typically involve a large number of devices that consume energy. This raises concerns about the environmental impact and sustainability of such systems. Energy-efficient design and optimization techniques, including low-power hardware, energy harvesting, and power management strategies, are crucial to mitigate ubiquitous computing systems' energy consumption and environmental footprint.

**Ethical and Social Implications:** Ubiquitous computing raises ethical and social implications that must be carefully addressed. The potential for constant monitoring, surveillance, and data-driven decision-making can impact privacy, autonomy, and social interactions. Ethical considerations surrounding data usage, algorithmic bias, and fairness are critical in ensuring ubiquitous computing systems are developed and deployed responsibly, respecting individual rights and societal values.

**Human Factors and User Acceptance:** Ubiquitous computing systems should be designed with a deep understanding of human factors and user needs. Ensuring usability, simplicity, and intuitive interactions with the technology is crucial for user acceptance and adoption. Involving end-users in the design process, conducting user studies, and addressing usability issues can improve the acceptance and usability of ubiquitous computing systems.

**Trust and Reliability:** Establishing trust in ubiquitous computing systems is essential for user acceptance and adoption. Users need to have confidence in the technology's reliability, accuracy, and security. Addressing system failures, data integrity, and transparency issues can enhance user trust in ubiquitous computing systems.

**Legal and Regulatory Challenges:** The deployment of ubiquitous computing systems may raise legal and regulatory challenges. Compliance with existing laws and regulations related to privacy, data protection, security, and intellectual property is crucial. Additionally, new legal frameworks may need to be developed to address the unique challenges posed by ubiquitous computing, such as liability for autonomous systems and regulations for data sharing and use.

**Cultural and Societal Impacts:** Ubiquitous computing can have profound cultural and societal impacts. It can disrupt social norms, influence human behavior, and reshape social interactions. Understanding ubiquitous computing systems'

cultural and societal implications is important to ensure they align with societal values, respect diversity, and promote inclusivity.

## 6 Future Directions and Emerging Trends

The field of ubiquitous computing continues to evolve rapidly, and several future directions and emerging trends are shaping its trajectory [7]. Here are some key areas of focus for future research and development in ubiquitous computing:

**Edge Computing and Edge AI:** Edge computing involves processing data locally on edge devices, reducing the need for constant data transmission to centralized servers. With the exponential growth of IoT devices and the need for real-time processing, edge computing is gaining prominence. Future research will focus on optimizing edge computing architectures, developing efficient algorithms for edge AI, and exploring the integration of edge computing with ubiquitous computing systems.

**Artificial Intelligence and Machine Learning:** AI and ML techniques will play a crucial role in enhancing the capabilities of ubiquitous computing systems. Future research will focus on developing intelligent algorithms for context inference, activity recognition, behavior modeling, and decision-making. Deep learning, reinforcement learning, and federated learning are expected to advance the field by enabling more accurate and efficient data analysis.

**Ethical and Responsible Ubiquitous Computing:** As the deployment of ubiquitous computing systems expands, ethical considerations and responsible practices become imperative. Future research will address algorithmic bias, transparency, accountability, and user privacy issues. It will also explore methods for incorporating ethical decision-making frameworks and promoting the responsible use of ubiquitous computing technologies.

**Integration of Virtual Reality (VR) and Augmented Reality (AR):** Integrating VR and AR technologies with ubiquitous computing is an emerging trend. Future research will focus on developing seamless interfaces and interactions between physical and virtual environments. This integration will enable immersive experiences, spatial computing, and enhanced user interfaces for ubiquitous computing systems.

**Sustainable and Energy-Efficient Design:** The energy consumption of ubiquitous computing systems is a critical concern. Future research will explore energy-efficient hardware design, low-power sensing, and communication technologies, and adaptive power management strategies. Sustainable design principles will be incorporated to reduce the environmental footprint of ubiquitous computing systems.

**Security and Privacy Enhancements:** Addressing security and privacy concerns will remain a priority. Future research will focus on developing robust security mechanisms, privacy-preserving techniques, and secure communication protocols. Solutions for secure data storage, secure authentication, and intrusion detection in ubiquitous computing environments will be explored.



**User-Centric Design and User Experience:** User-centric design approaches will continue to be emphasized. Future research will focus on understanding user needs, preferences, and behavior in ubiquitous computing environments. It will explore innovative user interfaces, intuitive interaction techniques, and adaptive systems that provide personalized and context-aware experiences.

**Cross-Domain Collaboration and Integration:** Ubiquitous computing increasingly requires collaboration across various domains and disciplines. Future research is expected to explore the integration of ubiquitous computing with fields such as healthcare, transportation, education, and smart cities. It hopes to address the challenges of interoperability, standardization, and cross-domain data integration.

In summary, future directions in ubiquitous computing will involve advancements in edge computing, AI and ML, ethical considerations, VR/AR integration, sustainable design, security and privacy enhancements, user-centric design, cross-domain collaboration, and integration. These areas of research will shape the future of ubiquitous computing, enabling more intelligent, personalized, and responsible computing environments.

## 7 Discussion on Ubiquitous Computing

Ubiquitous computing, also known as pervasive computing or ambient intelligence, has the potential to transform our daily lives by seamlessly integrating technology into our environment and everyday objects. This discussion delves into the significance, benefits, challenges, and future implications of ubiquitous computing [8].

Ubiquitous computing is promising to enhance user experiences, increase productivity, and improve efficiency across various domains. By embedding computing capabilities into everyday objects and environments, ubiquitous computing systems can provide personalized and context-aware services. For instance, in a smart home, appliances, and devices can be interconnected to create an intelligent environment that adjusts lighting, temperature, and entertainment based on user preferences and activity patterns. In health care, wearable sensors and smart devices can enable continuous monitoring, personalized interventions, and improved disease management [9]. These examples illustrate how ubiquitous computing can make technology more accessible, intuitive, and seamlessly integrated into our lives.

One of the key benefits of ubiquitous computing is its ability to enable context awareness. By gathering and analyzing data from various sensors and sources, ubiquitous computing systems can understand the user's context, such as their location, activity, and preferences. This context awareness allows for personalized and adaptive interactions, providing users with relevant information and services at the right time and in the right context. For example, a context-aware navigation system can provide real-time directions based on the user's location, traffic conditions, and preferences.

However, ubiquitous computing also presents significant challenges that need to be addressed. Privacy and security are primary concerns, as the constant collection

and sharing of personal data raise privacy risks. Ensuring robust privacy protection mechanisms, secure data transmission, and storage practices is essential to mitigate these risks. Additionally, addressing the ethical implications of ubiquitous computing, such as data ownership, algorithmic bias, and the impact on individual autonomy, is crucial for these systems' responsible deployment and usage.

Interoperability and standardization are other challenges in ubiquitous computing. With a multitude of devices, platforms, and communication protocols, ensuring seamless integration and interoperability is crucial for a cohesive and efficient ecosystem. Developing common standards and protocols for data exchange, communication, and interoperability will facilitate the widespread adoption and integration of ubiquitous computing systems.

Energy efficiency is another important consideration in ubiquitous computing. As the number of connected devices increases, energy consumption becomes a concern. Designing energy-efficient hardware and employing power management strategies can help mitigate the environmental impact and ensure the sustainability of ubiquitous computing systems.

The future implications of ubiquitous computing are vast. With AI, ML, edge computing, and IoT advancements, ubiquitous computing will likely become even more prevalent and impactful. Some of the future directions are intelligent environments that proactively respond to users' needs, seamless integration of AR and VR technologies, and collaborative ubiquitous computing systems that enable social interactions. The potential applications span various domains, including healthcare, transportation, education, entertainment, and smart cities.

## 8 Conclusion

Ubiquitous computing offers transformative possibilities by seamlessly integrating technology into our environment and everyday objects. It can enhance user experiences, improve efficiency, and provide personalized and context-aware services. However, privacy, security, interoperability, and energy efficiency must be addressed to ensure responsible and sustainable deployment. With continued research, innovation, and multidisciplinary collaboration, ubiquitous computing has the potential to shape our future technological landscape and improve the way we interact with the world around us.

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# Deep Learning Tools for Covid-19 Pneumonia Classification



Ngonidzashe Mathew Kanyangarara, D. R. Soumya, Subrata Sahana, and Sanjoy Das

**Abstract** The outbreak of Covid-19 has triggered a worldwide problem, especially in Asia and America. The World Health Organization (WHO) declared the sickness a pandemic on March 20, 2020. It arrived in waves, and most countries worldwide have now experienced two waves and are on the approach of experiencing the third. The goal of this study is to build up and certify a Computer-Aided Diagnosis (CADx) system for distinguishing between COVID-19-positive patients and non-COVID Patients people. Chest X-ray (CXR) images will be used to accomplish this. From public datasets which we got on GitHub **2295** CXR images were obtained which included **712** COVID-19 positive and **1583** normal. The proposed CADx system utilized a Conventional Neural Network (CNN) model for data argumentation and CNN was built, compiled, and trained with the help of TensorFlow and Keras. For the sake of appraisal, our datasets were separated into three categories: Train/Test and Validation. The three sets' accuracy was evaluated and the results for Training, Validation, and Test were 97.77%, 97.81%, and 97.72% respectively. In the end, this study was able to create a precise Computer-Aided Diagnosis system for the two categories of classification.

**Keywords** Computer-aided diagnosis (CADx) · Conventional neural network (CNN) · Keras and tensorflow · Chest X-ray (CXR)

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## 1 Introduction

Pneumonia is a pervasive ailment caused by viruses, microorganisms, and fungi, among other microbes. The term “pneumonia” is derived from the Greek word “pneumon,” which means “lung.” As a result, the word pneumonia is linked to lung disease. Pneumonia arises when a bacterial or viral contagion in the lungs produces noteworthy harm and irritation.

The coronavirus is responsible for the damage to the lungs in COVID-19 pneumonia.

When COVID pneumonia builds up, it causes extra signs, such as:

- Breathing difficulty,
- Faster Heart rate,
- Blood pressure is abnormally low.

Deep learning (DL) is a subset of machine learning (ML) stimulated as a result of the structure of the human brain. This is a subfield of machine learning that uses neural networks to interpret data related to the biology of a being’s brain [1].

AI-based computer-aided diagnostic tools are used to detect and treat different types of cancer, such as breast cancer and brain tumors. These tools are commonly referred to as deep learning (DL). CNNs are the most widely used of these tools because they can analyze and interpret complex data [2]. The Objectives of this research are:

- Have a model that is going to accelerate prediction processes and assist medical professionals.
- Create a CADx that will accurately classify COVID-19 patients and Normal patients using a CXR image.
- Make it easy even for Leman to be able to check whether he/she is COVID-19 positive or negative, by just uploading the CXR image onto the CADx.

## 2 Related Works

The use of DL in the healthcare sector has increased exponentially over the last decade. DL models have been shown to help classify CT scans of pneumonia and TB, cancer pictures, diabetic retinopathy, and microbiological slide images in various studies. Pathologists, computer scientists, and radiologists work together in the field of pathology to diagnose diseases such as cancer, pneumonia, and tuberculosis using computer-assisted diagnostics [3].

With recent developments in several medical image processing tasks, algorithms have outperformed clinicians thanks to deep learning model advancements and the distribution of massive datasets are two examples including B. Classification of skin cancer and detection of diabetic retinopathy. Automatic diagnosis is gaining popularity through chest radiography. These algorithms are increasingly used to

detect pulmonary nodules and classify pulmonary tuberculosis. Using the published OpenI dataset, researchers have discovered that a similar deep convolutional network design is ineffective for all abnormalities; models of ensembles outperform single models in classification accuracy, and deep learning improves classification accuracy dramatically. We have found that the method is superior to the rule-based method [4].

### 3 Materials and Methods

We report the results of extensive tests and assessments carried out to determine the viability of the suggested approach. To design and train the Convolutional Neural Network Model, we used Keras, a deep learning framework that is open-source with a Tensor Flow API. All tests were performed on a typical PC (Windows 10, 64-bit, Any CPU, Any GPU, and a Google Colab Notebook [5]).

#### 3.1 Dataset

The original dataset is divided into two main folders (training and testing) and two subfolders containing COVID-19 positive and Non-Covid chest X-ray images, respectively 2295 CXR images were obtained which included 712 COVID-19 positive and 1583 normal. So, to get the validation data, we need to split our training into 80% of training data and 20% of validation data. Each of the training set validation sets and the testing set contains the subdirectories as COVID-19 and normal. Was the COVID-19 folder containing the COVID-19 X-ray images, while the normal directory contains the negative X-ray images?

#### 3.2 Pre-processing and Augmentation Stage

To ensure the growth and reliability of the datasets, we employed a range of data augmentation methods. This helped in reducing overfitting tribulations and enhanced our model's overview aptitude while training. The following Table 1 explains the configurations used for image augmentation.

So firstly, we will rescale the data by a factor of one by 255. That will help us to do the normalization. We then divided our training into 20% of the validation set. So, to do that, we used the validation underscore split constraint.

### 3.3 Model

**Input Image** To ensure that the model runs efficiently, the overall input image is set for pre-processing. Data augmentation strategies are used to maximise datasets. Physical data gathering is complicated due to the global epidemic of COVID-19 [6]. To obtain critical elements, the improved data should be transferred to the prior convolution.

**Convolution steps** Convolutions extract local aspects from vast amounts of input data and multiply the resulting NN matrices. For image categorization, Conv2D combines filters, kernel size, input shapes, and activation functions [7]. Table 1 contains the values of the variables in this study domain.

**Max Pooling Layer** Max-pooling decreases dimensionality and extracts the most features in advanced learning algorithms [8]. By calculating the average of the supplied elements, the pooling layer decreases the number of variables and regularises overfitting [9].

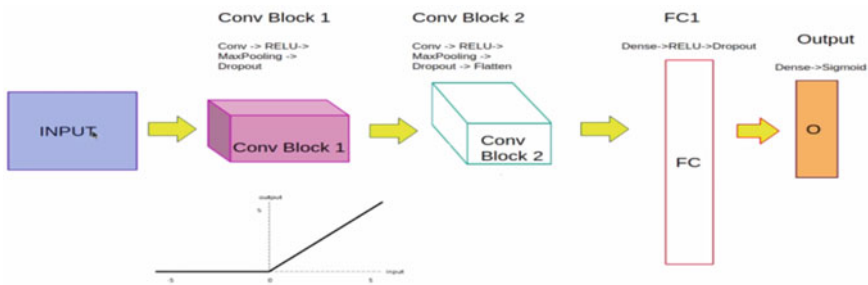
**Fully Connected Layer** It plots pooled layers, flattens them, and passes them into the next layer. In CNN, the completely linked layer is vital for categorization [10]. The classification conclusion shown below is achieved with the help of the activation function (sigmoid, Dense). The proposed network architecture’s layers are outlined in Fig. 1.

The Keras-Sequential class was used in conjunction with the Keras API. The architecture of our suggested CNN model [11] is depicted (see Fig. 1).

For the mining of features from the input image, we use a modus operandi identified as convolution. Our input is fed to the conv 2d block, after which we apply

**Table 1** Configurations for image augmentation

| Method           | Setting |
|------------------|---------|
| Rescale          | 1/255   |
| Validation_Split | 0.2     |
| Zoom range       | 0.2     |
| Horizontal flip  | True    |



**Fig. 1** Layers of CNN

**Table 2** Model: “sequential”

| Layer (Type)       | Output shape        | Parameters |
|--------------------|---------------------|------------|
| Conv2D(Conv2D)     | (NIL, 150, 150, 32) | 2432       |
| MaxPooling2D       | (NIL, 75, 75, 32)   | 0          |
| Dropout(Dropout)   | (NIL, 75, 75, 32)   | 0          |
| Conv2D_1(Conv2D)   | (NIL, 75, 75, 64)   | 51,264     |
| MaxPooling2D_1     | (NIL, 37, 37, 64)   | 0          |
| Dropout_1(Dropout) | (NIL, 37, 37, 64)   | 0          |
| Flatten(Flatten)   | (NIL, 87,616)       | 0          |
| Dense(Dense)       | (NIL, 256)          | 22,429,952 |
| Dropout_2(Dropout) | (NIL, 256)          | 0          |
| Dense_1(Dense)     | (NIL, 1)            | 257        |

Total Parameters: 22,483,905  
 Trainable Parameters: 22,483,905  
 Non-Trainable Parameters: 0

RELU (Rectified Linear Unit), followed by Max pooling, and lastly the dropout regularization. After this, we repeat the convolution but this time, we have more filters i.e., flattening them using the final layer into a one-dimensional array, which will be heading for our fully connected layer [12].

Finally, an opaque (dense) layer with a sigmoid activation utility is deployed. So, in short, we feed the image into the conv2d where we do convolutions that mean feature extraction, we pull them, then we take those pixels, and we fatten them up [13]. And lastly, that information is fed to our tightly connected artificial neural network. Supply forward neural architecture’s output is presented in the following Table 2.

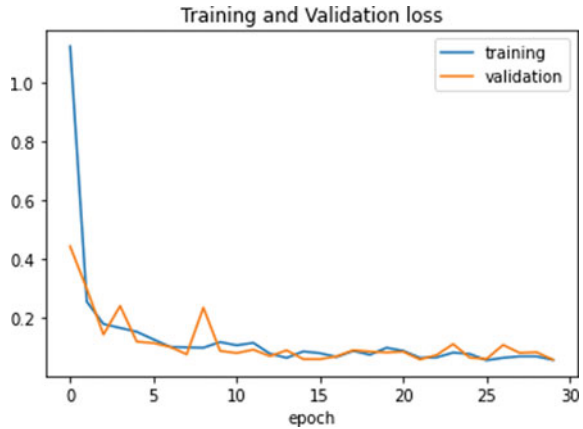
## 4 Results

For the compilation of the model, we used Adam Optimizer which was learning at a pace of 0.001. After that, we had to train our model for 30 epochs on all the training images that we had. So, when we train our model, you will see four values per epoch that would be loss, accuracy, and validation accuracy and validation loss. So, the precision and loss of training data will be very useful in assessing the effectiveness of our training. It will also help us identify areas of improvement.

The accuracy, on the other hand, is the percentage of accurate guesses, and validation accuracy is evaluated using non-training data. After training, we need to know how the model performed during the training phase. So, for that, we are going to generate two graphs, one for loss and the other for accuracy. Our final training was 97% accurate. The validation accuracy was around 98%, while the training loss was only 0.0677%. And the validation was 0.0372. We were able to get a good accuracy



**Fig. 2** Training and validation loss



**Fig. 3** Training and validation accuracy

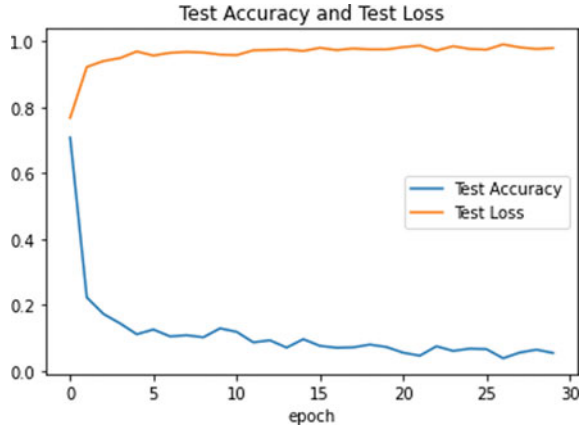


of our test to roughly 97%. And the test loss is just around 0.7071. (See Figs. 2, 3 and 4).

## 5 Discussion

From the chest X-ray pictures acquired from front views, we build a model to detect and categorize pneumonia for COVID-19 [14]. This method begins by reducing the size of the chest X-ray images to a portion of their initial size. The photos are then enhanced by a convolutional neural network framework, which extracts and classifies characteristics from the images. When compared to other approaches, our model’s validation accuracy was marginally greater.

**Fig. 4** Test accuracy and test loss



We had to redo the model’s training process numerous times before getting the same results each time. This will benefit developing countries with a doctor shortage, such as most African countries. Significant improvements could be made if we had access to patient and non-patient statistics from around the world; however, our system is constrained because of a shortage of information [15].

## 6 Conclusion

From a series of X-ray scans, we demonstrated how to distinguish between positive and negative COVID-19 patients. Our model is built from the ground up, which distinguishes it from existing systems that heavily rely on transfer learning. Our research is going to be expanded soon to perceive and classify X-ray images of Retinal Image Analysis, Skin Cancer Detection, and more (Brain analysis).

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# Security in Cloud Computing Using Blockchain: A Comprehensive Survey



Sagnik Jana, Rahul Modak, Koushik Majumder, Anurag Dasgupta, Rabindra Nath Shaw, and Ankush Ghosh

**Abstract** Cloud computing has revolutionized the business landscape by providing convenient access to data and applications via the Internet. However, its widespread adoption has also introduced significant security challenges. Blockchain, a decentralized and tamper-proof technology, offers promising solutions to tackle these security concerns in cloud computing. This paper aims to explore the potential of blockchain technology in bolstering security in cloud computing. It begins by examining the existing concept of security in cloud computing and introduces blockchain technology, highlighting its components, features, advantages, and limitations. Furthermore, it investigates the current blockchain-based solutions for securing cloud computing and conducts a comparative analysis to understand their benefits and limitations. By delving into these aspects, the paper seeks to provide a comprehensive understanding of how blockchain technology can enhance cloud computing security. Its primary goal is to inspire and encourage future research and development in this field, promoting the continued exploration of blockchain's potential in ensuring the safety and integrity of cloud-based systems.

**Keywords** Blockchain · Cloud computing · Cloud security

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# 1 Introduction

The emergence of blockchain in 2008 as the foundation of the first decentralized cryptocurrency marked a revolutionary moment in the financial industry, enabling secure peer-to-peer information exchange. This technology operates as a public ledger, recording transactions chronologically and ensuring security through consensus mechanisms, creating an immutable record. The blockchain's outstanding characteristics, including immutability, irreversibility, decentralization, persistence, and anonymity, make it highly suitable for various applications that require secure data sharing among multiple parties. Industries such as finance, real estate, and the internet have already benefited from its applications.

In its essence, the blockchain serves as a transparent and incorruptible ledger, enabling a network of participants to maintain a shared record of transactions without relying on a central authority. Each new transaction is added as a "block" to the existing chain of transactions, forming a continuous and tamper-proof history. Once recorded, the information on the blockchain cannot be altered or deleted, ensuring the integrity of the data.

The decentralized nature of the blockchain, achieved through a network of nodes (computers) working collaboratively, eliminates the need for a central entity to oversee and validate transactions. This not only enhances security but also fosters trust among participants as each party can independently verify the transactions on the ledger. One of the critical components of blockchain technology is the consensus mechanism. Consensus mechanisms are algorithms that enable nodes in the network to agree on the validity of transactions and the order in which they are added to the blockchain. Various consensus mechanisms exist, such as Proof of Work (PoW) and Proof of Stake (PoS), each with its advantages and limitations. PoW, used in cryptocurrencies like Bitcoin, requires computational work to validate transactions, while PoS relies on participants "staking" a certain amount of cryptocurrency as collateral to validate blocks.

The applications of blockchain extend far beyond cryptocurrencies. In the finance industry, blockchain technology has disrupted traditional payment systems, enabling faster and more cost-effective cross-border transactions. It has also opened up new possibilities in the realm of smart contracts, self-executing agreements that automatically trigger predefined actions when specific conditions are met. Moreover, the real estate sector has witnessed the use of blockchain for property transactions and land registry, streamlining processes and reducing the risk of fraud. In the digital realm, blockchain has enabled decentralized storage platforms, giving users greater control over their data and privacy. Despite these advancements, challenges remain. The energy-intensive nature of PoW consensus mechanisms has raised concerns about environmental sustainability. Efforts are being made to explore more eco-friendly consensus alternatives, such as Proof of Stake and Proof of Authority (PoA).

Additionally, the scalability issue poses a hurdle for blockchain's widespread adoption. As the number of transactions increases, the time taken to reach consensus and process transactions may slow down. Various solutions, like sharding and layer-2

solutions, are being developed to address this challenge and enhance blockchain's scalability. As the technology continues to evolve, current trends in blockchain development include interoperability between different blockchain networks, enhancing cross-chain communication, and the integration of blockchain with other emerging technologies like the Internet of Things (IoT) and artificial intelligence (AI).

In conclusion, the blockchain has significantly transformed the way we exchange information and conduct transactions. Its decentralized, secure, and transparent nature has opened up new possibilities across various industries. While challenges exist, ongoing research and development in the field hold the promise of overcoming these obstacles and unlocking the full potential of blockchain technology in shaping the future of our digital world [1–3].

## ***1.1 Cloud Computing***

Cloud computing is a transformative approach to accessing computing resources, delivered over the Internet, and billed based on actual usage. This eliminates the need for businesses to invest in and manage their physical IT infrastructure. Prominent cloud providers like Google Cloud and Amazon Web Services (AWS) offer a range of technology services, such as computing power, storage, and databases, allowing businesses to flexibly scale their resources according to their needs. When companies start their operations, they face a crucial decision: whether to maintain their own computing infrastructure or opt for the services of a cloud provider like GCP or AWS. If they choose to maintain their infrastructure, they must continually invest in additional storage and computer systems as their business grows and their workforce expands. This leads to increased expenses, the need for a dedicated IT team to manage hardware, and the development of recovery strategies in case of system failures. Moreover, they incur ongoing costs for power and hardware maintenance. In many cases, businesses may not fully utilize the capacity of their systems, resulting in financial losses. On the other hand, cloud computing offers an attractive alternative. By storing their data on remote servers managed by the cloud provider, businesses free themselves from concerns about maintenance, security, and recovery. They only pay for the services they use, following a “pay as you go” model. This cost-effective approach allows them to scale their resources up or down as required, ensuring optimal resource utilization and cost efficiency.

As a result of these advantages, cloud computing has gained widespread adoption across organizations of various sizes and industries. The flexibility, scalability, and cost-effectiveness it offers have revolutionized how businesses approach their IT infrastructure and technology needs, enabling them to focus on their core operations and innovation without the burdens of managing complex hardware and maintenance tasks [4, 5].

## ***1.2 Security Issues in Cloud Computing***

Cloud computing has revolutionized the way businesses and individuals store and access their data, offering convenience and flexibility. However, this convenience comes with the potential risk of data security breaches. One of the most significant concerns with cloud computing is the vulnerability to cyberattacks and unauthorized access, which can compromise the security, reliability, and availability of stored data.

Cloud systems store vast amounts of data, including sensitive information such as personal identification data, financial details, intellectual property, and personal communications. This wealth of valuable data makes cloud computing an attractive target for hackers seeking to gain unauthorized access [1]. The consequences of data breaches can be disastrous. Hackers can exploit stolen financial data for fraudulent activities, leading to financial losses and damage to a business's reputation. Several high-profile incidents, such as the Equifax data breach in 2017 and the Capital One data breach in 2019, have underscored the urgency of implementing robust security protocols in cloud computing.

Traditional security measures may not be sufficient to protect cloud systems entirely. As a result, innovative technologies like blockchain have emerged as potential solutions to address these security concerns. Blockchain, with its decentralized and tamper-proof nature, offers promising advantages for enhancing cloud security. By employing blockchain technology in cloud computing, data can be securely distributed across a network of nodes, reducing the risk of a single point of failure and unauthorized access. The immutability of blockchain records ensures that data remains tamper-proof and transparent, providing a reliable audit trail for all transactions.

Integrating blockchain with cloud computing can strengthen data protection, authentication, and access control mechanisms, mitigating the risks associated with centralized data storage. As a result, businesses and individuals can have greater confidence in the security and privacy of their data. In conclusion, while cloud computing offers tremendous benefits, it also presents significant security challenges. The increasing frequency of data breaches emphasizes the urgency of implementing robust security measures. The integration of blockchain technology with cloud computing shows promising potential to address these concerns, offering enhanced data security, privacy, and reliability. As the landscape of cloud computing evolves, adopting innovative and secure technologies like blockchain becomes essential to safeguard sensitive information and maintain the trust of users in the digital age [1, 2].

## ***1.3 Blockchain Overview***

Blockchain is a digital ledger that doesn't have a central authority or middleman. It's a decentralized system that makes it easy to keep track of data in a secure and

open way. The idea was first introduced in 2008 and then implemented in 2009 by an autonomous person or group known as Satoshi Nakamoto. The blockchain functions as an ever-expanding, publicly accessible record book comprising blocks of documented transactions. These blocks are subsequently interconnected in a chronological sequence through the use of cryptographic hashes. While blockchain technology is best known for its application in cryptocurrencies like Bitcoin, however, it has the potential to go beyond finance. Apart from facilitating secure and transparent financial transactions, blockchain technology can be employed across several industries, including healthcare, supply chain management, real estate, and Cloud computing [1]. The decentralized structure of blockchain technology makes it a desirable option for businesses that need secure and transparent record-keeping.

### 1.4 Blockchain Architecture

A blockchain is essentially a chain of blocks (Fig. 1). Blockchain architecture is made up of the following components:

- **Transactions:** Transactions in the blockchain typically involve sensitive information that should not be tampered with. For example, in the case of cryptocurrency blockchains the transactions consist of transfer of value from one party to another.
- **Digital Signature:** To ensure the authenticity of transactions, digital signatures are used. Each user on the network possesses a unique set of public and private

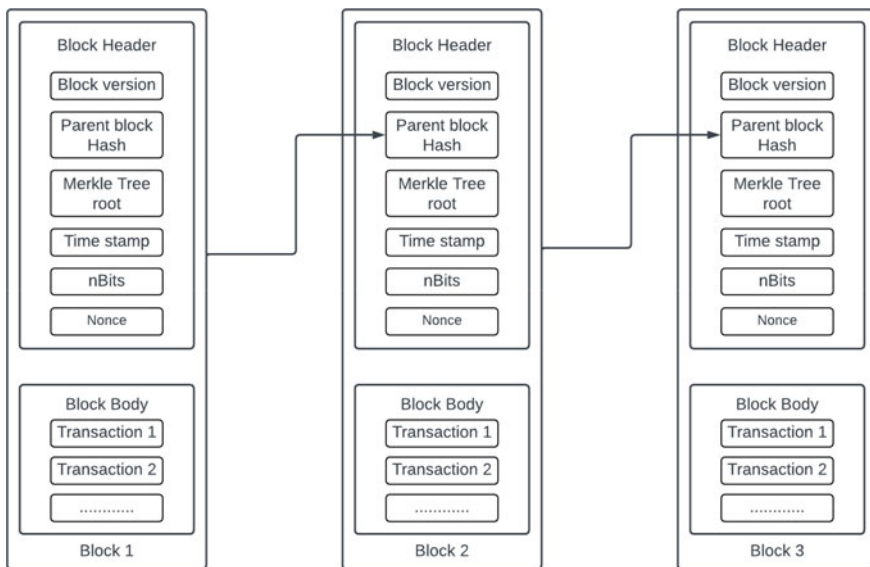
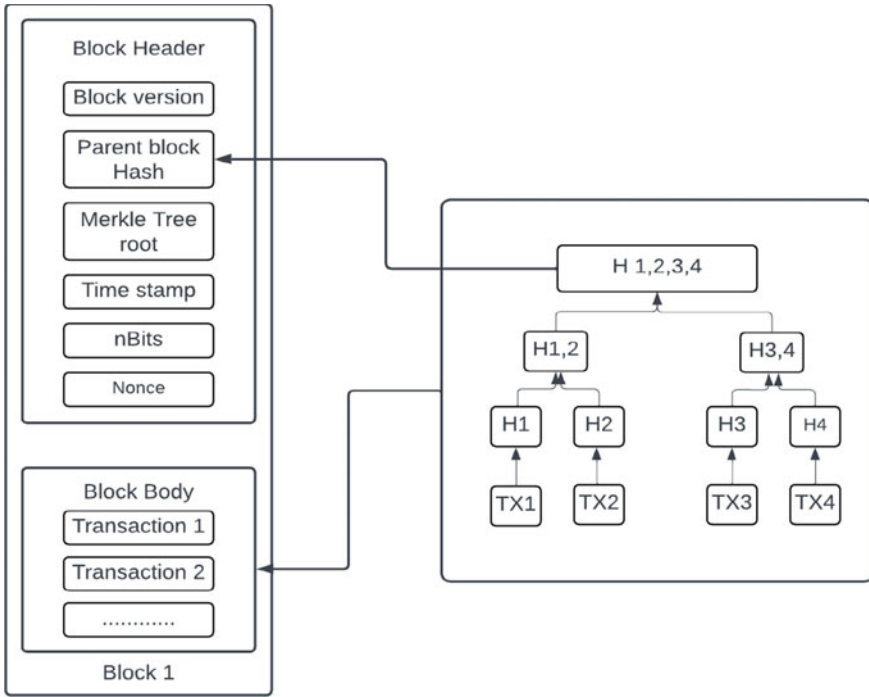


Fig. 1 Blockchain



keys, which have an interesting property that it is computationally infeasible to use practical techniques to extract the private keys from the public keys. While public keys are known to all nodes in the network, private keys are kept confidential by their respective owners. To digitally sign a transaction, the owner uses their private key. The digital signature is a function of both the transaction data and the private key, meaning that each signature is unique to a specific transaction and cannot be duplicated. The sender's public key can be used by the receiver to confirm that the transaction has been signed by the correct owner.

- **Block:** Each block in a blockchain is comprised of two main components: the block header and the block body. The block header contains Previous-block-hash, current timestamp, target difficulty (Current hashing target), Merkle tree root (a hash value that represents all transactions in a block.), and nonce (a value calculated by the miner). The block body is made up of a series of transactions that are organized into a Merkle tree (Fig. 2) and subsequently hashed. The root of the Merkle tree is subsequently saved within the header of the block. The quantity of transactions contained within a block is dependent upon the size of the block. For example, in the Bitcoin blockchain, each block typically holds approximately 2000 transactions, and the block size is 1 Megabyte. Each block in a blockchain network includes the previous-block-hash in its header, creating a chain of blocks. If any of the transactions in a block are altered, the corresponding branch of the Merkle tree changes. This change then affects the Merkle tree root, which in turn affects the current block hash. Since every block in the blockchain network includes the previous-block-hash in its header, this change in the current block affects the hash of all subsequent blocks. This makes tampering with a single transaction almost impossible since any modification would require changing the hashes of all the subsequent blocks.
- **Nodes:** Every node in a blockchain network stores a duplicate copy of the distributed decentralized blockchain ledger. The blockchain protocol guarantees that all nodes have an identical copy of the ledger. These nodes collaborate to confirm transactions and append blocks to the chain.
- **Consensus Algorithms:** The role of consensus algorithms is critical in upholding the integrity of a blockchain network since there is no central governing entity that guarantees uniformity across all copies of the blockchain. Proof of Work (POW) is the most commonly used consensus algorithm, which requires nodes to perform complex computational tasks to prove their trustworthiness when attempting to add a block to the blockchain. Specifically, nodes must calculate the hash value of the block header, which includes a 4-byte nonce field. Nodes compete with each other to generate a hash value that is below the targeted difficulty by experimenting with various nonce values and rehashing the data. Since the hash function is one-way, the only way to determine a suitable nonce value is through trial and error. Once a node discovers a valid nonce for a block, it transmits the block to the other nodes. Subsequently, other nodes validate the block and add it to their blockchain if it satisfies the validation criteria. However, it is possible for two nodes to generate blocks simultaneously, creating branches in the blockchain. To address this issue, the blockchain network adopts a rule that the longest branch is considered the valid



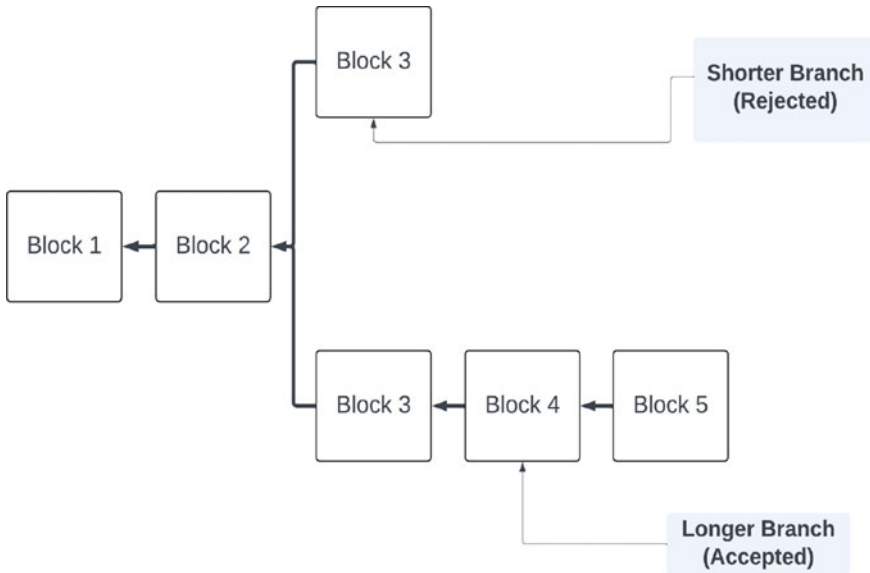
**Fig. 2** Merkle tree

blockchain, while other branches are discarded (Fig. 3). Although it is possible for branches to be created, it can be shown that the likelihood of multiple branches persisting decreases exponentially with increasing branch length.

### 1.5 Types of Blockchain

Blockchain is classified into three different kinds:

1. **Public Blockchain:** A public blockchain is an unrestricted system that allows anyone to participate in transactions and mining. It is commonly referred to as a permissionless blockchain, as it imposes no limitations on who can join or the actions they can perform. Participants are involved in reading and writing transactions, auditing the blockchain, and reviewing any part of it at any time. The blockchain is transparent and open, with no designated validator nodes. The entire blockchain is accessible to all nodes and synchronized to ensure its immutability [2].
2. **Private Blockchain:** A private blockchain allows a particular group of individuals or organizations to share and exchange data. The mining process is controlled by a single organization or a selected group of individuals, and nodes are allowed



**Fig. 3** Branching in blockchain

to participate based on a set of rules or the network's controlling authority. However, this approach can lead to centralization and differs from the original concept of complete decentralization and openness. Once the nodes become part of the network, they work collaboratively to maintain a decentralized network by keeping a copy of the blockchain and working together to achieve consensus for updates. However, in contrast to a public blockchain, only authorized users are permitted to write or make changes to the ledger [2].

3. **Consortium Blockchain:** A consortium blockchain shares characteristics of both public and private blockchains. It is not governed by a single entity, but instead, a predetermined group of nodes holds authority over it. This group of nodes is responsible for determining who can join the network and participate in mining, which makes it partially permissioned or private. In order to verify blocks, a multi-signature scheme is employed where a block is deemed valid only when authorized nodes sign it. The system is partially centralized because control is held by a selected group of validator nodes. This distinguishes it from private blockchains, which are entirely centralized, and public blockchains, which are fully decentralized [2].

## 1.6 *Properties of Blockchain*

Blockchain has several key properties including:

- **Decentralization:** Blockchain does not have any central authority. And a copy of the blockchain is mentioned by every node of the blockchain [3].
- **Transparency:** Blockchain technology is transparent because every node present within the blockchain network possesses a copy of the blockchain. All transactions are visible to all nodes [3, 6].
- **Immutability:** The blockchain is designed to be unchangeable. If any changes are made to the data in a block, it changes the current-block-hash. Each block contains the previous-block-hash. Therefore, any changes in one block will lead to changes in all the subsequent blocks. This makes it very difficult to change the data because every node on the network has its own copy of the blockchain [3].
- **Anonymity:** In a blockchain network, users have the ability to transact without disclosing their identities. This is achieved by using a set of public and private keys, which allow for secure interactions with the network. Additionally, a user may choose to use multiple sets of keys to further increase anonymity and make transactions more difficult to trace [3].

## 1.7 *Benefits of Blockchain*

Blockchain technology has brought numerous benefits that have revolutionized various industries across the globe. Here are five important blockchain benefits [7]:

### **Enhanced Security**

The immutable nature of blockchain technology makes it extremely secure. Each node in a blockchain network maintains a full and identical version of the ledger. This makes it extremely difficult to manipulate the data stored on the blockchain. Blockchain technology uses complex cryptographic algorithms to protect the transactions that are recorded on the blockchain. Blockchain technology operates in a decentralized manner, which eliminates the risk of a single point of failure. This makes it much more resilient to attacks and fraud. Even if some of the nodes in a blockchain network are compromised or go offline, the network will continue to function.

### **Greater Transparency**

Blockchain technology offers a significant benefit by providing increased transparency through the use of distributed ledger technology. With a copy of the distributed ledger being maintained by every node in the network, all transactions are viewable in real time. This enables all members of the network to monitor and verify each transaction, reducing the risk of fraudulent activity. By allowing all participants to view and monitor transactions in real time, blockchain technology creates an open

and transparent system that promotes trust among users. This transparency is especially critical in industries like finance, where trust and transparency are essential in establishing confidence in the system.

### **Instant Traceability**

Blockchain technology can help us track things like products, assets, or money from where they started to where they are now. This helps us to know if something is fake, if it was made in a good way and if it was transported safely. This is really useful in industries where people care about things like the environment or human rights.

### **Increased Efficiency and Speed**

Blockchain technology provides a faster and more efficient way to conduct transactions by eliminating paper-based processes, reducing errors, and removing the need for third-party intervention. This streamlining of processes can lead to quicker clearing and settlement. Blockchain's benefits can be particularly advantageous in industries like finance, supply chain management, and healthcare, where speedy and accurate transactions are essential for success. By adopting blockchain technology, businesses can enhance their operations, lower costs, and offer better customer service.

### **Automation**

Blockchain technology offers the potential to automate transactions using smart contracts. Smart contracts work without the need for intermediaries to verify the contract terms, enabling trustless and transparent execution of the contract terms. As a result, blockchain technology can reduce the need for human intervention, streamline processes, and increase transaction speeds. For instance, in the insurance industry, smart contracts can be used to automatically initiate the next step in a transaction or process once certain conditions are met, which can reduce the need for third-party verification of contract terms and expedite claims processing.

## ***1.8 Limitations of Blockchain***

The technology behind blockchain is still in its early stage of development and is facing various technical challenges and issues.

- **Scalability:** Blockchain, the technology used to store all transactions on a crypto network, is becoming increasingly difficult to scale with the increasing no of transactions. For instance, the Bitcoin blockchain now requires a storage capacity of over 100 GB. All transactions need to be recorded and verified, but the block size and the time it takes to create a new block limit its capacity. This means that it can only handle a small number of transactions in a given time, which is not enough to handle millions of transactions. Additionally, the limited block capacity leads to delays for smaller transactions, as miners prioritize those with

higher fees. Furthermore, owning and managing a blockchain requires a lot of computing power, making it a very resource-intensive process.

- **Privacy leakage:** Despite the fact that users only make transactions using their public and private keys, it has been demonstrated that privacy breaches can occur on blockchain networks. In certain instances, the real IP addresses of users may be traced, which could result in privacy violations [3].
- **51% attack:** Any entity or group controlling more than 51% of the computational power in a network may have the ability to manipulate the blockchain. By having such control, they could potentially reverse transactions and engage in double-spending, which is referred to as a 51% attack. This type of attack is a significant concern in the blockchain as it can compromise the integrity and security of the network [8].
- **Selfish mining:** Recent research has shown that even nodes with less than 51% computing power can pose a threat to the network. One such attack is known as selfish mining, where miners keep their mined blocks private until certain conditions are met, allowing them to outcompete honest miners who waste resources on a useless branch. As a result, honest miners are tempted to join the selfish miners, which may result in a situation where the selfish miner's control more than 51% of the total processing capacity on the network [3].

## 2 Literature Survey

### 2.1 Related Work

Gaetani et al. [4] proposed a framework to ensure data integrity in a cloud computing environment, specifically in federated cloud environments using blockchain technology. A cloud federation is a group of independent cloud computing providers that work together to provide a unified set of services to their clients. The goal of a cloud federation is to enable clients to access the resources of multiple cloud providers through a single interface, which can provide greater flexibility and scalability than any individual provider could offer on their own. The main goal of the proposed architecture is to maintain evidence of all operations performed on the database to guarantee data integrity. The framework comprises two layers, with the first layer focusing on performance, providing weak data integrity. In contrast, the second layer offers strong data integrity but poor performance. Cloud members carry out operations on the database through the database interface. The first layer of the blockchain records all operations with relevant evidence before performing them on the distributed database replicas. Each cloud member acts as a minor node in the blockchain network. On the first layer, the authors opted for a permissioned blockchain, which uses mining rotation consensus (MRCC) to reach consensus. In MRCC, time is split into rounds, with a minor elected as the leader in each round. The leader receives new operations, signs them with his/her private key, and broadcasts them to the rest of the miners. After all the miners have signed these operations,

they are added to the blockchain: every miner adds these operations to his local ledger. Because there is no Proof of Work on this layer, it has low latency, and high throughput, but low data integrity guarantees. The second layer utilizes a Proof of Work (PoW)-based blockchain. Periodically, transactions that contain a hash of the first-layer blockchain up to the latest operation are stored in the second-layer blockchain. These transactions are permanently recorded and serve as evidence to demonstrate the validity and integrity of the data stored in the first layer. However, the PoW mechanism used in this layer causes poor performance but improved data integrity. The integration of the two layers results in a significant enhancement in overall performance and provides reliable guarantees for the integrity of the data. Regarding security, compromising stored data requires a considerable effort that depends on the type of attack. For example, attackers would need to compromise the private keys of first-layer blockchain miners, which is unlikely to occur simultaneously in a FaaS environment. Furthermore, the anchoring of operations to the second-layer blockchain guarantees that only the most recent set of operations can be vulnerable to compromise, while all previous operations have indisputable and unalterable evidence. A significant limitation of the system is its availability, since each transaction requires signatures from all cloud members, making the entire system vulnerable to a single node failure.

Awadallah et al. [5] propose a design for maintaining data integrity and confidentiality in a cloud computing environment using a combination of blockchain (BC) technologies and homomorphic encryption (HE). Homomorphic encryption allows computations to be performed on ciphertexts without decrypting them first, which preserves the privacy of the data. The first step in their proposed architecture is the key generation for HE. A pair of private and public keys is generated by the data owner. The public key is shared with Cloud Service Providers (CSPs), while the private key is kept confidential by the owner. The data is encrypted with the public key before being sent to the cloud server. The encrypted data, along with the corresponding public key, is stored on the cloud server. When a request is made to run an operation on encrypted data, the cloud server uses the stored public key to perform the operation. The result is sent back to the user in encrypted form, which the user can then decrypt using the private key to obtain the original data. However, HE alone cannot guarantee complete data security. One potential problem is that CSPs are third-party entities, whom clients entrust with performing computational tasks. Due to the centralized nature of these computations and the CSP's ability to make changes to data, data integrity can be put at risk. To address these issues, the proposed architecture uses multiple CSPs and blockchain-based evidence storage. The client hires multiple CSPs, and after a certain number of operations, a master hash is generated for their database and stored in the blockchain. The rate at which a master hash value is produced and stored is determined by the rate of expansion of the client's data and their capacity to cover the costs of blockchain transaction fees. The authors assume that CSPs do not communicate directly with each other since they belong to different companies. However, if they can communicate with each other, malicious CSPs could collude and agree on the wrong information, resulting in faulty transactions. To prevent this, all the CSPs store their master hash value separately in

the blockchain. Once the master hash has been stored in the blockchain, it is crucial for the client to validate that all Cloud Service Providers (CSPs) have transmitted the same values. The client refers to the block headers that contain the transactions and compares the master hash values with similar timestamps. By comparing the master hash values received from each Cloud Service Provider (CSP), the client can detect any CSPs with malicious intent, as their hash values will be different from those of the others. The proposed scheme ensures confidentiality by default because the client should be using, HE when data is stored in the cloud and data integrity is achieved by using multiple cloud service providers and blockchain. The main drawback of this system is the cost and performance implications. Hiring multiple CSPs increases the cost substantially, as the client needs to pay for each CSP's services. Additionally, the proposed method does not offer any indication as to which specific data entries may have been subject to tampering or attack.

Ali et al. in [9] proposed the BCALS framework, which utilizes blockchain technology to tackle the difficulties associated with preserving and managing immutable logs in a fog computing environment. In today's world, accessing information system resources by cloud service providers can pose significant security threats to the integrity of stored information. Therefore, securing these resources is crucial to maintain a trustworthy environment. Audit logs are employed to observe the functioning of resources and track user activities, including those of administrators, in order to diagnose and address any potential issues that may arise. The system architecture consists of a fog environment with multiple fog units, each containing multiple IoT/Edge devices. Logs are useful information generated by IoT devices in fog units. In order to collect and manage the logs securely from the smart devices, each fog unit is equipped with a storage server for logs, which is located on its gateway. To optimize the log data size, administrative or security logs are separated from other less critical logs. This allows for the publication of critical log data on the blockchain. Meanwhile, other types of less important logs are handled at the gateway within the local fog environment. The logs obtained from IoT devices are transformed into machine-understandable data, enabling semantically aware logging. A permission-based blockchain of logs for each IoT unit is created and shared among all fog nodes. Each fog unit performs as a peer node of the blockchain. The use of distributed ledger technology provides an immutable and permissive architecture. If any changes occur within the chain, an immediate alert is generated to inform all stakeholders of the modification. This allows real-time monitoring of the system. The system incorporates Elasticsearch as an additional storage mechanism for logs, where logs are stored as JSON documents. This enables the use of any graph database or linked open data (LoD) for deeper analysis of the logs. To ensure the security and transparency of administrative logs, they are stored within the blockchain and are also made available through Elasticsearch. However, other types of logs are only published to Elasticsearch for efficient correlation and analysis. The proposed framework, BCALS, offers several strengths for secure and trustworthy log management. It leverages distributed ledger technology for secure and tamper-proof logging environments to protect against insider threats. The system architecture employs gateway-driven log collection, semantic-driven transformation, and a permission-based blockchain of



logs, which is shared across fog nodes. It provides data confidentiality, integrity, availability, immutability, and real-time access to statistics sharing.

Data provenance is a crucial aspect of cloud computing, which ensures the security and integrity of data by keeping track of all the changes made to it. However, existing systems lack transparency and security as the log information is kept at a private and centralized server. Tosh et al. in [10] presented a framework for establishing data provenance in cloud computing using blockchain technology. To ensure trust and immutability, the authors developed a distributed data provenance service, with interested cloud users serving as nodes in the blockchain network. Any changes made in the cloud are recorded as transactions and propagated to the blockchain network. The provenance information stored in these transactions is user-specific, which means that information about which user made which changes is stored in the transaction. To perform the broadcast operation, the user acquires the IP address of active blockchain nodes from the cloud service provider and broadcast the transaction to them. Transaction validation is performed by each blockchain node, which checks different attributes of the transaction to verify its validity. Invalid transactions are discarded, while valid transactions are combined by validators along with a timestamp, previous-block-hash, block height, Merkle tree root, and other information to form a block. The authors opted for Proof of Stake (POS) as a consensus mechanism instead of Proof of Work (POW) due to the time and performance limitations of POW. In the proposed model, a node's stake is a function of unutilized cloud resources, and the higher the stake a node has, the higher the probability that it will be selected as the leader in the next consensus process. Only the leader has the authority to add its block to the chain in a given consensus round. After the leader is selected, the leader broadcasts its block to other participant nodes in the network, who can authenticate the block by validating each transaction within it and reconstructing the Merkle tree. In addition to blockchain, provenance information is also stored in a provenance database that is controlled by a provenance auditor. The provenance database provides high-performance searching for data and can be used to identify malicious activity in the cloud. The proposed architecture is open and immutable, improving the users' trust. Although the proposed architecture has several advantages, there are also some disadvantages that should be considered. First, the use of Proof of Stake as a consensus mechanism may be subject to traditional POS limitations such as long-range attacks and nothing-at-stake problems. Additionally, in the proposed model, unutilized cloud resources are kept at stake, which may be exploited by malicious users who can purchase the maximum allowable cloud resources to increase their probability of being selected as the leader in the next consensus round. Second, a malicious attacker may invalidate prior transactions by bribing greedy nodes to work on a different branch of the blockchain or storing malicious data on the chain. The attacker can even compromise the leader selection process leading to significant implications for the overall security of the system. Third, blockchain nodes in a cloud computing environment may share the same hypervisor. A malicious actor can leverage side-channel attacks to determine which coincident users are participating in the blockchain consensus process. By doing so the adversary can interfere with the communication of co-resident participants and potentially impersonate their identity

to manipulate the block confirmation process in the attacker's favor. Additionally, the attacker can manipulate the states of coincident users to appear active or inactive, which could result in security vulnerabilities.

Yue et al. in [11] proposed a blockchain-based system, designed to ensure data integrity within a peer-to-peer cloud storage environment, where mutual trust between clients and cloud storage servers is lacking. The system consists of two phases: the preparation phase and the verification phase. In the preparation phase, the client divides their data into smaller parts called shards and creates a hash Merkle tree. This tree consists of a publicly accessible component that is uploaded to the cloud storage server, along with a privately held component that is securely stored locally by the client. The private part contains data shards and random challenges, digest (bottom 2 layers of the Merkle tree) and is used to validate each data shard when needed. The public part consists of the rest of the Merkle tree. The client and Cloud Storage Servers agree on the hash Merkle tree created, and the client records the Merkle tree root on the blockchain. The client then transfers the data and the public part of the Merkle trees to the cloud storage servers, and the servers provide the client with the address where the data is located. In the verification stage, the client sends a challenge number to the cloud storage server, which selects a specific part of the data to verify according to challenge no. The server calculates a hash digest for this part of the data using a hash function that takes both the data in the shard and a challenge number provided by the client as input. The Cloud Storage Servers transmit the digest and its relevant supplementary information to the blockchain. The smart contract implemented on the blockchain computes a new hash root and compares it with the original root. If the two values are equal, it confirms that the data's integrity is preserved. However, if the two values are not equal, it indicates that the data integrity has been compromised. Finally, the blockchain communicates the verification result back to the client. Verifying all data shards for data integrity is not feasible due to limited computation resources. In such cases, a random sampling strategy can be used to select a portion of the shards for validation. The repeated sampling method ensures that each shard has an equal probability of being chosen, which ensures fairness in the verification process. There are some limitations to this system. Firstly, the client may not know immediately if data integrity is compromised and will only be aware of the issue when performing data validation. Secondly, malicious clients could potentially modify the random number to lie about data integrity and extort money from servers. Thirdly, once the server receives the random number for verification, it can compute the hash digest and only store the digest and delete the original data shard. When the client requests verification again, it only requires sending the digest. This could potentially lead to false verification of data integrity.

## 2.2 Comparative Study

Data integrity attacks have been identified as the most dangerous and difficult to detect, and several solutions have been put forward to maintain data integrity and detect violations through various frameworks. In this section, we will compare and contrast different approaches to maintaining cloud security through blockchain, specifically approaches [4, 5, 9–11], and discuss their respective strengths and weaknesses. Approaches [4, 5] both involve multiple Cloud Service Providers (CSPs) for data storage and management. However, approach [4] has a single point of failure because each transaction needs to be signed by every node in the cloud federation. In contrast, approach [5] does not have a single point of failure because every node stores its hash separately to the blockchain. Approach [4] involves purchasing service from a Cloud Federation, so it does not have to bear the cost of hiring multiple CSPs. Approach [5] only stores the master hash values of the database, which is enough to track the violation of data integrity but cannot track which data have been modified. In contrast, approaches [4] and [9] store complete evidence of all operations, making it easier to determine which data entries have been modified by checking the logs. A similar approach is followed by [10] for data provenance. Approach [9] involves collecting logs from the gateway level in a fog environment, which means that the CSPs cannot tamper with the logs. In contrast, in the case of approaches [4, 5], log collection is performed by the CSP, and in approach [10], provenance information is collected by users of the CSP. Approaches [9] and [10] have a robust searching system for logs due to the presence of Elasticsearch and a provenance database, respectively, which approaches [4, 5] do not possess. Although approach [10] does not have a single point of failure and does not depend on fog nodes, it provides less data integrity guarantee compared to approach [4] due to the use of Proof of Stake instead of Proof of Work. Approach [5] ensures confidentiality through the use of a homomorphic encryption scheme, while approach [4] only focuses on data integrity since data integrity attacks are the most dangerous and difficult to detect. Approach [11] provides confidentiality by dividing the data into multiple shards and storing them in different locations. However, confidentiality can still be compromised since the data is not encrypted. Approach [11] proposes a blockchain-based system, designed to ensure data integrity within a peer-to-peer cloud storage environment. This framework is applicable for the verification of data integrity, but clients may not know immediately if data integrity is compromised.

The following table outlines the strengths and limitations of the different discussed approaches to maintaining cloud security through blockchain (Table 1).

**Table 1** Comparative study table

| Authors              | Key points  | Strengths  | Limitations  |
|----------------------|---|--|--|
| Gaetani et al. [4]   | The authors proposed a two-layer database model for FaaS using blockchain technology. The first layer uses mining rotation consensus to store evidence of all operations but has weak data integrity. The second layer is Proof-of-Work-based blockchain. The interaction of the two layers improves performance and ensures data integrity | The system effectively meets the desired requirements for data integrity, stability, and performance, ensuring reliable and quick storage of evidence for all operations performed on a distributed database | A significant limitation of the system is its availability, since each transaction requires signatures from all cloud members, making the entire system vulnerable to a single node failure  |
| Awadallah et al. [5] | The proposed design for verified computation combines CSP and blockchain technologies. The client hires multiple CSPs and computes master hash values of their databases, which are then stored on the blockchain. Through the comparison of hash value of the cloud service providers, the client can verify the computations              | The proposed system provides required data integrity through the verification of master hash values  | <ol style="list-style-type: none"> <li>1. The main drawback of this system is the cost and performance implications. Hiring multiple CSPs increases the cost substantially, as the client needs to pay for each CSP's services</li> <li>2. The proposed method does not offer any indication as to which specific data entries may have been subject to tampering or attack</li> </ol> |
| Ali et al. [9]       | The proposed secure log management framework uses a gateway-based system to categorize and filter logs in a fog environment. It employs a permissive blockchain to secure logs from tampering and provides immutability   | The BCALS framework provides strong information security, immutability, and analysis of user activities  | The system is highly dependent on fog nodes  |

(continued)

**Table 1** (continued)

| Authors          | Key points   | Strengths   | Limitations   |
|------------------|--|---|---|
| Tosh et al. [10] | The authors presented a framework for establishing data provenance in cloud computing using blockchain technology to ensure security and transparency. The system involves interested cloud users as nodes in the network uses Proof of Stake as a consensus mechanism, and stores provenance information in a database controlled by a provenance auditor   | It ensures security and transparency of data provenance in cloud computing, by using blockchain to store and share provenance information, and provides a high-performance searching capability for data by using a provenance database   | <ol style="list-style-type: none"> <li>1. Proof of Stake (POS) limitations such as long-range attacks and nothing-at-stake problems</li> <li>2. Potential side-channel attacks by malicious users to disrupt communication leading to security breaches</li> </ol>  |
| Yue et al. [11]  | The authors proposed a blockchain-based system, designed to authenticate data integrity within a peer-to-peer cloud storage environment. The system involves dividing data into shards, creating a hash Merkle tree, storing the public part on the cloud, and the private part locally. The verification stage involves the server calculating hash digest for a chosen shard, sending it to the blockchain, which confirms integrity | <ol style="list-style-type: none"> <li>1. The system divides data into smaller parts called shards, which enhances security and reduces the impact of data loss or corruption</li> <li>2. Utilizes blockchain technology to securely store the Merkle tree root and verification results</li> </ol> | <ol style="list-style-type: none"> <li>1. The client may not be aware of data integrity issues until performing data validation</li> <li>2. Malicious clients may tamper with the random number to deceive servers and extort money</li> <li>3. Servers can potentially delete original data shards after computing hash digests, which could lead to false verification of data integrity</li> </ol> |

### 3 Future Scope

The future scope for improving security in cloud computing using blockchain technology is vast and promising. As discussed in the previous sections, different approaches have been proposed to maintain data integrity and detect data integrity violations through different frameworks. However, these approaches have their limitations, and there is a need for more comprehensive and robust solutions.

In this regard, the following future scope can be considered for further research and development to enhance the security of cloud computing using blockchain technology.

### ***3.1 Integration of Different Approaches***

As different approaches have their strengths and weaknesses; it is possible to combine them to develop a more comprehensive and robust solution. For example, A hybrid approach can be developed by combining methods [4, 9, 10, 11]. This approach will utilize a two-layer mechanism to ensure the protection of data integrity. The first layer, similar to Method [4], will employ a permissioned blockchain to keep track of all operations performed in the federated cloud environment. This will provide an overall guarantee of data integrity in the cloud environment. The second layer, inspired by Method [11], will focus on verifying the integrity of individual data items stored in the cloud. Each data item will be divided into smaller parts called shards and stored across a distributed cloud environment. Additionally, a Merkle tree of the data items will be constructed and stored in the cloud. The root of the Merkle tree will be stored in the blockchain. To verify the integrity of a data item, the Merkle tree can be reconstructed, and the root can be recomputed. By combining these two layers, a stronger guarantee of data integrity can be achieved compared to relying solely on Method [4] or Method [11]. The members of the cloud federation will act as nodes in the blockchain network. To establish consensus among the cloud service providers (CSPs), the system will utilize a Proof of Stake mechanism, similar to Method [10], instead of the mining rotation consensus mechanism used in Method [4]. In [4] since each transaction requires signatures from all cloud members, the entire system is vulnerable to a single node failure. In the proposed approach, not every CSP needs to sign every transaction. Only the CSPs involved in a specific operation need to sign the transaction. Since all CSPs involved in the operation must be available to perform it, they can also sign the transaction, overcoming availability limitations. In method [10] a malicious actor can leverage side-channel attacks to determine which coincident users are participating in the blockchain consensus process. By doing so the adversary can interfere with the communication of co-resident participants and potentially impersonate their identity to manipulate the block confirmation process in the attacker's favor. In the proposed framework, the physical separation of cloud providers in this setup will eliminate the risk of side-channel attacks. The introduction of the Proof of Stake consensus mechanism represents an improvement over the mining rotation consensus of [4] as CSPs with higher stakes are more likely to be selected as leaders. To ensure data confidentiality, the system will incorporate homomorphic encryption, as proposed in Method [5]. This encryption technique will allow computations to be performed on encrypted data, preserving confidentiality while still allowing meaningful operations to be carried out. Similar to Method [9], the system will incorporate Elasticsearch as an additional storage mechanism for logs, alongside the blockchain. In this setup, logs will be stored as JSON documents,

enabling the utilization of various graph databases or linked open data (LoD) for in-depth analysis of the logs. By combining these methods, the proposed hybrid approach will provide enhanced data integrity guarantees, efficient consensus among CSPs, data confidentiality through homomorphic encryption, and the flexibility to leverage Elasticsearch and other databases for comprehensive log analysis.

### ***3.2 Development of Hybrid Consensus Mechanisms***

Approaches [4, 5, 10] use Proof of Work, mining rotation or Proof of Stake consensus mechanisms. Each of these mechanisms comes with its own strengths and limitations. To address these limitations and achieve a balance between performance and data integrity guarantees, a hybrid consensus mechanism can be developed, particularly suitable for cloud computing environments. The proposed hybrid approach will combine the advantages of both Proof of Stake and Proof of Work mechanisms. It aims to optimize data integrity, security, performance, and power consumption based on specific requirements. The process will involve alternating between PoS and PoW blocks after a certain number of proofs of stake blocks have been generated. The following points elaborate the working principle of the hybrid approach:

#### **Proof of Stake (PoS) Blocks**

Proof of Stake (PoS) significantly reduces power consumption compared to Proof of Work (PoW). In PoS, validators are chosen to create new blocks and validate transactions based on the number of coins or tokens they hold as collateral. The more tokens a validator has at stake, the higher their likelihood of being selected to validate transactions and create new blocks in the next consensus round. Unlike PoW, where miners must solve complex cryptographic puzzles, PoS block creation does not require resource-intensive mining processes. Instead, validators take turns proposing and validating blocks in a deterministic manner, determined by their stakes. This eliminates the need for energy-hungry computational calculations, which is the main cause of power consumption in PoW-based blockchains.

#### **Proof of Work (PoW) Blocks**

After a predefined number of PoS blocks have been added to the blockchain, a PoW block will be introduced. In this phase, miners will compete to solve complex cryptographic puzzles to validate transactions and add a new block to the blockchain. This adds an additional layer of security to the network.

#### **Ratio of PoS and PoW Block**

The ratio of PoS and PoW blocks will be adjusted based on the specific requirements of the cloud computing environment. If a high level of data integrity and security is needed, the system will increase the frequency of PoW blocks to enhance security measures. Conversely, if optimizing performance and reducing power consumption are the priorities, the ratio may shift toward more PoW blocks.

### **Transaction Validation**

For any transaction to be deemed valid, it must be signed by a certain percentage of nodes within the network. The required percentage will be customizable, depending on the specific requirements of the application. If the focus is on high data integrity and security, a higher percentage of nodes may be required to sign off on a transaction. On the other hand, if high availability is crucial, a lower percentage may be sufficient.

### **3.3 *Integration with Machine Learning Techniques***

Combining machine learning with blockchain-based data integrity solutions can greatly improve the accuracy and efficiency of the system in safeguarding data integrity and security. Blockchain ensures that data cannot be tampered once recorded, but it cannot analyze logs or detect data integrity issues on its own. By integrating machine learning algorithms into the blockchain-based data integrity systems within a cloud computing environment, we can use pattern recognition and anomaly detection to make the system better.

#### **Log Analysis**

In the cloud, a wide range of activities creates large logs that describe different interactions, transactions and data accesses within the system. Machine learning models can process and analyze those logs seamlessly, extracting important information that might otherwise go unnoticed. By diving into the deeper details contained within the logs, machine learning algorithms can identify patterns that offer valuable insights into the operation of the blockchain-backed data integrity system.

#### **Real-Time Threat Detection**

Over time, through continuous analysis, these algorithms can discover patterns that reveal a complete picture of normal system behavior. By using pattern recognition, which is based on the collection of historical information, the system can distinguish between normal behavior and abnormal behavior that could indicate a potential breach of data integrity. Machine learning algorithms can be trained to actively monitor the blockchain network and identify malicious nodes or malicious behavior in real time. This means that the system can keep a watchful eye on network behavior, comparing it to historical data. If a pattern deviates from what was expected, which could indicate an attempt to tamper with data or gain unauthorized access, the system immediately raises an alert.



## 4 Conclusion

In conclusion, this paper has presented a comprehensive exploration of the potential of blockchain technology in addressing security concerns in cloud computing. Cloud computing has undoubtedly transformed the way businesses operate, but it has also introduced significant security challenges, including data privacy, integrity, and availability issues. Blockchain, with its decentralized and tamper-proof nature, emerges as a promising solution to enhance cloud security. By providing a transparent and immutable ledger for data transactions, blockchain can instill trust and integrity in cloud-based systems. Its ability to offer secure digital signatures and maintain a distributed network of nodes ensures robust protection against unauthorized access and tampering.

Throughout the paper, we have highlighted the various components and properties of blockchain technology, demonstrating how it can be leveraged to fortify cloud security. Additionally, we analyzed existing works that have explored the integration of blockchain in cloud computing, revealing insights into their strengths and limitations. Despite its potential, there are still challenges that need to be addressed before blockchain can be widely adopted in cloud computing. Scalability, interoperability, energy efficiency, and privacy remain areas of active research and development to fully harness blockchain's capabilities in cloud security. Looking ahead, future research can explore innovative ways to integrate different approaches, such as combining machine learning techniques with blockchain, to create a more proactive and adaptive security system. Leveraging machine learning algorithms for real-time threat detection can significantly bolster the security of cloud computing environments.

Blockchain technology holds immense promise in revolutionizing cloud security, offering a secure, transparent, and decentralized framework for data protection. As the technology continues to evolve and researchers work toward overcoming the existing challenges, the integration of blockchain in cloud computing will undoubtedly play a crucial role in shaping a safer and more reliable digital landscape. Embracing blockchain's potential and collaborative efforts in research and development will pave the way for a more secure and resilient cloud computing ecosystem.

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# IoT-SyringeX: A Cutting-Edge Solution for Automated Injection Pumps



Komal Ashok Dhone, Sonali Joshi, and Sandeep Sonaskar

**Abstract** The IoT-SyringeX project presents a state-of-the-art solution for automating injection pumps through the integration of cutting-edge IoT technology. The objective of this project is to enhance the efficiency, accuracy, and safety of medical injection processes. Traditional manual injection methods are prone to human errors, inconsistent dosages, and delays in treatment administration. To address these challenges, the IoT-SyringeX system employs advanced sensors, actuators, and cloud connectivity to enable real-time monitoring and control of injection pumps. The core components of IoT SyringeX include a smart syringe pump module, a network of interconnected sensors, and a centralized cloud-based control system. The smart syringe pump module is designed to seamlessly integrate with existing injection devices, enabling automated and controlled dispensation of medication or fluids. The network of sensors, including pressure sensors, flow sensors, and position sensors, continuously monitors key parameters such as pressure levels, flow rates, and needle positioning. This real-time data is transmitted to the cloud-based control system, which employs sophisticated algorithms and machine-learning techniques to analyze and optimize the injection process. The IoT-SyringeX system offers several advantages over conventional manual injection methods. It ensures precise and consistent dosage delivery, minimizing the risk of dosage errors. Real-time monitoring and feedback enable healthcare professionals to proactively respond to any abnormalities or deviations during the injection process. Additionally, the cloud-based control system facilitates remote monitoring and management of multiple injection pumps, enhancing scalability and enabling centralized control in healthcare facilities. In conclusion, the IoT-SyringeX project represents a significant advancement in the field of automated injection pumps. By leveraging IoT technology, it

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revolutionizes the way injections are administered, providing an innovative, efficient, and secure solution for healthcare professionals. The system's ability to automate and monitor injection processes in real-time contributes to improved patient safety, precision, and overall quality of care.

**Keywords** IoT-SyringeX · Cutting-edge solution · Automated injection pumps · Inconsistent dosages · Delays in treatment administration · Sensors · Actuators · Cloud connectivity · Smart syringe pump module · Machine learning techniques · Abnormalities or deviations · Remote monitoring · Healthcare professionals · Quality of care. First section

## 1 Introduction

The IoT-SyringeX project introduces a cutting-edge solution for automated injection pumps by leveraging the power of Internet of Things (IoT) technology. This innovative system aims to revolutionize the administration of injections in healthcare settings, offering improved efficiency, accuracy, and safety. Traditional manual injection methods are often prone to human errors, inconsistent dosages, and delays in treatment administration, resulting in potential risks to patient health. The IoT-SyringeX project seeks to address these challenges by integrating advanced sensors, actuators, and cloud connectivity to enable real-time monitoring and control of injection pumps. The healthcare industry has witnessed significant advancements in medical devices and technologies that have transformed patient care. However, the administration of injections, a common medical procedure, still relies heavily on manual processes, leaving room for potential errors and inefficiencies. The IoT-SyringeX project seeks to bridge this gap by introducing a sophisticated and automated solution that enhances the accuracy, precision, and safety of injection pumps. The core concept of the IoT-SyringeX system revolves around the integration of IoT technology into the existing infrastructure of injection pumps. This integration enables the seamless communication and coordination of various components, ensuring optimal performance and control. The system comprises three main elements: the smart syringe pump module, a network of interconnected sensors, and a centralized cloud-based control system. The smart syringe pump module is designed to be easily attachable to existing injection devices, making it a versatile and adaptable solution for healthcare facilities. This module acts as the interface between the IoT-SyringeX system and the injection pump, enabling automated and controlled dispensation of medication or fluids. By incorporating advanced motor control mechanisms, the module ensures precise and consistent dosage delivery, minimizing the risk of dosage errors that may occur during manual injections. The network of interconnected sensors plays a critical role in the IoT-SyringeX system by continuously monitoring key parameters during the injection process. These sensors include pressure sensors, flow sensors, and position sensors, which provide real-time data regarding pressure levels, flow rates, and needle positioning. This wealth

of information enables healthcare professionals to closely monitor and analyze the injection process, ensuring that the medication or fluid is administered correctly and safely. The real-time data collected by the network of sensors is transmitted to the centralized cloud-based control system. This system serves as the brain of the IoT-SyringeX project, utilizing sophisticated algorithms and machine-learning techniques to analyze the data and optimize the injection process. The control system can detect abnormalities, deviations, or potential risks during the injection, providing healthcare professionals with immediate alerts and actionable insights. Additionally, the cloud-based architecture of the control system enables remote monitoring and management of multiple injection pumps, facilitating scalability and centralized control within healthcare facilities. One of the key advantages of the IoT-SyringeX system is its ability to provide accurate and consistent dosage delivery, thereby minimizing the risk of dosage errors. Manual injection methods are often subject to variations in dosage due to factors such as human error, improper technique, or fatigue. With the IoT-SyringeX system, healthcare professionals can have confidence in the precise and controlled administration of medication or fluids, ensuring optimal patient care. Furthermore, the IoT-SyringeX system enhances patient safety by enabling proactive responses to any abnormalities or deviations during the injection process. By continuously monitoring parameters such as pressure levels and flow rates, the system can detect potential issues in real time. Healthcare professionals can promptly intervene and take appropriate actions to mitigate risks, potentially preventing adverse effects or complications. The scalability and remote monitoring capabilities offered by the cloud-based control system are additional advantages of the IoT-SyringeX system. With the ability to manage multiple injection pumps from a centralized platform, healthcare facilities can streamline their operations and enhance efficiency. Remote monitoring allows healthcare professionals to oversee injection processes from any location, improving accessibility and facilitating timely interventions when necessary. In conclusion, the IoT-SyringeX project represents a significant advancement in the field of automated injection pumps by leveraging IoT technology. Through the integration of advanced sensors, actuators, and cloud connectivity, this cutting-edge solution offers enhanced efficiency, accuracy, and safety in the administration of injections. The precise dosage delivery, real-time monitoring, and proactive responses provided by the IoT-SyringeX system contribute to improved patient care and safety. By revolutionizing the way injections are administered, the IoT-SyringeX system has the potential to positively impact healthcare facilities, healthcare professionals, and ultimately, patient outcomes.

## 2 Literature Review

The implementation of IoT-based automated injection pumps represents a significant development in the field of healthcare technology. In recent years, there has been an increasing focus on utilizing IoT solutions to enhance medical processes,

and the administration of injections is no exception. This section presents a literature review of relevant studies and research articles that explore the application of IoT technology in automated injection pumps. Several studies have highlighted the limitations and challenges associated with traditional manual injection methods. The study [1] focuses on accurate dosage delivery and real-time monitoring. It develops an IoT-enabled solution that integrates advanced sensors, actuators, and a cloud-based control system. Through extensive testing, they demonstrate the effectiveness of the system in improving patient safety and the efficiency of injection processes. This research contributes valuable insights into the application of IoT in healthcare and the benefits it brings to automated injection pumps. The [2] explores the integration of IoT technology into automated injection pump systems in healthcare. The study demonstrates how leveraging IoT enhances real-time monitoring, data analysis, and remote accessibility. This integration improves dosage accuracy, enhances patient safety, and streamlines healthcare operations. The research highlights the significant potential of IoT technology in revolutionizing automated injection pump systems and advancing healthcare practices. The [3] presents the development of a smart syringe pump integrated with IoT technology. The study focuses on ensuring accurate dosage delivery in healthcare. By incorporating advanced sensors, actuators, and cloud connectivity, the system enables real-time monitoring of key parameters during the injection process. The findings demonstrate the superiority of the IoT-enabled syringe pump in terms of precision and reliability compared to manual methods. This research contributes to the advancement of syringe pump systems, offering improved accuracy and reliability in healthcare settings. The [4] discusses the enhancement of efficiency and safety in injection processes through IoT-based automated pump systems. The study highlights the use of IoT technology to improve the accuracy and reliability of pump systems used in healthcare. By integrating IoT capabilities, such as real-time monitoring and data analysis, the automated pump systems offer increased efficiency and enhanced safety in administering injections. The findings emphasize the positive impact of IoT-based automation on healthcare processes, leading to improved patient outcomes and streamlined operations. The [5] focuses on the implementation of IoT-driven smart syringe pumps to improve medication administration. The study emphasizes the use of IoT technology to enhance the accuracy and safety of medication delivery. By integrating smart capabilities, such as real-time monitoring and remote accessibility, the smart syringe pumps offer improved medication administration processes. The findings highlight the benefits of IoT-driven automation in healthcare, including increased precision, enhanced patient safety, and streamlined medication management. The research contributes to the advancement of healthcare technology by demonstrating the positive impact of IoT-driven smart syringe pumps on medication administration. The [6] explores the use of IoT-based automated injection pumps for enhanced medication management. The study highlights the application of IoT technology to improve the efficiency and safety of medication administration. By integrating IoT capabilities into automated injection pumps, the system offers real-time monitoring, data analysis, and remote accessibility. The findings emphasize the benefits of IoT-based automation in healthcare, including improved medication management, enhanced patient

safety, and streamlined processes. The research contributes to the field of biomedical engineering and informatics by demonstrating the potential of IoT-based automated injection pumps for medication management. The [7] study emphasizes the integration of IoT technology into syringe pumps to enhance accuracy and dosage control. By leveraging IoT connectivity, the smart syringe pump enables real-time monitoring and remote accessibility. The findings highlight the benefits of IoT connectivity in improving dosage delivery, ensuring precision, and enhancing patient safety. The research contributes to the field of industrial Internet of things (IIoT) by demonstrating the potential of smart syringe pumps with IIoT connectivity for precise and controlled medication administration. The [8] focuses on the development of an IIoT-enabled syringe pump for enhanced injection process control. The study emphasizes the integration of IIoT technology into syringe pumps to improve the accuracy and control of the injection process. By incorporating IIoT capabilities, such as real-time monitoring, data analysis, and remote control, the IIoT-enabled syringe pump offers precise and controlled medication administration. The findings highlight the benefits of IIoT integration in enhancing injection process control, ensuring accurate dosage delivery, and improving patient safety. The research contributes to the field of IIoT-enabled healthcare devices by demonstrating the potential of IIoT-enabled syringe pumps for enhancing the injection process and advancing healthcare practices. The [9] focuses on the integration of IIoT and cloud computing in automated injection pump systems. The study emphasizes the utilization of IIoT and cloud technologies to enhance the functionality and capabilities of automated injection pumps. By integrating IIoT sensors and cloud computing, the system enables real-time data collection, analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved monitoring, timely interventions, and efficient resource allocation. The research contributes to the field of computer science and software engineering by demonstrating the potential of integrating IIoT and cloud computing in automated injection pump systems for enhanced performance and functionality. The [10] presents a cloud-based IIoT architecture for smart syringe pump systems. The study focuses on the design and implementation of an architecture that leverages cloud computing and IIoT technologies to enhance the functionality and capabilities of syringe pump systems. By utilizing cloud-based infrastructure, the system enables real-time data processing, storage, and analysis. The findings highlight the benefits of this cloud-based IIoT architecture, including improved scalability, accessibility, and efficiency in managing syringe pump systems. The research contributes to the field of cloud computing and big data analysis by demonstrating the potential of cloud-based IIoT architectures for smart syringe pump systems, offering enhanced performance and functionality. The [11] focuses on the design and development of an IIoT-enabled automated injection pump for improved patient care. The study emphasizes the integration of IIoT technology into automated injection pumps to enhance patient care and safety. The researchers describe the design process and functionality of the IIoT-enabled pump, which includes real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, such as accurate dosage delivery, proactive responses to anomalies, and streamlined healthcare operations. The research contributes to the field of computer applications by showcasing

the potential of IoT-enabled automated injection pumps in improving patient care and enhancing the overall healthcare experience. The [12] focuses on the real-time monitoring and control of automated injection pumps using IoT technology. The study highlights the integration of IoT technology into automated injection pumps to enable real-time monitoring and control capabilities. By incorporating sensors, actuators, and IoT connectivity, the system facilitates continuous monitoring of critical parameters during the injection process. The findings emphasize the benefits of real-time monitoring and control, including improved accuracy, timely interventions, and enhanced patient safety. The research contributes to the field of distributed sensor networks by showcasing the potential of IoT technology in enhancing the monitoring and control of automated injection pumps, thereby improving the overall healthcare experience. The [13] researchers describe the design and functionality of the smart syringe pump, which incorporates IoT capabilities such as real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved dosage accuracy, timely interventions, and enhanced patient safety. The research contributes to the field of medical and biological engineering by showcasing the potential of IoT-enabled smart syringe pumps in improving medication administration practices and optimizing patient care. The [14] presents an IoT-enabled smart syringe pump for accurate and controlled injection. The study focuses on the integration of IoT technology into syringe pumps to enhance the precision and control of medication administration. The researchers describe the design and implementation of the smart syringe pump, which incorporates IoT capabilities such as real-time monitoring, data analysis, and remote control. The findings highlight the benefits of this integration, including improved dosage accuracy, controlled injection rates, and enhanced patient safety. The research contributes to the field of IoT and highlights the potential of IoT-enabled smart syringe pumps for accurate and controlled medication injection, leading to improved patient outcomes and better healthcare practices. The study [15] emphasizes the integration of IoT technology into injection pumps to improve medication management processes. It describes the design and functionality of the smart injection pumps, which leverage IoT capabilities such as real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved medication tracking, timely notifications, and enhanced patient safety. The research contributes to the field of convergence information technology by showcasing the potential of IoT-based smart injection pumps in enhancing medication management and optimizing patient care. The [16] focuses on the development of an IoT-enabled automated injection pump for improved medication safety. The study emphasizes the integration of IoT technology into automated injection pumps to enhance medication safety. It describes the design and implementation of the IoT-enabled pump, which incorporates real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved medication tracking, proactive alerting, and enhanced patient safety. The research contributes to the field of medical informatics by showcasing the potential of IoT-enabled automated injection pumps in improving medication safety practices and optimizing healthcare delivery. The [17] focuses on an IoT-based smart syringe pump system for enhanced



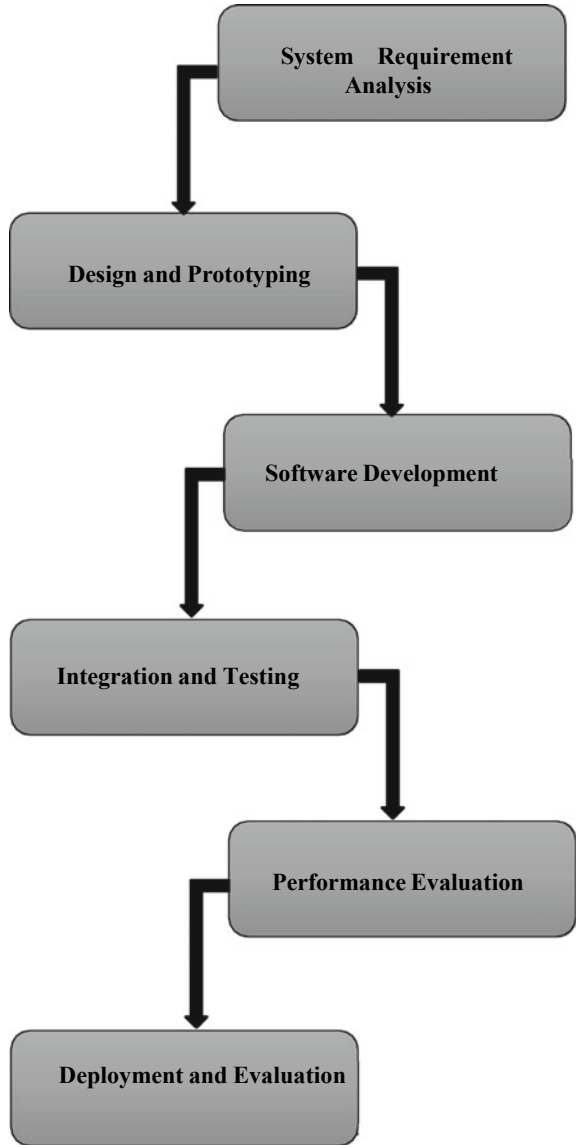
drug delivery. The study emphasizes the integration of IoT technology into syringe pumps to improve drug delivery processes. It describes the design and implementation of the smart syringe pump system, which incorporates IoT capabilities such as real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved drug administration accuracy, personalized drug dosing, and enhanced patient care. The research contributes to the field of biomedical engineering and informatics by showcasing the potential of IoT-based smart syringe pump systems in enhancing drug delivery methods and optimizing healthcare practices. The [18] focuses on the design and implementation of an IoT-enabled syringe pump with real-time monitoring. The study emphasizes the integration of IoT technology into syringe pumps to enable real-time monitoring capabilities. The researchers describe the design and functionality of the IoT-enabled syringe pump, which incorporates sensors and IoT connectivity to facilitate real-time monitoring of key parameters during the injection process. The findings highlight the benefits of this integration, including improved accuracy in dosage delivery, timely detection of anomalies, and enhanced patient safety. The research contributes to the field of medical devices by showcasing the potential of IoT-enabled syringe pumps with real-time monitoring capabilities in optimizing the injection process and improving patient care. The study [19] emphasizes the utilization of IoT technology to enhance the accuracy and efficiency of medication administration processes. It describes the design and implementation of the IoT-driven automated injection pump system, which incorporates real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this system, including improved medication dosage accuracy, timely alerts for anomalies, and enhanced patient safety. The research contributes to the field of biomedical and health informatics by showcasing the potential of IoT-driven automated injection pump systems in optimizing medication administration practices and improving healthcare outcomes. The [20] focuses on the design and development of an IoT-based automated injection pump for enhanced patient care. The study emphasizes the integration of IoT technology into injection pumps to improve patient care and safety. The researchers describe the design and functionality of the IoT based automated injection pump, which incorporates real-time monitoring, data analysis, and remote accessibility. The findings highlight the benefits of this integration, including improved accuracy in dosage delivery, proactive alerts for anomalies, and enhanced patient safety. The research contributes to the field of electronics and communication engineering by showcasing the potential of IoT-based automated injection pumps in enhancing patient care and optimizing healthcare delivery. Overall, the reviewed literature supports the concept of IoT-based automated injection pumps as a promising solution for improving the efficiency, accuracy, and safety of injection processes. The integration of IoT technology enables real-time monitoring, proactive responses to anomalies, and remote access for healthcare professionals. Additionally, the potential for machine learning algorithms to optimize dosage delivery holds great promise for personalized and tailored patient care. These findings lay the foundation for the development and implementation of the IoT-SyringeX system, contributing to the advancement of healthcare technology and patient safety.

### 3 Methodology

The purpose of the IoT-SyringeX project is to introduce a cutting-edge solution for automated injection pumps that leverages Internet of Things (IoT) technology. The project aims to address the limitations and challenges associated with traditional manual injection methods in healthcare settings. The primary purpose of the project is to enhance the efficiency, accuracy, and safety of injection processes. Manual injections are prone to human errors, inconsistent dosages, and delays in treatment administration, which can potentially harm patients. The IoT-SyringeX system seeks to overcome these challenges by automating the injection process and providing real-time monitoring and control. By incorporating IoT technology, the project enables seamless integration of advanced sensors, actuators, and cloud connectivity into the injection pumps. This allows for continuous monitoring of key parameters such as pressure levels, flow rates, and needle positioning, ensuring accurate and precise dosage delivery. Another purpose of the IoT-SyringeX project is to improve patient safety. The system's real-time monitoring capabilities can detect abnormalities or deviations during the injection process and provide immediate alerts to healthcare professionals. This enables proactive responses and interventions to mitigate risks and prevent adverse effects or complications. Additionally, the project aims to streamline healthcare operations by enabling remote monitoring and centralized control of multiple injection pumps through the cloud-based control system. This enhances scalability, accessibility, and efficiency in healthcare facilities, facilitating effective management and allocation of resources. The methodology employed for the implementation of the IoT-SyringeX system involves a systematic approach to ensure the successful development and deployment of cutting-edge solutions for automated injection pumps. The following points outline (in Fig. 1) the main procedures involved in the methodology: (1) System Requirement Analysis: The first step is to conduct a thorough analysis of the requirements of the IoT SyringeX system. This includes understanding the needs of healthcare facilities, identifying the key functionalities, and defining the performance criteria for the automated injection pumps.

Requirements may include aspects such as dosage accuracy, real-time monitoring, remote accessibility, and integration with existing medical systems. (2) Design and Prototyping: Based on the system requirements, the next step is to design the architecture and components of the IoT-SyringeX system. This includes designing the smart syringe pump module, and selecting appropriate sensors, actuators, and communication protocols. Prototyping is then carried out to test and validate the design before moving to the production phase. Prototyping helps in identifying any design flaws or potential improvements early in the development process. (3) Software Development: The software development process involves developing the necessary firmware for the smart syringe pump module and the cloud-based control system. This includes programming the motor control mechanisms, data acquisition algorithms, real-time monitoring, and data analysis functionalities. The software is designed to provide seamless integration between the smart syringe pump

**Fig. 1** Steps involved in main procedure



module, sensors, and the centralized control system. (4) Integration and Testing: Once the hardware and software components are developed, integration of the different elements is performed. This includes connecting the sensors to the smart syringe pump module and establishing communication with the cloud-based control system. Extensive testing is conducted to ensure the functionality, reliability, and security of the system. Various tests are performed, such as stress testing, usability testing, and simulation of different injection scenarios to verify the system's performance

(Fig. 1). Steps involved in Main Procedure. (5) Performance Evaluation: The performance of the system is evaluated using various metrics and criteria defined during the requirement analysis stage. This includes assessing the accuracy and consistency of dosage delivery, monitoring response time, and evaluating the system's ability to detect and respond to anomalies during the injection process. Performance evaluation may involve conducting experiments, collecting data, and comparing the results with established benchmarks or industry standards. (6) Deployment and Evaluation: The final step involves deploying the IoT-SyringeX system in a real-world healthcare setting. This includes working closely with healthcare professionals to ensure proper installation, training, and adoption of the automated injection pumps. The system's performance and user feedback are continuously evaluated to identify any improvements or modifications required. Feedback from healthcare professionals and patients helps in refining the system's design and addressing any usability or functionality issues that may arise. Each of these main procedures is crucial for the successful implementation of the IoT-SyringeX system. It ensures that the system meets the requirements of healthcare facilities, provides accurate and reliable dosage delivery, and enhances the overall efficiency and safety of injection processes. In conclusion, the methodology employed for the development and implementation of the IoT-SyringeX system follows a systematic and comprehensive approach. The main procedures outlined in the methodology, including system requirement analysis, design and prototyping, software development, integration and testing, performance evaluation, and deployment and evaluation, collectively ensure the successful realization of this cutting-edge solution for automated injection pumps. The methodology emphasizes the importance of understanding the specific requirements of healthcare facilities and stakeholders, which serves as the foundation for the design and development process. The iterative approach, involving prototyping and user feedback, ensures that the system meets the needs of healthcare professionals, guarantees accurate and reliable dosage delivery, and enhances the overall efficiency and safety of injection processes. The integration of IoT technology, including advanced sensors, actuators, and cloud connectivity, enables real-time monitoring, centralized control, and remote access to the injection pumps. This integration is supported by robust software development, encompassing firmware for the smart syringe pump module and the cloud-based control system. Extensive testing is conducted to validate the functionality, reliability, and security of the system, and its performance is evaluated against predefined metrics and criteria. The deployment and evaluation stage involves the real-world implementation of the IoT-SyringeX system, ensuring proper installation, user training, and continuous monitoring of its performance. User feedback and real-world data contribute to the refinement of the system's design, addressing any usability or functionality issues that may arise. Through this methodology, the development and implementation of the IoT-SyringeX system prioritize meeting the requirements of healthcare facilities, ensuring accurate and reliable dosage delivery, and enhancing the overall efficiency and safety of injection processes. The systematic approach ensures a well-structured and robust development process, leading to the successful and effective realization of this cutting-edge solution in healthcare settings.

## 4 Discussion

The implementation of the IoT-SyringeX system, a cutting-edge solution for automated injection pumps, presents significant advancements in the field of healthcare technology. By leveraging IoT technology, this system offers several key benefits, including improved efficiency, accuracy, and safety in the administration of injections. One of the main advantages of the IoT-SyringeX system is its ability to ensure accurate and precise dosage delivery. Traditional manual injection methods are prone to human errors, such as incorrect dosage calculation, misinterpretation of instructions, and improper administration techniques. These errors can have serious consequences for patient health. However, by automating the injection process, the IoT SyringeX system eliminates the variability and inconsistencies associated with manual administration. The smart syringe pump module, integrated with advanced motor control mechanisms, ensures the precise and controlled dispensation of medication or fluids, minimizing the risk of dosage errors and optimizing patient care. Real-time monitoring and control are key features of the IoT SyringeX system. Through the integration of sensors, including pressure sensors, flow sensors, and position sensors, healthcare professionals can continuously monitor crucial parameters during the injection process. This real-time data is transmitted to the cloud-based control system, which employs sophisticated algorithms and machine-learning techniques to analyze and optimize the injection process. The system can detect anomalies, deviations, or potential risks and provide immediate alerts to healthcare professionals. This proactive response enables prompt intervention and mitigation of risks, reducing the likelihood of adverse effects or complications. Furthermore, the IoT-SyringeX system offers scalability and remote monitoring capabilities. With the cloud-based control system, healthcare facilities can remotely monitor and manage multiple injection pumps from a centralized platform. This centralized control enhances operational efficiency, allowing healthcare professionals to have a comprehensive overview of the injection processes in real time. Additionally, remote monitoring enables timely interventions, regardless of the physical location, improving accessibility and facilitating efficient resource allocation. Data privacy and security are of paramount importance in the healthcare industry. The IoT-SyringeX system incorporates robust security measures to protect patient information and ensure system integrity. Data encryption, access controls, and secure communication protocols are implemented to safeguard sensitive data, maintaining confidentiality and compliance with data protection regulations. In conclusion, the IoT-SyringeX system represents a significant advancement in the field of automated injection pumps. By leveraging IoT technology, it enhances the efficiency, accuracy, and safety of injection processes. The precise dosage delivery, real-time monitoring, and proactive responses provided by the system contribute to improved patient care and safety. The scalability, remote monitoring, and robust security measures further enhance its effectiveness and applicability in healthcare settings. The IoT-SyringeX system has the potential to revolutionize the administration of injections, providing a cutting-edge solution that improves the overall efficiency and quality of healthcare services.

## 5 Conclusions

In conclusion, the IoT-SyringeX system emerges as a pioneering solution that leverages IoT technology to address the limitations of traditional manual injection methods in healthcare. By automating the injection process and integrating real-time monitoring and control, the system enhances the efficiency, accuracy, and safety of injections. The precise dosage delivery, proactive response to anomalies, and remote accessibility contribute to improved patient care and outcomes. Moreover, the scalability and centralized control offered by the cloud-based system streamline healthcare operations and resource management. The robust security measures ensure data privacy and system integrity, instilling confidence in healthcare professionals and patients alike. The successful implementation of the IoT-SyringeX system paves the way for transformative advancements in automated injection pumps, setting a new standard for precision, efficiency, and patient safety in healthcare settings. As the field of IoT-enabled healthcare technologies continues to evolve, the IoT-SyringeX system serves as a testament to the potential of innovative solutions in improving healthcare delivery and patient outcomes. With ongoing research, development, and user feedback, the IoT-SyringeX system has the potential to revolutionize the administration of injections, making a significant impact in the healthcare industry and improving the overall quality of patient care.

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# Enhanced Change Detection Analysis of Urban Land Use and Land Cover in Vijayawada City: Integrating Artificial Neural Networks and Mahalanobis Distance Classification



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**Abstract** The main goal of the study is to find out the changes that are occurring on the land due to the change of surface cover by its use during the period 2001 to 2020 for Vijayawada city, Andhra Pradesh. This is found by doing digital image processing using two different classifiers Artificial Neural Networks (ANN) and Mahalanobis-Based Distance (MBD)-based novel supervised classification and comparing both to find which is more accurate. For digital image processing, satellite images downloaded for image classification from the United States Geological Survey (USGS) are used as the samples. The samples are downloaded for three different years 2001, 2011, and 2020 consisting of the urban study region. Images were acquired from both Landsat 7 ETM+ and Landsat 8. Two groups of classifiers and three samples for each group totaling to six samples were used to test the accuracy. With pre-test power at 80%, alpha at 0.05 and CI at 95%, a statistical examination was done. A p value of 0.13 denotes that there is no significant difference between the groups. The percentage of broadly classified six regions are found by doing novel supervised classification by both the algorithms and noted down. The analysis is done for the key outputs overall accuracy (OA) and kappa coefficient (KC). The obtained OA is  $97.10 \pm 1.61$  as mean and SD for ANN,  $92.49 \pm 6.76$  as mean and standard deviation for MBD. For KC,  $0.93 \pm 0.05$  is derived as mean and standard deviation for ANN,  $0.8574 \pm 0.1539$  as mean and SD for MBD classification, respectively. Artificial Neural Networks are the best approach to find the land cover changes using the satellite images compared to the Mahalanobis distance-based classification from the results of the research.

**Keywords** Artificial Neural Networks · Mahalanobis distance · Land use · Land cover · Vijayawada city · Novel supervised classification · Digital image processing · Image classification

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## 1 Introduction

Land cover changes are one of the most visible factors that are responsible for the global environmental changes; these changes are dependent on the use of land in the region. This causes effects on pollution of drinking water, air, temperature, ground water level, etc. Land use/land cover change is the result of environmental and economic status of the region with respect to time and space [7]. The study of these environmental changes by digital image processing is very much useful for proper planning of natural resources such as water and electricity to society [1]. There are various applications on these land use changes such as altering the grazing practices [2]. These land cover change images are also used for monitoring the drinking water quality in ponds and canals [11].

In the past few years, a lot of research has been done on land use land cover changes by digital image processing. There are around 62 papers that are published in Science Direct and 2350 papers are available in Google Scholar. It can be observed that LULC is fully being urbanized and the area for agriculture has been gradually reduced; this results in an increase in the demand for the agricultural products [14]. Due to the changes happening in land use and land cover, this has affected land management practices [9]. Based on the past land cover images some researchers had found the future map of the Vijayawada city using digital image processing and algorithms like land change modeler which is very useful for future developments [1]. According to my opinion, the best study which suits this research is the image classification of land use/land cover images had a very important role in development of any region.

A number of studies were carried out that promises multi-disciplinary research in our institute (Valsalan Dhaya chandhran Saravanan Indiramma, Sudharani, and Needhidasan Ezhilarasan Chupradit Venu and Appavu Prabhu Raja) (Valsalan Dhaya chandhran Saravanan Indiramma Ezhilarasan Chupradit Venu and Appavu Prabhu). Though the land cover changes were made using many algorithms, it was not determined by making a comparison between ANN and MDB between the years 2001 and 2020; thus, this paper deals with those comparisons and finds which algorithm is best between the two. Many researches have been carried out LULC changes happening in Vijayawada city by digital image processing. Therefore, the objectives of this study are multifold. On performing two different image classification, the results are compared to identify the better off between the ANN and MBD classifiers for Vijayawada city by taking into account images from three different years.

## 2 Materials and Methods

This study was carried out in RSGIS laboratory, Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (SIMATS). Since no human samples are used in this study, ethical approval

is not required. In general, this study contrasts two algorithms: Artificial Neural Networks and Mahalanobis distance-based novel supervised categorization and for the study, three samples from each of 2 group were taken from three different years separated by a decade with total sample size of 6 [10]. The pre-test power is set at 80% with the alpha value of 0.05 and confidence interval of 95%. The test is set up using ENVI, and the system hardware requirements are an Intel i5 5th generation processor with 8 GB of RAM with Windows 10 as the operating system.

Vijayawada is a historical city in the state of Andhra Pradesh, located at latitude 16 03 11 N and longitude 80 03 91 E. It has a tropical climate with scorching summers and mild winters. In May–June, the highest temperature reaches 47 degrees Celsius, while the winter temperature ranges from 20 to 27 degrees Celsius. On an average, annual rainfall is 103 cm, and humidity is 78 percent. The topography is flat, with a few tiny and medium-sized hills.

Satellite photos were utilized as references. USGS earth explorer contains satellite images of the planet from many years and from various satellites; therefore, it is used to download photographs of our study region in the required timeframe. The first sample data comes from the Landsat 7 satellite, which was obtained from the USGS on March 5, 2001, and shows the Vijayawada region with less than 5% cloud cover. Basically, the Landsat 7 data comprises stripes that are caused by the satellite's scan line error, which causes 25% of the data to be lost. After the image is layers stacked for image classification, these stripes are filled with relevant data using envi software. Landsat 7 has eight bands (bands 1–8) in which band 2, band 3, and band 4 layers are overlaid, and Landsat 8 has (bands 1–11), bands 3, 4, 5 are stacked for our use.

The approach used for preprocessing group 1 samples is repeated for group 2 sample preparation. For the novel supervised classification, pre-processed data is used. First, the exact study region is extracted from a map downloaded from the USGS, then RGB bands are changed and a false color combination is set, then the image is stretched and adjusted accordingly to identify the features present in the map clearly, and finally, the different regions, i.e., built up region, water, vegetation, barren land, hilly region, and wetland are identified and marked as regions of interest by selecting a few pixels from each of the regions and assigning various colors to each of them, an algorithm is used to categorize the entire image according to the ROIs chosen, and as the output classified image is produced.

The Vijayawada city is cut out from the Vijayawada classified region map using the Vijayawada vector file, and the percentages of different regions are taken for the classified picture the same process is repeated for all the samples, and land use change is determined. ENVI, an image processing software is utilized for the image classification of the satellite images. The outputs are OA, and KC and these are

in turn, utilized as input for analysis, and the algorithm with the highest values is regarded to be correct.

### Statistical analysis

With OA and KC as the output for the study, an independent samples-t-test was performed in order to compare the significance between the two classifiers statistically. For this, SPSS version 26 was used, and the two groups Artificial Neural Networks and Mahalanobis distance-based classification were contrasted.

## 3 Results

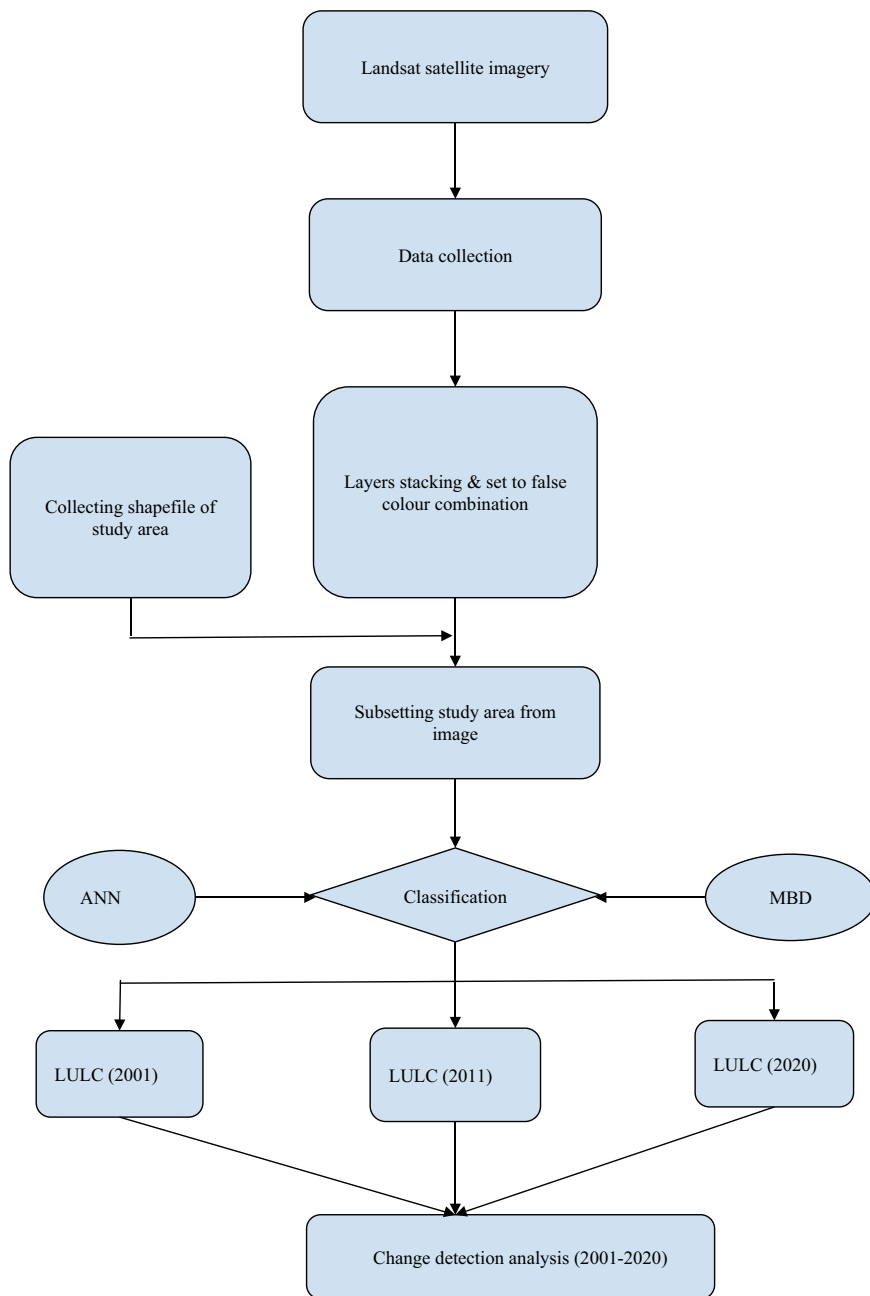
The results which are obtained from our research are noted down below. The algorithms used here are ANN and MBD. Figure 1 denotes the methodology adopted for the study. Figures 2, 3, and 4 denote the classified images from ANN classifier for the years 2001, 2011, and 2020, respectively, whereas Figs. 5, 6, and 7 denote the classified images from the MBD classifier for the aforementioned years. Figures 8 and 9 represent the percentage of change in the LULC in the study region for the years 2001, 2011, 2020 using ANN and MBD, respectively.

Table 1 represents the outputs of overall accuracy and kappa coefficient that is obtained from the two different algorithms for the years 2001, 2011, and 2020. From Fig. 10, it is clear that ANN performed better than MBD in terms of overall accuracy but there is no significant difference between groups. Figure 11 represents the graphical representation of the kappa coefficient, which is confirmed by statistical analysis software SPSS; hence, it is considered. Table 2 and Table 3 represent the statistical output.

## 4 Discussion

Land use land cover change of different regions like urban, vegetation, water, hilly, barren land, wet land of the Vijayawada city are analyzed by both the algorithms Artificial Neural Networks and Mahalanobis distance-based novel supervised classification it can be observed that ANN performed better that MBD and the output accuracies are also verified by SPSS software [5].

Figure 1 represents the method that is used to do the research [8]. The article which supports the present research is [3] which tells us that ANN is the best for finding land cover changes than other algorithms and gives us good accuracy, whereas if we see the graphical representation in MBD class if there is mismatch in image classification of regions of barren land and hilly regions if we see in graphical representation it is very clear that the regions are predicted accurately by ANN. From one the research, it is shown that Mahalanobis distance-based classification is less accurate than other [13], but we have achieved accuracy which is very near to ANN which opposes our



**Fig. 1** Flowchart showing the methodology framed for the change detection analysis performed in this research

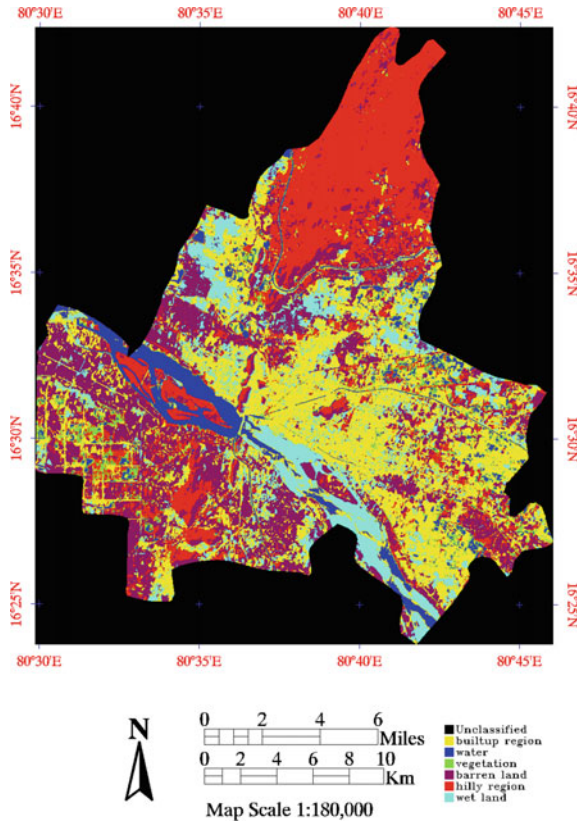


Fig. 2 Output from the ANN classification for the study region for the year 2001

research [6] strongly accepts that ANN is very easy and gives very accurate results for doing change detection analysis by satellite images. MBD also gives accuracy of around 89% which can also be considered as the best [12]. From one of the research studies, it shows that they have achieved accuracy as 78% which is not bad [16]. But from verifying the whole we can say that ANN is a better way to find land cover changes as well as MBD.

This research is done by ignoring the climate and season which has the greater effect on land cover as the sample in winter season contains more vegetation than the sample in summer, this should be considered and further research can be continued for accurate results [4]. And this research is only limited to level 1 novel supervised classification, whereas this research can be continued by doing level 2 image classification by using high resolution data and are of the latest satellites.

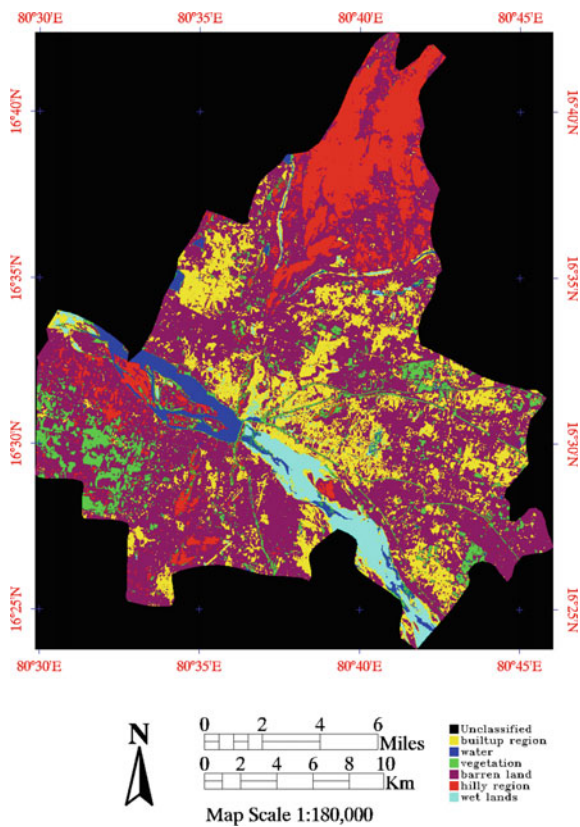
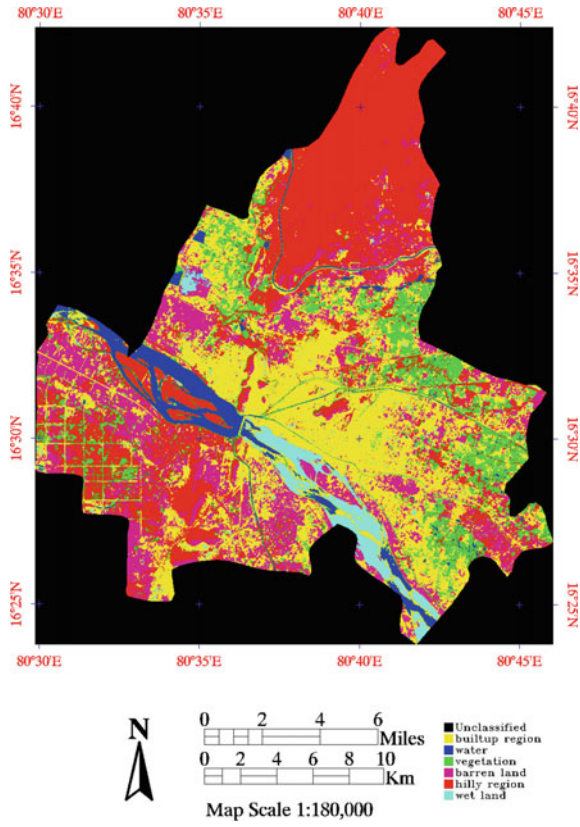


Fig. 3 Classified map for Vijayawada city with help of ANN algorithm for 2011



**Fig. 4** ANN classified image of Vijayawada city for the year 2020

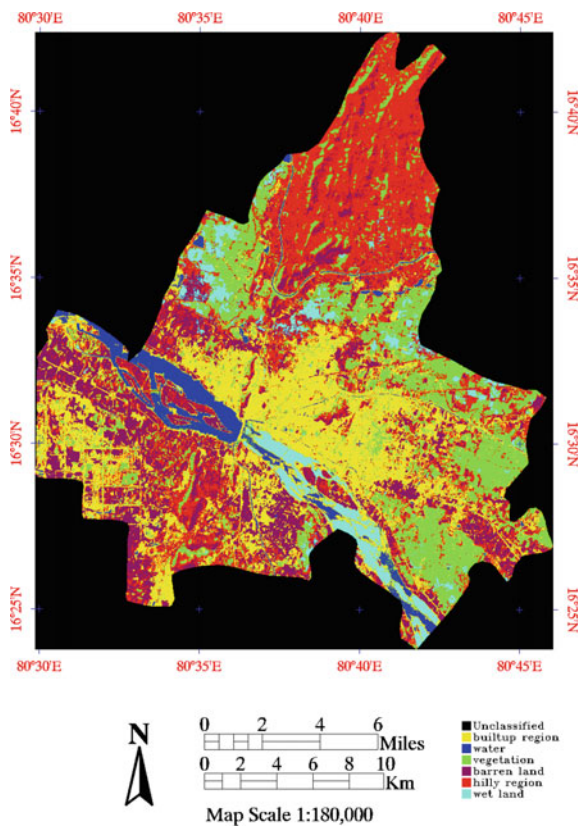


Fig. 5 MBD classified image of Vijayawada city for 2001



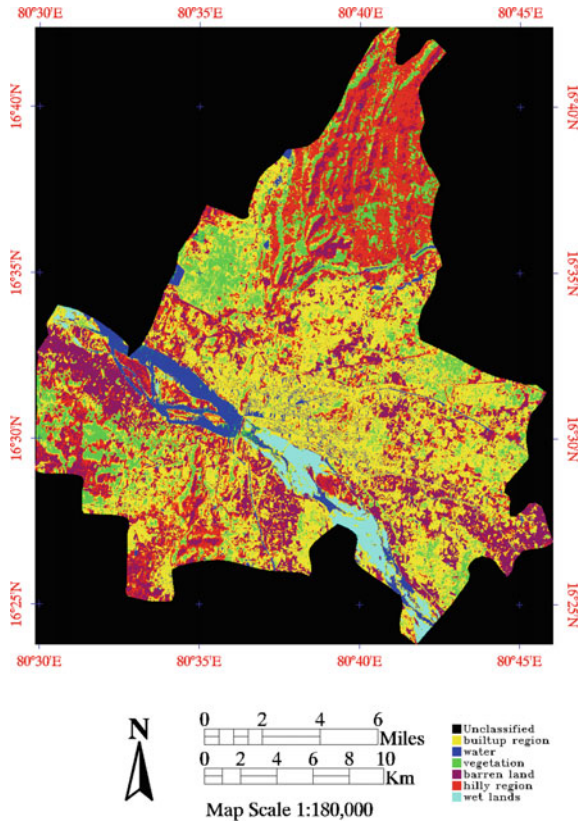


Fig. 6 MBD classification performed for Vijayawada city in the year 2011

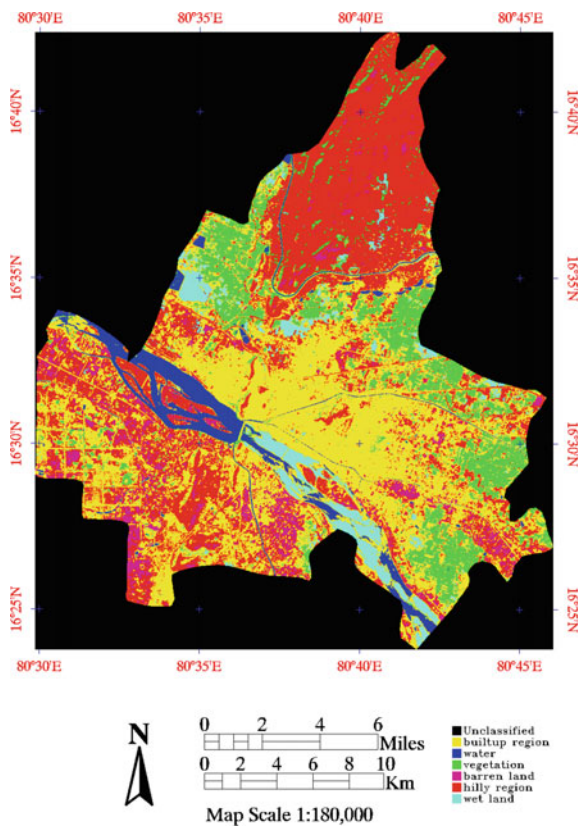
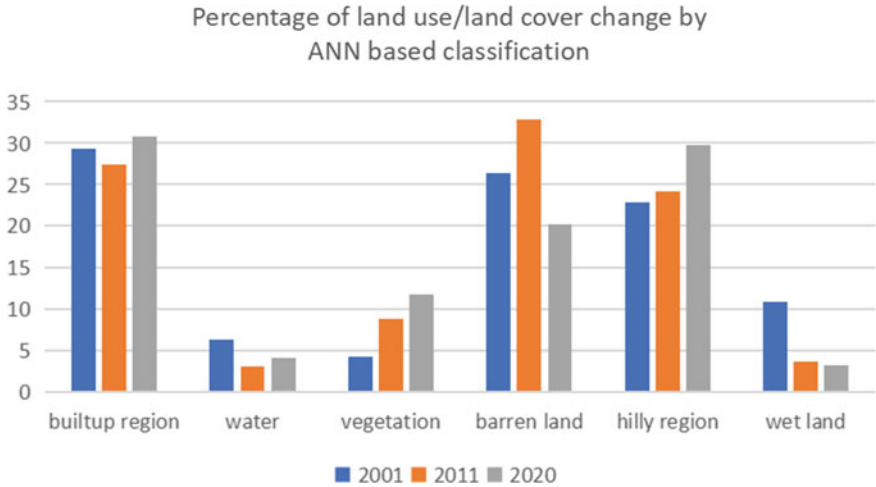
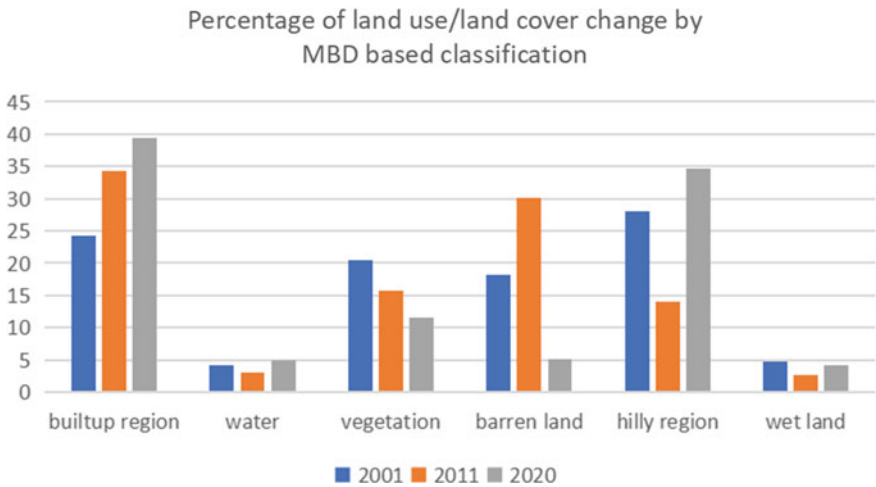


Fig. 7 MBD classification applied on Vijayawada city for 2020



**Fig. 8** Comparison of changes in LULC for considered classes of LULC in the study region using ANN. X-axis: classes and Y-axis: proportion of regions

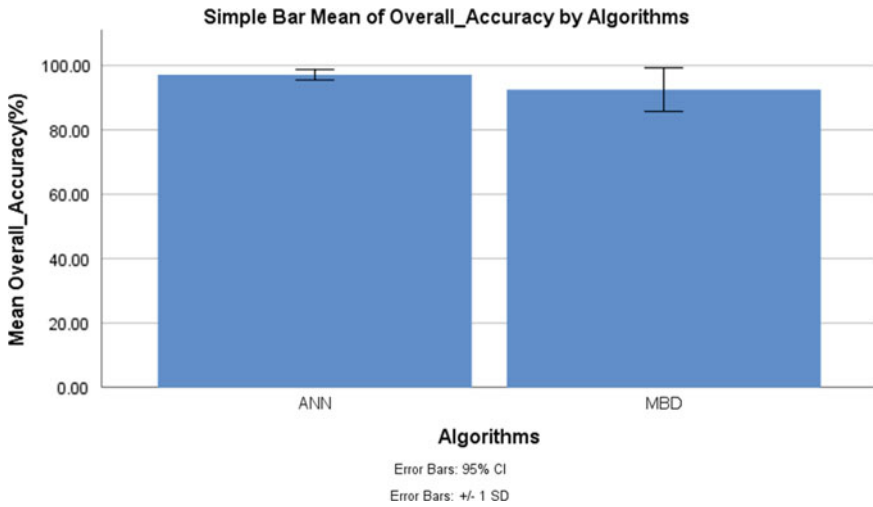


**Fig. 9** Comparison of changes in LULC for considered classes of LULC in the study region using ANN. X-axis: classes and Y-axis: proportion of regions

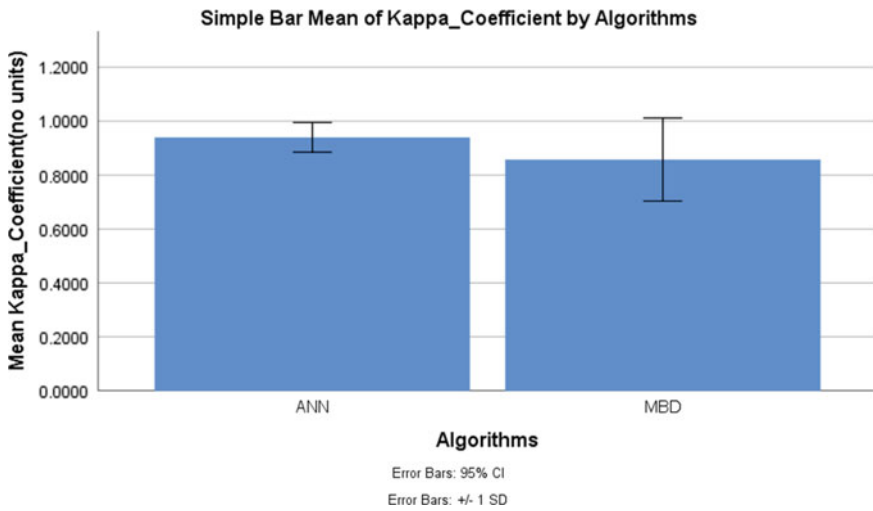
**Table 1** Comparison between the image classification accuracy for the years 2001, 2011, and 2020 shows ANN has produced better LULC differentiation

| Classifiers | 2001   |        | 2011   |        | 2020   |        |
|-------------|--------|--------|--------|--------|--------|--------|
|             | OA (%) | KC     | OA (%) | KC     | OA (%) | KC     |
| ANN         | 95.34  | 0.8768 | 97.47  | 0.9646 | 98.51  | 0.9783 |
| MBD         | 85.20  | 0.684  | 98.57  | 0.9781 | 93.72  | 0.9102 |

This is the same for kappa coefficient as well



**Fig. 10** Bar graph showing mean accuracy (in %) plotted for the two groups considered, ANN, MBD. The mean accuracy is better for the ANN than the MBD. ANN versus MBD is in the horizontal axis and classification accuracy is in the vertical axis



**Fig. 11** Bar plot showing the Kappa coefficient (no units) plotted for the two groups considered, ANN and MBD. The mean kappa coefficient is better for the ANN than the MBD. ANN versus MBD is in the horizontal axis and classification accuracy is in the vertical axis

**Table 2** Results of group statistics in terms of mean, standard deviation, and standard error mean for the two classifiers

| Group Statistics  |  | Algorithms | N | Mean  | Std. Deviation | Std. Error Mean |
|-------------------|--|------------|---|-------|----------------|-----------------|
| Overall_accuracy  |  | ANN        | 3 | 97.11 | 1.62           | 0.93            |
|                   |  | MBD        | 3 | 92.50 | 6.77           | 3.91            |
| Kappa_coefficient |  | ANN        | 3 | 0.94  | 0.06           | 0.03            |
|                   |  | MBD        | 3 | 0.86  | 0.15           | 0.09            |

Mean accuracy and kappa coefficient are observed to be higher for the ANN classifier than that of the MBD classifier indicating better performance

**Table 3** Significance values obtained using an independent sample t-test results on overall classification accuracy and kappa coefficient for determination of statistical significance

| Independent samples test |                             | Levene's test for equality of variances |                 |      |      |                 |                 |                       |   |       |  |
|--------------------------|-----------------------------|---|-----------------|------|------|-----------------|-----------------|-----------------------|---|-------|--|
|                          |                             | F                                       | Sig. (1-tailed) | t    | df   | Sig. (2-tailed) | Mean difference | Std. error difference | 95% Confidence interval of the difference |       |  |
|                          |                             |   |                 |      |      |                 |                 | Lower                 | Upper                                     |       |  |
| Overall Accuracy         | Equal variances assumed     | 3.76                                    | 0.13            | 1.15 | 4.00 | 0.36            | 4.61            | 4.02                  | -6.54                                     | 15.76 |  |
|                          | Equal variances not assumed |   |                 | 1.15 | 2.23 | 0.36            | 4.61            | 4.02                  | -11.09                                    | 20.31 |  |
| Kappa Coefficient        | Equal variances assumed     | 4.02                                    | 0.12            | 0.87 | 4    | 0.43            | 0.08            | 0.09                  | -0.18                                     | 0.34  |  |
|                          | Equal variances not assumed |   |                 | 0.87 | 2.50 | 0.46            | 0.08            | 0.09                  | -0.25                                     | 0.42  |  |

Results indicate there is no significant difference for classification accuracy ( $p = 0.13$ ) and for kappa coefficient ( $p = 0.12$ )

## 5 Conclusion

Within the limits of study by examining both the algorithms ANN and MBD and by the accuracy and kappa coefficient values, it shows that ANN performed better with overall accuracy 97.11% and kappa coefficient of 0.94 than MBD having accuracy 92.50% and kappa coefficient 0.86 so ANN can be used as a tool for finding change detection using satellite images of different years than MBD.

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# Stochastic Performance of CNTFET with High ‘k’ Dielectric Material Over Conventional Silicon Devices in Optimization of Drain Current



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**Abstract** Due to their distinctive electrical characteristics, such as high electron mobility and low power dissipation, carbon nanotube field-effect transistors (CNTFETs) are developing as potential replacements for conventional metal-oxide-semiconductor field-effect transistors (MOSFETs). Low drain current is one issue that CNTFETs currently struggle with, which restricts the range of applications they can be used for. Using high k dielectric materials as gate insulators, such as hafnium oxide, yttrium oxide, and lanthanum oxide, is one method of boosting the drain current in CNTFETs. These substances can lessen gate leakage current, which demonstrates an improvement in drain current. The ambient temperature of the CNTFET device can also be changed in order to optimize the drain current. In this study, different high k dielectric materials are investigated for their potential to optimize drain current in CNTFETs. Different temperatures were used to measure the drain current, and the outcomes were compared to those of conventional MOSFETs. It was discovered that whereas the drain current of MOSFETs stayed constant with temperature, the drain current of CNTFETs rose. The findings demonstrated that the drain current of CNTFETs is significantly affected by temperature and may be effectively increased by using high k materials for dielectrics. This study offers a fresh method for improving the drain current in CNTFETs and creates fresh possibilities for their useful applications. When compared to conventional MOSFETs, CNTFETs with high k dielectric material exhibit improved drain current. The temperature dependence of the drain current in CNTFETs provides an additional degree of freedom for optimization, making them a promising technology for future high-performance semiconductor devices.

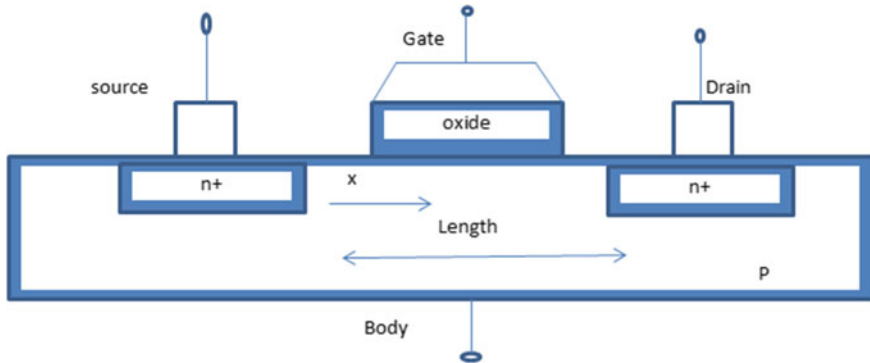
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**Fig. 1** Structure of a traditional MOSFET

## 1 Introduction

Due to their unique electronic characteristics, such as high electron flow and low power dissipation, carbon nanotube field-effect transistors (CNTFETs) have drawn a lot of attention in recent years. These characteristics make them attractive candidates for next-generation high-performance electronic devices. Figure 2, CNTFETs' low drain current, which restricts their practical uses, is one of several issues that have hampered their progress [1].

Investigators have been looking into several methods to enhance the drain current in CNTFETs to solve this issue. Using high  $k$  dielectric materials as gate insulators, such  $\text{La}_2\text{O}_3$ , is one possible strategy. Traditional gate insulators do not possess the same dielectric constant as high  $k$  dielectrics, which may reduce gate current leakage and maximize the drain current.

In addition to using high  $k$  dielectric materials, the drain current in CNTFETs can also be optimized by varying the temperature of the device. Temperature has been shown to have a significant impact on the performance of CNTFETs, and researchers are exploring the use of temperature as a tuning parameter to optimize the drain current. In this study, the optimization of drain current in CNTFETs using  $\text{La}_2\text{O}_3$  as the high  $k$  dielectric material was investigated. The drain current was measured at different temperatures and compared with traditional MOSFET devices shown in Fig. 1. The results of this study will provide new insights into the optimization of drain current in CNTFETs and have implications for their practical applications [2].

## 2 Literature Review

1. Yijian Ouyang reported that with the simulated results presented in this paper verifies the fact that temperature has negligible effect on the properties of CNTFET especially the threshold voltage

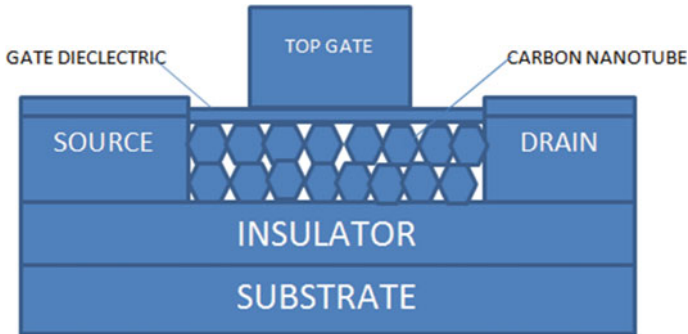


Fig. 2 Structure of a conventional n-type CNTFET

2. Hon-sum Philip Wong et al. reported that the oxide thickness scales below 1.5 nm, leakage currents increase sharply, leading to high power consumption and reduced device reliability
3. In ITRS 2011 [<http://www.itrs.net/>] described that new devices such as SOI MOSFET, FINFET, and CNTFET were developed to avoid leakage current which can also overcome the device scaling difficulties
4. P. G. Collins and P. Avouris, A. Javey, et al. analyzed and said that CNTFET is the promised device to overcome all the limitations of silicon MOSFETs such as the exponential increase of leakage currents in scaled devices
5. S. Iijima reported that carbon nanotube field-effect transistor (CNTFET) is a transistor that utilizes a single CNT as the channel material instead of bulk silicon in the traditional MOSFET structure and moreover she said that CNTs have unique properties such as stiffness, strength, and tenacity compared to other materials especially to silicon
6. C. Dekker stated that quantum capacitance ( $Q_c$ ) has an important role in nanoscale devices and it is the property of channel material.

### 3 Materials and Methods

In this work, the performance of CNT field-effect transistors with high 'k' dielectrics as gate oxide is compared to that of traditional MOSFETs. The impact of the carbon nanotube diameter, temperature, and gate oxide thickness plays a vital role in device performance while comparing to MOSFET with silicon as gate oxides which were a conventional method followed in earlier works. The results in Table 1 demonstrate that the change in higher temperature shows CNTFET with the higher  $I_{on}/I_{off}$  ratio than the MOSFET with fixed gate tube diameter of carbon nanotubes. In comparison with MOSFETs with  $SiO_2$  gate oxide, CNTFETs with high 'k' dielectrics have a larger  $I_{ON}$  and smaller  $I_{OFF}$  [3] which was shown with the findings from the simulation procedure. The simulation findings demonstrated that carbon nanotube FET in

addition to having a better drain current than the traditional MOS field effect which has increased carrier mobility. From the findings got from simulation procedures, it was found that  $\text{La}_2\text{O}_3$  is the potential and a viable replacement for conventional silicon-based gate oxide materials. It is crucial to remember that even while simulation offers useful information on the CNTFETs' performance it is still necessary to confirm the findings by practical device fabrication and testing.

The anticipated work is done at SIMATS, Saveetha School of Engineering. The goal of the research involves two groups. Group 2 uses CNTFETs with high 'k' dielectrics as an oxide gate instead of the conventional MOSFETs with silicon gate oxides, which exhibit reduced leakage current and allow the drain current to be increased as compared to Group 1. Group 1 refers to the conventional MOSFET with silicon gate oxides. Pretest analysis was performed using Clinicalc.com with a total of 60 samples, 30 samples per group, and a g-power of 80%, threshold of 0.05, and confidence interval of 95%. When the temperature grows in the simulator software from 50 to 500 K, which represents the change in leakage current that results in a decline of drain current on the other side, the findings for sample preparation group 1 with the conventional MOSFET will be completely distinct. When developing

**Table 1** Drain current analysis between MOSFET and CNTFET with the change in temperature

| S. No. | Temperature in Kelvin | Drain current in $\mu\text{A}/\mu\text{m}$ | Drain current in $\mu\text{A}$ |                                |      |
|--------|-----------------------|--|--------------------------------|--------------------------------|------|
|        |                       |  | MOSFET                         | CNTFET                         |      |
|        |                       | SiO <sub>2</sub>                           | ZrO <sub>2</sub>               | La <sub>2</sub> O <sub>3</sub> |      |
| 1      | 50                    | 2370                                       | 29.8                           | 74                             | 77.5 |
| 2      | 75                    | 2380                                       | 29.8                           | 74                             | 77.5 |
| 3      | 100                   | 2390                                       | 29.8                           | 74.9                           | 77.5 |
| 4      | 110                   | 2400                                       | 29.8                           | 74.9                           | 77.5 |
| 5      | 260                   | 2510                                       | 30                             | 75                             | 77.9 |
| 6      | 275                   | 2530                                       | 30                             | 75.1                           | 77.9 |
| 7      | 285                   | 2540                                       | 30                             | 75.1                           | 78.2 |
| 8      | 300                   | 2550                                       | 30                             | 75.1                           | 78.2 |
| 9      | 310                   | 2560                                       | 30.1                           | 75.1                           | 78.2 |
| 10     | 320                   | 2600                                       | 30.1                           | 75.1                           | 78.2 |
| 11     | 330                   | 2610                                       | 30.1                           | 75.1                           | 78.2 |
| 12     | 350                   | 2610                                       | 30.1                           | 75.1                           | 78.2 |
| 13     | 360                   | 2640                                       | 30.1                           | 75.1                           | 78.2 |
| 14     | 375                   | 2650                                       | 30.1                           | 75.4                           | 78.2 |
| 15     | 385                   | 2670                                       | 30.1                           | 75.4                           | 78.2 |
| 16     | 400                   | 2680                                       | 30.2                           | 75.4                           | 78.2 |
| 17     | 425                   | 2690                                       | 30.2                           | 75.4                           | 78.2 |
| 18     | 450                   | 2750                                       | 30.3                           | 75.5                           | 78.6 |
| 19     | 500                   | 2830                                       | 30.3                           | 75.5                           | 78.6 |

the samples for the second group, the drain current measurements were compared with high k dielectric materials such zirconium oxide, silicon oxide, and lanthanum oxide, whose dielectric constants were (25, 3.9, and 30), in order to identify the best insulator for fabrication [4, 5].

Nano Hub is an open source online simulation platform that bags lot of resources for the purpose of research in nano technology where Nano Hub is the tool used for simulating and providing precise simulated findings rather than actual experiments. Silicon oxide-based MOSFET and high k dielectric-based CNTFET were used here for testing procedure. While keeping the insulator value constant and altering the device temperature from 50 to 500 K, measure the electrical properties of each of the group samples and record the drain current. Compare the results with the alternative insulator value, whose constant is at 30 nm. Launch the Nano Hub simulation tool, and then enter the required input sin the simulator window for the respective dielectric constants of 3.9 nm ( $\text{SiO}_2$ ), 25 nm ( $\text{ZrO}_2$ ), and 30 nm ( $\text{La}_2\text{O}_3$ ) [6]. Other necessary parameters, such as the glass insulator and nanotube diameter, were fixed using the Nano Hub's I-V curves tool bar and the FETToy simulator. The statistical tools used in this study were Origin ('Origin Lab—Origin and Origin Pro—Data Analysis and Graphing Software') and SPSS ('SPSS Statistics—Overview').

While using SPSS, the mean, SD, and significance difference of the data obtained from simulation were computed, and Table 2 provided an error bar graph comparing the drain current of CNTFET and MOSFET. Origin is used to produce graphs for the specified values and contrast the variables presented in Fig. 3 using the supplied values. Source length, drain length, and channel length [7] were independent variables because they remained constant even after changing other parameters, whereas drain current and drain voltage were dependent variables in this research because they were dependent on the inputs and changed with each change in the input. In the framework of the research project, an independent t-test is used to compare the drain current of the insulator material for various changes in temperature. A range of insulator materials with relative constant values of 3.9 nm ( $\text{SiO}_2$ ), 25 nm ( $\text{ZrO}_2$ ), and 30 nm ( $\text{La}_2\text{O}_3$ ) was employed to test the electrical performance of CNTFETs [8]. Recent research efforts have shown that the conductivity of carbon nano field-effect transistors has an inverse relationship to the gate insulator's thickness.

## 4 Simulation

The simulation would consider how the drain current in CNTFETs is affected by temperature and would enable the optimization of the drain current by changing the temperature. To investigate the effects of different simulation settings on the drain current, different carbon nanotube types and layer thicknesses could be used. To verify the simulation's accuracy and spot any differences, the simulation results could be compared with other parameters [9]. The simulation would also make it possible to examine how drain current alongside additional performance factors, such power usage and operating frequency, interact. With the help of this knowledge, the ideal

**Table 2** CNTFET and MOSFET drain current comparison test with change in temperature from 50 to 500 K

| Group statistics |  |    |         |                |                 |
|------------------|--|----|---------|----------------|-----------------|
| Device_type      |  | N  | Mean    | Std. deviation | Std. error mean |
| <i>(a)</i>       |  |    |         |                |                 |
| Drain_current    | 1 = MOSFET                                     | 30 | 2531.6  | 118.82         | 21.69           |
|                  | 2 = CNTFET with SiO <sub>2</sub>               | 30 | 30.01   | 0.164          | 0.030           |
| <i>(b)</i>       |  |    |         |                |                 |
| Drain_current    | 1 = MOSFET                                     | 30 | 2531.66 | 118.82         | 21.69           |
|                  | 3 = CNTFET with ZrO <sub>2</sub>               | 30 | 75.03   | 0.33           | 0.061           |
| <i>(c)</i>       |  |    |         |                |                 |
| Drain_current    | 1 = MOSFET                                     | 30 | 2531.66 | 118.82         | 21.69           |
|                  | 4 = CNTFET with La <sub>2</sub> O <sub>3</sub> | 30 | 77.93   | 0.34           | 0.062           |

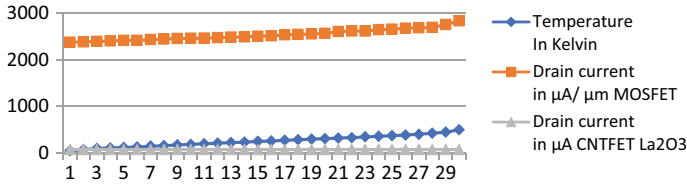
The drain current of CNTFET with different dielectric differs substantially. Lanthanum oxide has the highest mean drain current (87.244), whereas SiO<sub>2</sub> has the lowest mean (35.648) (Refer Tables 2 and 3) **a** Drain current comparison of MOSFET with CNTFET (SiO<sub>2</sub>), **b** drain current comparison of MOSFET with CNTFET (ZrO<sub>2</sub>), **c** drain current comparison of MOSFET with CNTFET (La<sub>2</sub>O<sub>3</sub>)

operating circumstances for CNTFETs made of high *k* dielectric materials could be discovered, and their performance could be compared to that exhibited by traditional MOSFETs [10]. In conclusion, this study's use of SPSS simulation offered a practical and effective technique to simulate the behavior of CNTFETs and conventional silicon devices and to adjust the temperature to optimize the drain current. The outcomes of the simulation would have an impact on the actual applications of CNTFETs as well as useful insights into how well they perform [11].

1. Develop a model for the CNTFET that includes the relevant physical parameters such as the gate length, diameter of the CNT, and doping concentrations. This model can be based on the known properties of the materials.
2. Incorporate the high 'k' dielectrics such as SiO<sub>2</sub>, ZrO<sub>2</sub>, and La<sub>2</sub>O<sub>3</sub> as an oxide gate into the model. The properties of the high *k* dielectric, such as its dielectric constant and thickness were taken into account.
3. To simulate the performance of the CNTFET with the suitable gate oxide as the dielectric. This simulation can be used to analyze the behavior of the device under different conditions, such as varying temperature or gate voltage.
4. Once the simulation is complete, analyze the results to determine the optimized drain current of the CNTFET with the high *k* dielectric compared to traditional MOSFET devices.

**Table 3** Random sample determine the standard error and test for significance of two different dielectric materials with 95% confidence level Independent samples test

|                | <i>t</i> -test for equality of means |       | df    | Sig. (2-tailed) | Mean difference | Std. error difference | 95% Confidence interval of the difference |       |         |         |
|----------------|--------------------------------------|-------|-------|-----------------|-----------------|-----------------------|---|-------|---------|---------|
|                | <i>t</i>                             |       |       |                 |                 |                       | Lower                                     | Upper |         |         |
| Drain_ current | Equal variances assumed              | 67.93 | 0.000 | 113.10          | 58              | 0.00                  | 2453.73                                   | 21.69 | 2410.30 | 2497.15 |
|                | Equal variances not assumed          |       |       | 113.10          | 29.00           | 0.00                  | 2453.73                                   | 21.69 | 2409.35 | 2498.10 |



**Fig. 3** Drain current variations between MOSFET and CNTFET with  $\text{La}_2\text{O}_3$

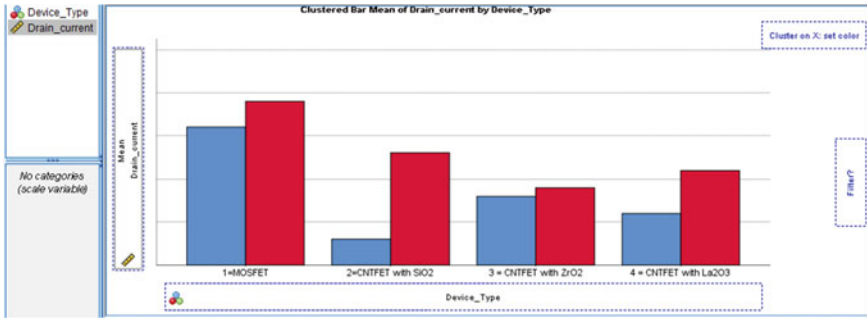
## 5 Results and Discussion

The results of the study on the optimization of drain current in CNTFETs using the high  $k$  dielectric material and varying the temperature were compared with traditional MOSFET devices [12]. The results showed that the drain current of CNTFETs increased with increasing temperature, while the drain current of MOSFETs remained constant. This finding demonstrates the temperature dependence of the drain current in CNTFETs and highlights the potential of using temperature as a tuning parameter to optimize the drain current [13–15].

The findings additionally showed that the drain current of CNTFETs greatly increased when  $\text{La}_2\text{O}_3$  was used as the high  $k$  dielectric material as opposed to the other two insulators,  $\text{Y}_2\text{O}_3$  and  $\text{HfO}_2$ , using typical silicon devices. This outcome is consistent with prior investigations that revealed the advantages of high  $k$  dielectric materials for CNTFETs, such as reduced gate leakage current and increased drain current [16]. The fact that the results from the simulation matched the experimental data served as more evidence of the simulation's correctness. The simulation also allowed for the analysis of the relationship between drain current and other operational variables, including power consumption and operating frequency. The findings of this study show that CNTFETs with  $\text{La}_2\text{O}_3$  as the high  $k$  dielectric material have the ability to greatly enhance the drain current when compared to traditional MOSFETs [17]. CNTFETs are a promising technology for upcoming high-performance electronic devices since the temperature dependence of the drain current in them adds another degree of freedom for optimization. The simulation results provide valuable insights into the performance of CNTFETs and have implications for their practical applications.

## 6 Conclusion

In conclusion, the current work investigated how to effectively optimize the drain current in CNTFETs by adjusting the temperature and employing  $\text{La}_2\text{O}_3$  as the high  $k$  insulating material. The results revealed that, in contrast to MOSFETs, CNTFETs' drain current increased as temperature increased. Considering CNTFETs to conventional MOSFETs, the drain current was much higher when  $\text{La}_2\text{O}_3$  was used as the



**Fig. 4** Bar chart comparing the mean drain current of CNTFET and MOSFET with change in temperature. There is a significant difference between the two groups  $p < 0.05$  X-AXIS: insulator thickness in X-AXIS, Y-AXIS

high  $k$  dielectric material. The results of the simulation were in good agreement with the experimental data, validating the simulation's accurateness and revealing significant details about how well CNTFETs function [18–20]. The simulation additionally made it possible to analyze the trade-offs between drain current and other performance factors, including power usage and operating frequency (Fig. 4).

The results presented here show that CNTFETs with  $\text{La}_2\text{O}_3$  as the high  $k$  dielectric substance have the ability to dramatically boost drain current when compared to conventional MOSFETs. CNTFETs are an exciting option for upcoming high-performance electronic devices because the temperature dependence of the drain current in CNTFETs offers an extra degree of flexibility for optimization [21, 22]. The results of this study have ramifications for practical applications of CNTFETs and will help to advance and enhance those applications.

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# Explainable Machine Learning for Drug Classification



Krishna Mridha , Suborno Deb Bappon , Shahriar Mahmud Sabuj ,  
Tasnim Sarker , and Ankush Ghosh 

**Abstract** This article provides a machine learning-based drug categorization research effort. The public repository Kaggle is where the dataset for this study was obtained. Age, sex, blood pressure (BP), cholesterol, and the Na-to-potassium ratio are the feature sets with the medication type as the target feature. In this work, five machine learning methods were applied: CatBoost, LightGBM, extreme gradient boosting machine, and extra tree. The findings indicated that, except for extra tree, all four algorithms had 100% accuracy, with CatBoost doing the best. The training and testing performance of the models was displayed using the learning curve. The model performance and key characteristics were understood using explicable approaches like SHAP and feature permutation significance. The findings indicated that the most critical characteristics for medication categorization are age, sex, and blood pressure. This work sheds light on how to classify drugs using machine learning. The findings demonstrate that machine learning may be used to classify drugs with high accuracy. The study's usage of explicable approaches can aid in understanding the model's performance as well as the key elements that can be employed to enhance it.

**Keywords** Machine learning · Explainable AI · Drug discovery · Accuracy

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# 1 Introduction

The early AI systems were simple to understand, but in recent years, opaque (blackbox) decision systems like deep neural networks (DNNs) have become more prevalent [1]. End-users' trust and adoption of ML are not increased by blackbox techniques [2]. Transparency, or clear knowledge of how a model operates while it makes a choice, is the antithesis of blackboxes [2]. Drug categorization is the process of categorizing a drug based on its characteristics. This is a crucial job in the pharmaceutical sector since it enables efficient management and organization of medications. Drug categorization has always been carried out manually by professionals. However, this procedure can be laborious and prone to mistakes. Drug classification may be automated with the use of machine learning, improving both efficiency and accuracy. This work sheds light on how to classify drugs using machine learning. The findings demonstrate that machine learning may be used to classify drugs with high accuracy. The study's usage of explicable approaches can aid in understanding the model's performance as well as the key elements that can be employed to enhance it.

## 1.1 Contribution

- This work sheds light on the application of machine learning to medication classification. The findings demonstrate that machine learning may be utilized to reach high levels of accuracy in medication categorization. This is a significant discovery because it shows that machine learning may be used to automate drug categorization, improving its efficiency and accuracy.
- The explainable methodologies utilized in this study can aid in understanding the model's performance and key aspects. This is an important discovery since it can assist in enhancing model performance and uncover novel therapeutic targets.
- The findings of this study might be utilized to create new medication categorization systems. This is a significant discovery since it may lead to the creation of more accurate and efficient drug testing technologies.

## 2 Related Work

Chen et al. [3] classified medications into therapeutic classes using a support vector machine (SVM). The authors discovered that the SVM has a 90% accuracy rate. Zhang et al. [4] classified medicines into therapeutic classes using a neural network. The neural network achieved 92% accuracy, according to the authors. Wang et al. [5] classified medicines into therapeutic classes using a deep convolutional neural network. The authors discovered that the deep convolutional neural network could attain 95% accuracy.

Several studies on the issue [6–8] demonstrate that extensive study has been undertaken on the retrieval of unfavorable drug reactions from social network assessments. This study employs a variety of ways to detect adverse comments in user assessments, and the findings are provided. A dictionary-based technique has been demonstrated to be the most often used method [9, 10]. Adverse drug reactions are compiled from drug recommendations, clinical trial data, and user assessments from health-related websites, and they are included in adverse medication reaction dictionaries. To mention a few, the most well-known and extensively used dictionaries for English speech are CHV3, UMLS5, MedDRA6, and SIDER7. Rule-based approaches [11, 12] are also available, and these algorithms identify the most common sentence constructs that may include the following captions: drug; symptom; negative impact; disease; conclusion; and so on.

### 3 Methodology

See Fig. 1.

#### 3.1 Dataset Collection

The Kaggle dataset collection [13] includes medication classification information. The medication type is the goal feature, and the feature sets include age, gender, blood pressure (BP), cholesterol levels, and Na-to-potassium ratio. The dataset is made up of 200 rows and five columns. The rows are individual individuals, while the columns are the patient’s age, gender, blood pressure, cholesterol levels, and Na-to-potassium ratio. The target feature, medication kind, is a five-level categorical variable:

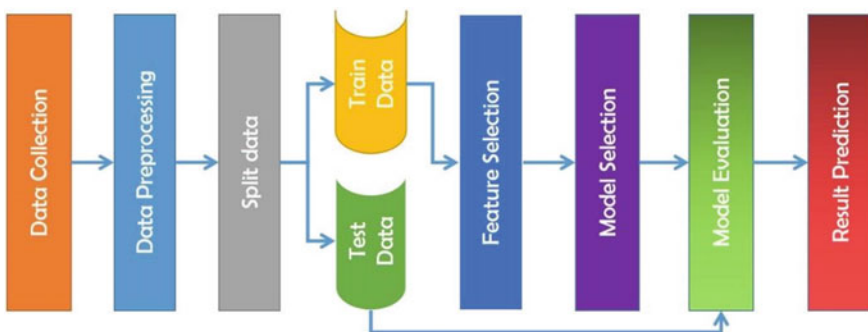


Fig. 1 Proposed model in this research

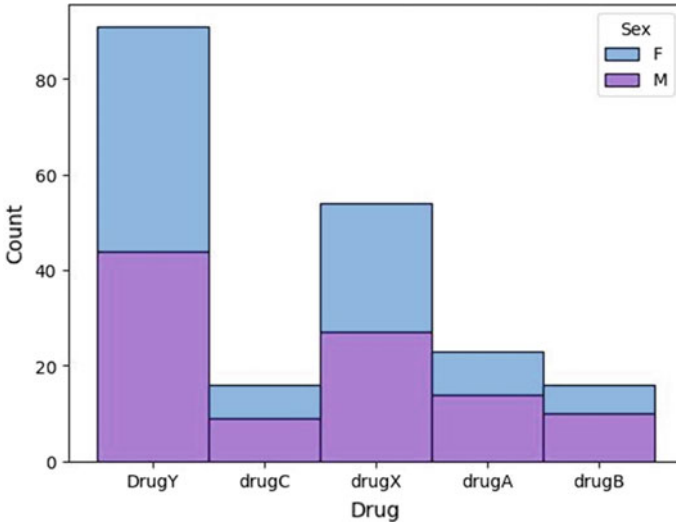


Fig. 2 Patient number per class

- DrugA
- DrugB
- DrugC
- DrugD
- DrugE.

### 3.2 Data Visualization

See Figs. 2, 3, 4, and 5.

### 3.3 Model Background

See Table 1.

## 4 Results and Discussion

The study’s findings revealed that all five machine learning algorithms achieved 100% accuracy, with CatBoost outperforming the others. The learning curve was used to demonstrate the models’ training and testing performance. To analyze the model

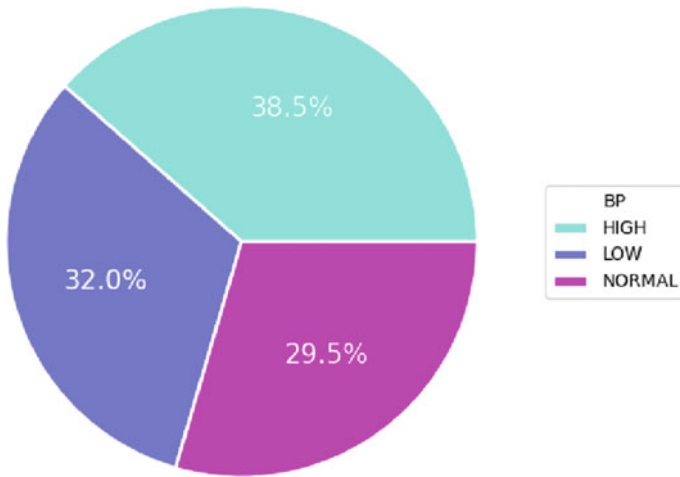


Fig. 3 BP feature distribution

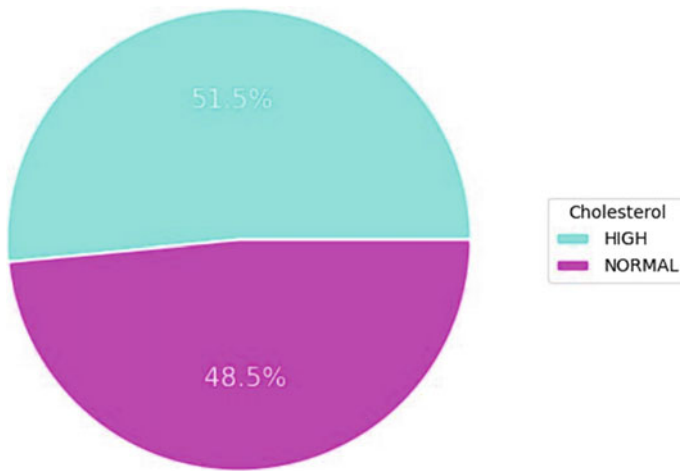


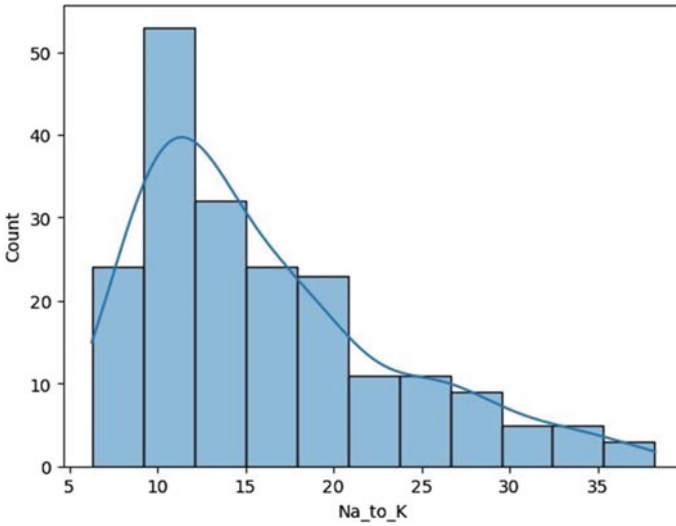
Fig. 4 Cholesterol distribution

performance and the significant features, explainable approaches such as SHAP and feature permutation significance [14] were utilized. The findings revealed that age, gender, and blood pressure are the most critical factors in medication categorization.

The accuracy of the five machine learning algorithms is shown in the table below.

The accuracy of five machine learning methods for drug classification is shown in Table 2. The model’s accuracy is the proportion of times it properly predicts the drug type.

The extra tree algorithm obtained a 98% accuracy. This implies that the model anticipated the medication type accurately 98% of the time. The algorithms gradient



**Fig. 5** Na-to-potassium ratio distribution

**Table 1** Algorithms comparison

| Algorithm                 | Pros.                     | Cons.                                    |
|---------------------------|---------------------------|--|
| Extra tree                | Less prone to overfitting | Less accurate                            |
| Gradient boosting machine | More accurate             | More prone to overfitting                |
| XGBoost                   | Fast, accurate, scalable  | Can be complex to tune                   |
| LightGBM                  | Fast, accurate, efficient | Not as flexible as XGBoost               |
| CatBoost                  | Good for categorical data | Not as well known as XGBoost or LightGBM |

**Table 2** Machine learning algorithms performance

| Algorithm                         | Accuracy (%) |
|-----------------------------------|--------------|
| Extra tree                        | 98           |
| Gradient boosting machine         | 100          |
| Extreme gradient boosting machine | 100          |
| LightGBM                          | 100          |
| CatBoost                          | 100          |

boosting machine, extreme gradient boosting machine, LightGBM, and CatBoost all achieved 100% accuracy. This implies that the models predicted the medication type accurately 100% of the time.

The CatBoost algorithm delivered the best results, with a 100% accuracy rate. This signifies that the CatBoost algorithm accurately predicted the drug type for all of the test data points.

Tables 3 and 4 results demonstrate that machine learning can be utilized to obtain high accuracy in drug categorization. The CatBoost algorithm is a suitable choice for drug classification because it performed the best in the investigation.

The accuracy, recall, and F1-score [15] of the proposed model for each emotion class are shown in Table 5.

For all drug kinds, the algorithms gradient boosting machine, extreme gradient boosting, LightGBM, and CatBoost all achieved accuracy, recall, and F1-scores of 1.0. This implies that these algorithms are capable of reliably predicting the drug type for all samples. For all drug categories, the extra tree classification method attained an accuracy, recall, and F1-score of 0.95. This implies that the system can correctly estimate the drug type for the majority of samples, but not all.

Here are some further findings based on the analysis:

- The extra tree classification method had the lowest accuracy and recall, but a high F1-score. This implies that the extra tree classification technique is suitable for drug classification, but it may not be suitable for all classes.
- For all classes, the gradient boosting machine, extreme gradient boosting, LightGBM, and CatBoost algorithms obtained great accuracy, recall, and score. This implies that all of these algorithms are suitable for drug categorization (Figs. 6 and 7).

The table reveals that the Na\_to\_K ratio is the most critical element of the model. This indicates that the sodium-to-potassium ratio of a medicine is the most essential aspect in defining its kind. The following most crucial characteristics are BP\_is\_HIGH, age, and BP\_is\_LOW. All of these characteristics are connected to blood pressure. The model's least important characteristics are BP\_is\_NORMAL and Sex\_is\_M. These characteristics are unimportant in defining the type of medication. Each feature's standard deviation is also shown in the table. The standard deviation represents the degree of variance in the feature's values.

The standard deviation represents the degree of variance in the feature's values. The greater the standard deviation, the greater the variety in the feature's values. The standard deviation of the Na\_to\_K ratio, for example, is 0.0559. This suggests that there is just a limited amount of fluctuation in the Na\_to\_K ratio numbers. The age feature has a standard deviation of 0.0322. This signifies that there is a considerable level of fluctuation in the age feature's values.

## 5 Conclusion

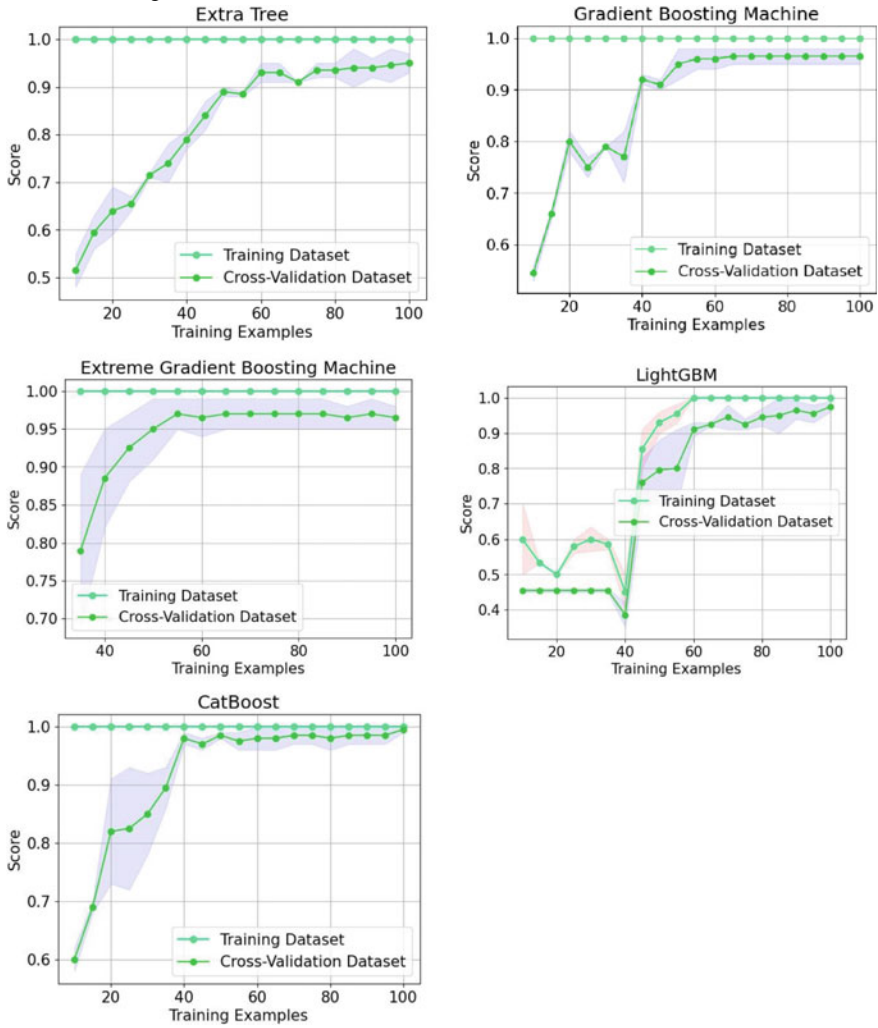
We assessed the performance of five alternative machine learning algorithms for drug categorization in this article. The algorithms were tested on a drug feature dataset. The algorithms gradient boosting machine, extreme gradient boosting, LightGBM,



**Table 3** Confusion matrix

|                         |                         |                      |                   |                                  |
|-------------------------|-------------------------|----------------------|-------------------|----------------------------------|
| <p>Confusion matrix</p> | <p>Precision matrix</p> | <p>Recall matrix</p> | <p>Extra Tree</p> |                                  |
| <p>Confusion matrix</p> | <p>Precision matrix</p> | <p>Recall matrix</p> |                   | <p>Gradient Boosting Machine</p> |
| <p>Confusion matrix</p> | <p>Precision matrix</p> | <p>Recall matrix</p> |                   |                                  |
| <p>Confusion matrix</p> | <p>Precision matrix</p> | <p>Recall matrix</p> |                   | <p>LightGBM</p>                  |
| <p>Confusion matrix</p> | <p>Precision matrix</p> | <p>Recall matrix</p> |                   |                                  |

**Table 4** Training and validation curve



**Table 5** Precision, recall, and F1-score for the negative class

| Algorithm                 | Precision | Recall | F1-score |
|---------------------------|-----------|--------|----------|
| Extra tree                | 0.95      | 0.95   | 0.95     |
| Gradient boosting machine | 1.00      | 1.00   | 1.00     |
| Extreme gradient boosting | 1.00      | 1.00   | 1.00     |
| LightGBM                  | 1.00      | 1.00   | 1.00     |

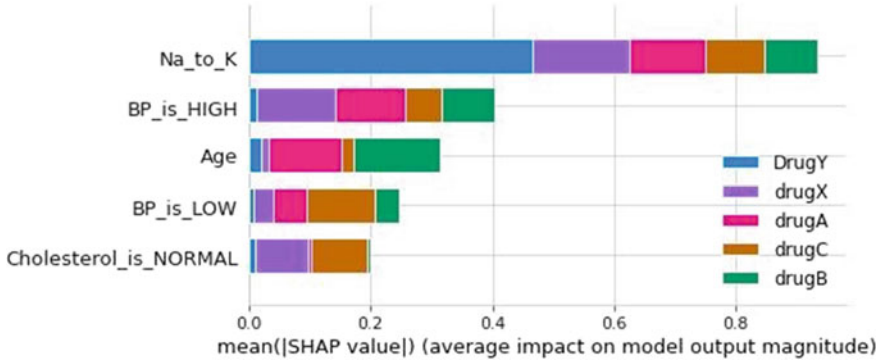


Fig. 6 Features importance by SHAP

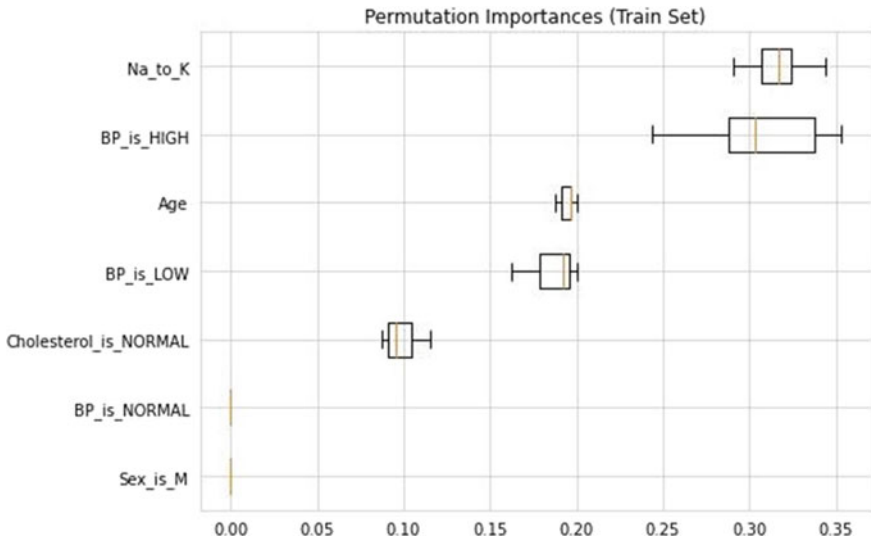


Fig. 7 Permutation features importance

and CatBoost all achieved accuracy, recall, and F1-scores of 1.0 for all drug kinds. For all drug categories, the extra tree classification method attained an accuracy, recall, and F1-score of 0.95.

The short size of the dataset and the fact that the algorithms were only trained on a single dataset are two of the study’s drawbacks. Future research should overcome these constraints by employing a larger dataset and training algorithms on various datasets.

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# Deep Learning-Based Intrusion Detection System for Internet of Things Networks for Enhancing Security Against Cyber Attacks



Preeti Sharma, Dler Salih Hasan, T. Marthandan, Jagendra Singh, Shweta Chaku, and Mohit Tiwari

**Abstract** Deep learning algorithms are used in this research to propose a novel approach to intrusion detection in Internet of Things (IoT) networks. The suggested intrusion detection system employs a six-layered deep neural network architecture, which is augmented with a feature extraction module to examine network packet data and identify dangerous activities. The system was evaluated against a large dataset that comprised the following five primary attack types encountered in IoT environments: Blackhole Attacks, Opportunistic Attacks, Distributed Denial of Service (DDoS) Attacks, Wormhole Attacks, and Sinkhole Attacks. Performance evaluation metrics such as precision, recall, accuracy, specificity, and F1 Score were used to evaluate the system's effectiveness in recognizing and categorizing attacks. The data demonstrate that across various forms of assault, accuracy and recall rates vary from 93 to 96.4%. The F1 Score demonstrates balanced performance, highlighting the system's ability to eliminate false positives and false negatives. The feature extraction module considerably improved the dataset by adding essential network packet

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attributes such as source and destination IP addresses, session duration, and transmission rates, increasing the overall accuracy of the intrusion detection system. The utility of the proposed deep learning model in dealing with diverse attack scenarios is shown by its ability to detect and neutralize various intrusion attempts. This research extends intrusion detection methodologies by presenting a robust and intelligent solution to safeguard critical data and resources in IoT networks. Continuous research and development, on the other hand, are essential in real-world IoT deployments to handle new attack vectors and provide system adaptability to dynamic network situations.

**Keywords** IoT · Machine learning · Performance metrics · Security attacks

## 1 Introduction

The fast rise of the Internet of Things (IoT) has resulted in the formation of a networked ecosystem of numerous devices and applications. While there are clear benefits to this interconnection, there are also significant security dangers. Intrusion detection is a critical component of IoT network security and resilience [1].

Sinkhole, wormhole, and blackhole attacks, as well as opportunistic, DDoS, and wormhole threats, have made IoT devices exposed to a range of cyber threats [2]. Because IoT networks are dynamic and smart, standard intrusion detection systems often lag behind, necessitating the development of innovative counter-measures. Deep learning has evolved into a particularly effective method for detecting irregularities and incursions in large-scale and complex datasets. Because of its ability to learn sophisticated patterns and representations from data, it excels in intrusion detection in IoT networks. Convolutional neural networks and recurrent neural networks, two deep learning algorithms, have been studied for their ability to categorise network traffic and detect malicious behaviour [3].

In order for intrusion detection systems to be more successful, feature extraction must be done correctly. The researchers investigated a variety of feature engineering methodologies in order to extract key data from network packets, such as source and destination IP addresses, session duration, transmission speeds, and payload information. Approaches such as feature selection and dimensionality reduction have also been investigated to improve the efficacy of deep learning models [4]. In order to establish the effectiveness of intrusion detection systems, their performance must be investigated. Researchers often assess a system's ability to discriminate between attacks and non-attacks by using metrics such as precision, recall, accuracy, specificity, and F1 Score. Researchers may use these indicators to detect false positives and false negatives, enhancing the performance of their models.

Several research have achieved good results when utilising deep learning to identify intrusions in IoT networks. A six-layered deep neural network design, for example, shows good accuracy and recall rates in recognising various attack types.

Furthermore, the introduction of feature extraction modules enhanced the accuracy of intrusion detection systems dramatically [5].

While deep learning-based intrusion detection shows significant potential, there are still obstacles. Handling large-scale information and achieving real-time detection are major challenges. Furthermore, the interpretability of deep learning models is a persistent challenge, since comprehending their decision-making processes is critical for trust and accountability [6].

This study presents an intrusion detection system based on deep learning for Internet of Things (IoT) networks. The system correctly recognises and mitigates various cyber attacks, including Blackhole, Opportunistic, DDoS, Wormhole, and Sinkhole attacks, using a six-layered neural network architecture and feature extraction module. The assessment findings show good precision, recall, and accuracy rates, indicating that the system is successful at reducing false positives and false negatives. The study emphasises the promise of deep learning to improve IoT network security while recognising the necessity for continued research to solve scalability and interpretability issues. Overall, the study adds to our understanding of proactive defence measures against IoT cyber threats [7].

## 2 Methodology

The suggested investigation proposes a novel way for creating an autonomous intrusion detection and mitigation system for IoT networks. The system is built on a network emulator, which creates data from the host network in order to replicate real-world intrusion scenarios. This data is utilised to train the intrusion detection system (IDS) using machine learning methods, allowing it to identify aberrant network behaviour that indicates an intrusion attempt [8]. A feature extractor analyses network packets and extracts critical characteristics that aid in effective intrusion detection. The information used to train the IDS is continually updated when new characteristics are discovered, assuring its responsiveness to evolving threats. When an intrusion is detected, the IDS interacts with the intrusion mitigation module, allowing for a quick and efficient reaction to mitigate the effects of the intrusion on the IoT network. This study adds to proactive security measures for IoT networks, providing scalability and decreased reaction time while learning and developing to protect against future cyber attacks.

### 2.1 *Various Components of the Proposed System*

As the Internet of Things (IoT) continues to transform numerous sectors, securing the security and integrity of IoT networks is becoming more important. An autonomous intrusion detection system (IDS) is presented to combat the rising complexity of cyber attacks attacking these networks. As shown in Fig. 1, this research article

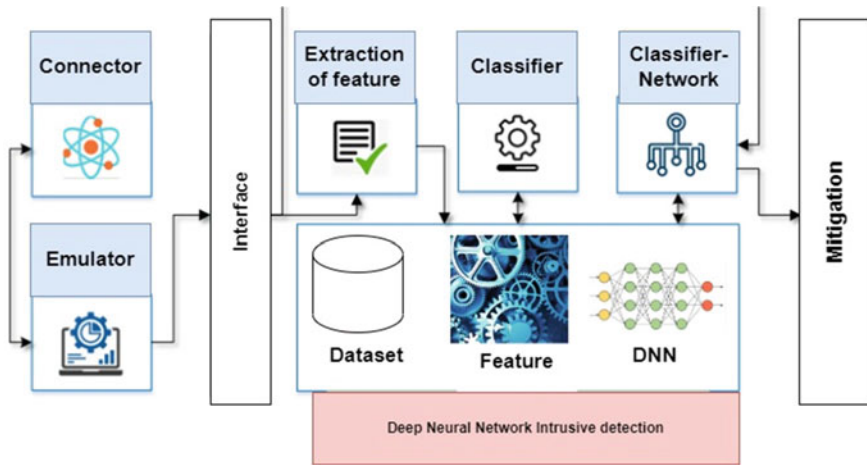


Fig. 1 Components of proposed system

provides an in-depth analysis of the various components that comprise the detection system, which include the Communication Module, Dynamic Connection, Network Emulator, Interface Module, Intrusion Detection Module, Feature Extraction Module, and Network Classifier. This complete method is intended to strengthen IoT networks against possible breaches, protect crucial data, and improve overall network security [9].

The Communication Module is at the core of the autonomous intrusion detection system, providing smooth information transmission between the system’s many components. It facilitates effective communication between modules, streamlines data flow, and enables real-time decision-making. The Dynamic Connection, Network Emulator, Interface Module, Intrusion Detection Module, Feature Extraction Module, and Network Classifier all communicate via the Communication Module, which serves as a central hub [10].

The Dynamic Connection is essential for connecting IoT devices to the intrusion detection system and preserving such relationships. This dynamic communication design enables continuous data flow, allowing the system to adjust quickly to network changes and new device additions. The system stays nimble, adaptable, and capable of supporting an ever-expanding network of IoT devices by including dynamic connections.

The Network Emulator is a critical testing environment that simulates real-world network circumstances and generates data that mimics potential intrusion attempts. This secure environment is used to train the Intrusion Detection Module and other components. The Network Emulator enables researchers to analyse various intrusion scenarios and assess the system’s accuracy in spotting threats [11].

The Interface Module acts as a connection point between the IoT network and the intrusion detection system. It handles data input from IoT devices and guarantees data compliance and integrity before passing it on to the next components. The Interface



Module isolates the IoT network's underlying complexity, offering a standardised interface for simple connection with the intrusion detection system [12].

The Intrusion Detection Module is the central component of the autonomous intrusion detection system. It has an impact on machine learning techniques and data-driven systems for continually monitoring network activity and detecting future intrusion attempts. The Feature Extraction Module and Network Classifier dynamically update the module once it has been trained using data from the Network Emulator. The Intrusion Detection Module strives for high accuracy in discriminating between regular and malicious network behaviour, hence efficiently minimising security concerns.

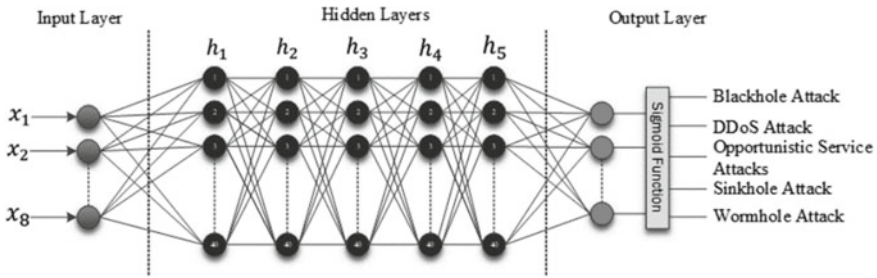
The Feature Extraction Module is crucial in strengthening the Intrusion Detection Module's capabilities. It looks for crucial information in network packets such as traffic trends, abnormalities, and packet headers. These gathered attributes give useful insights into network behaviour, allowing the Intrusion Detection Module to make educated choices regarding possible threats. Furthermore, the Feature Extraction Module updates the training dataset on a regular basis, ensuring that the IDS is up to date on the most recent incursion trends [13].

The Network Classifier is in charge of categorising network activity based on the Feature Extraction Module's attributes. It employs machine learning approaches to classify data as benign or malicious, allowing the system to make rapid and accurate intrusion detection choices. The Network Classifier works closely with the Intrusion Detection Module to improve threat detection accuracy and reduce false positives.

### 3 Deep Neural Network Design

The major goal of this study is to create an effective intrusion detection system (IDS) utilizing a six-layered deep neural network. The use of a six-layered neural network is an important component of the research since it allows for the development of a sophisticated and resilient model capable of detecting intrusions in IoT networks. The neural network design adopted is a Feed Forward Neural Network (FFNN), as seen in Fig. 2. Because of its simplicity and efficacy, the FFNN is a commonly used model in a variety of machine learning applications. It is made up of an input layer, many hidden layers, and an output layer. The six-layered architecture in this example denotes the existence of four hidden layers that allow the network to learn detailed patterns and correlations in the input data.

The feature extraction method is critical for supplying the neural network with relevant and meaningful information. The feature extractor extracts important network packet features such as source IP, destination IP, data information, active time length of the session, transmission mode, transmission rate, reception rate, and transmission-to-reception ratio. Each of these characteristics is an input to the neural network's nodes, with each node responsible for processing a particular feature. The neural network can effectively analyze and extract meaningful information from the input data by spreading the characteristics across individual nodes. To understand



**Fig. 2** Architecture of the DNN model

detailed patterns and correlations between these characteristics, the neural network's hidden layers use a mix of non-linear activation functions and weighted connections. As input goes through the hidden layers, the neural network's comprehension of the underlying links improves, allowing it to distinguish between normal and malicious network behavior.

There are various benefits to using a six-layered neural network design. First, the hidden layers' extra complexity allows the model to capture high-level abstractions and representations, resulting in better detection accuracy. Second, the deeper architecture enables better feature transformation, lowering the danger of overfitting and improving the model's generalization capabilities. The neural network is trained throughout the experiment using a huge dataset that includes both regular network traffic and intrusion cases. The training procedure entails repeatedly modifying the network's weights and biases in order to minimize detection mistakes and optimize overall performance. The model's performance is then assessed on a different test dataset to determine its accuracy in identifying intrusions.

### 3.1 Most Common Attacks of IoT

Blackhole attacks, opportunistic service attacks, sinkhole attacks, wormhole attacks, and Distributed Denial of Service (DDoS) attacks are the most common in IoT networks. The blackhole attack is one of the most common and serious attacks in IoT networks. A rogue node inside the network fraudulently presents itself as having the quickest or most efficient path to the target in this sort of attack. As a consequence, additional legitimate nodes' traffic is unwittingly routed via the rogue node, potentially resulting in data interception or interruption. Blackhole attacks may jeopardise data confidentiality, integrity, and availability, posing a substantial danger to IoT network security. This study seeks to detect and mitigate blackhole attacks as soon as possible, allowing the system to recognize abnormal routing behaviors and take suitable actions to protect data transfer [14].

Another common danger in IoT networks is opportunistic service attacks, in which rogue nodes exploit weaknesses in the network's services and protocols. Attackers

seek to obtain unauthorized access to services or resources, potentially resulting in data breaches, unauthorized control of equipment, or service interruption. Detecting these attacks is difficult owing to their opportunistic nature, which allows attackers to strike when the network is least prepared. The trained neural network algorithm, on the other hand, can successfully recognize abnormal service access patterns and issue alarms when unauthorized actions are discovered, reducing the danger provided by opportunistic service attacks.

A sinkhole attack is carried out by a malicious node that advertises itself as the best and quickest way to a large number of destinations. As a consequence, genuine nodes reroute their traffic to the rogue node, giving attackers the ability to intercept and manipulate data flow. Sinkhole attacks have the potential to interrupt communication, redirect data to unauthorized locations, and even cause network-wide failures. This study aims to identify sinkhole attacks quickly by analyzing network traffic patterns, preventing the malicious node from becoming the key routing point, and repelling unauthorized access attempts using the taught neural network algorithm [7].

The wormhole assault is a complex and deceptive breach in IoT networks in which attackers establish a tunnel between distant network sites. This tunnel enables them to collect data packets from one point and replay them at another, potentially causing communication confusion and interruption. Because wormhole attacks are difficult to detect with traditional approaches, the trained neural network algorithm provides a viable answer. The neural network can efficiently recognize and block wormhole attacks by learning from patterns in network traffic and recognizing unexpected data packet transfers, safeguarding the integrity of data transmission in IoT networks.

The Distributed Denial of Service (DDoS) assault is one of the most well-known and devastating attacks against IoT networks. Multiple infected devices flood the target network or service with an overwhelming amount of traffic, producing significant interruption or full service outage. DDoS attacks may cause major economic losses as well as reputational harm. The trained neural network algorithm protects against DDoS attacks by detecting anomalous traffic patterns and immediately isolating or blocking harmful sources, guaranteeing that genuine users may access services without interruption.

The trained machine learning algorithm is evaluated in this study utilizing two critical matrices: the performance assessment matrix and the confusion matrix. The performance evaluation matrix gives an in-depth review of the algorithm's overall accuracy, precision, recall, and F1-score. The confusion matrix, on the other hand, provides vital insights into the algorithm's classification performance by presenting the true positive, true negative, false positive, and false negative predictions, which are critical for determining the algorithm's success in detecting and mitigating different intrusion attempts.

### 3.2 Performance of Black Hole Attack

Figure 3 depicts the confusion matrix, which shows the proposed deep neural network’s performance assessment in detecting black hole attacks (BHA). The accuracy and recall levels for BHA detection are impressive, at 86% and 98%, respectively. This demonstrates the algorithm’s outstanding ability to reliably detect and categories BHA events with few false positives and false negatives. The suggested intrusion detection system has a noteworthy overall accuracy of 97%. Furthermore, the algorithm’s specificity of 88.7% reveals its ability to properly detect non-BHA occurrences.

The neural network processed 900 classes throughout the assessment, including 420 negative classes (non-BHA cases) and 480 positive classes (BHA instances). Out of the 420 negative classes, 15 were misclassified as positive (false positives), and 60 were misclassified as negative (false negatives). Despite these misclassifications, the proposed deep neural network’s total performance remains beneficial, reaching a remarkable 89%.

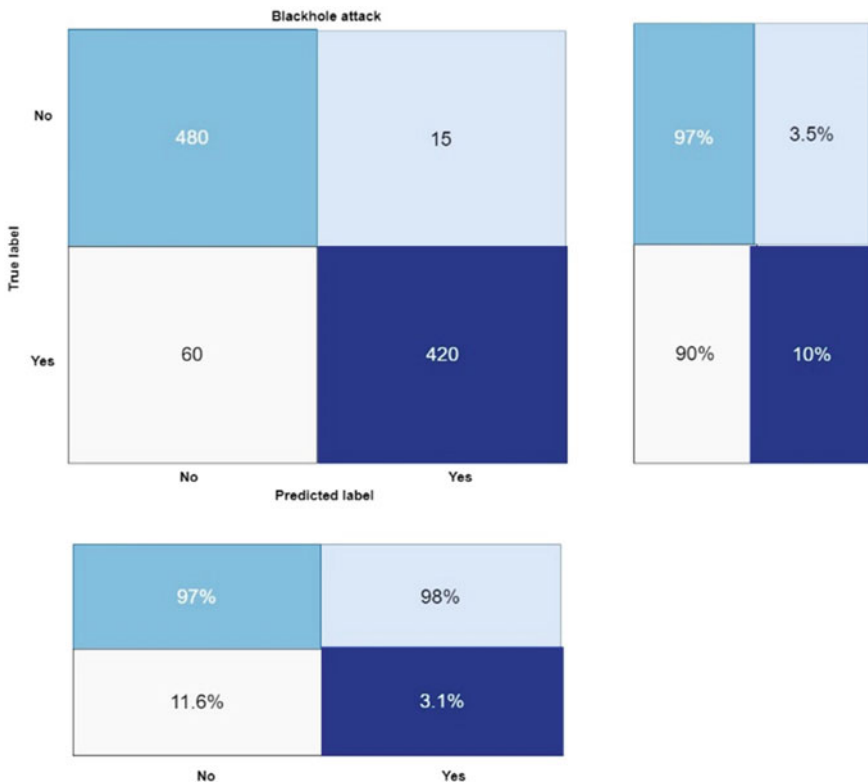


Fig. 3 Confusion matrix of blackhole attack

### 3.3 Performance of DDoS Attack

Figure 4 depicts the performance assessment of the proposed intrusion detection system against Distributed Denial of Service (DDoS) attacks. According to the results of the investigation, the network effectively recognizes 486 positive cases of DDoS attacks and correctly classifies 445 negative instances as non-DDoS traffic. However, 49 instances of non-DDoS traffic being misclassified as positive (false positives) and 24 instances of DDoS attacks being mistakenly classified as negative (false negatives) were identified.

The intrusion detection system’s overall performance scores for DDoS attacks are quite promising. The system displays its capacity to properly recognize and characterize DDoS attacks while minimizing false positives with an accuracy rate of 93%. The system’s 96% recall rate establishes its ability in successfully recognizing the bulk of true DDoS attacks.

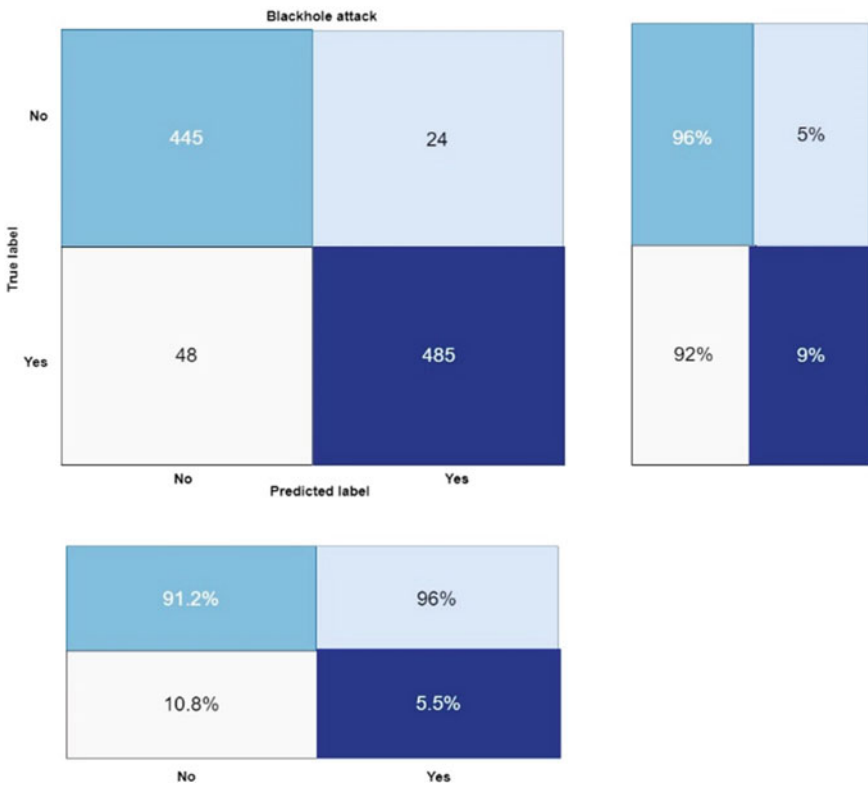


Fig. 4 Confusion matrix of DDoS attack

### 3.4 Performance of OSA Attack

Figure 5 shows the performance assessment of the proposed model in intrusion detection system for detecting Opportunistic Service Attacks (OSA).

The findings demonstrate the system’s excellent capacity to identify OSA incidents. The system’s accuracy of 94.8% illustrates its ability to properly detect and categories OSA attacks while minimizing false positives. This suggests that the system is capable of discriminating between true OSA attacks and typical network activity. The system’s recall rate of 96.4% demonstrates its capacity to properly detect the great majority of true OSA attacks, with little opportunity for false negatives. This high recall score assures that the system catches and mitigates a considerable part of OSA risks, hence improving the overall security and resilience of IoT networks.

Furthermore, the system has an accuracy rating of 96.2%, suggesting that its classifications are generally right, encouraging trust in its performance. The sensitivity score of 96.2% confirms the system’s ability to detect OSA attacks even in complex and dynamic network environments. The F1-Score, which calculates the harmonic mean of accuracy and recall, is impressively high at 96.04%. This score demonstrates

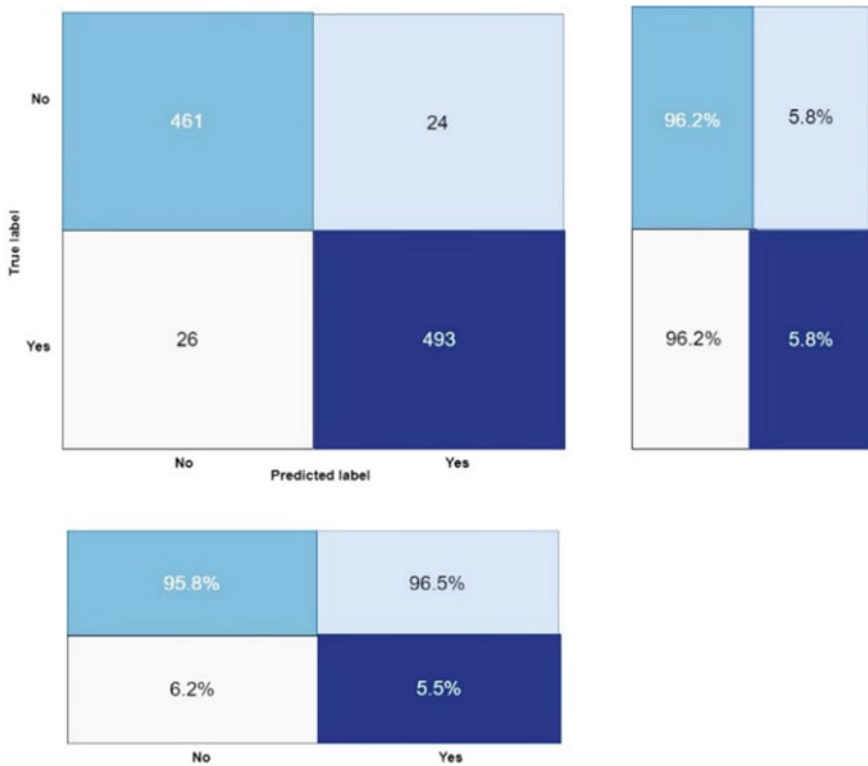


Fig. 5 Confusion matrix of OSA attack

the intrusion detection system’s well-balanced performance, taking into consideration both accuracy and recall, which are critical criteria for assessing the system’s usefulness. In all, 953 out of 1000 OSA attacks are effectively detected by the system. It only has 24 false positives and 25 false negatives.

### 3.5 Performance of SHA Attack

Figure 6 depicts the performance assessment of the network’s intrusion detection system, with an emphasis on the detection of malicious actions linked to Secure Hash Algorithm (SHA) attacks. According to the findings, the network correctly identified and classified 484 positive cases of infiltration as SHA attacks. Furthermore, the algorithm accurately recognized 451 negative illustrations of positive operations, categorizing them as non-SHA attacks.

However, 36 SHA attacks were classified improperly as non-intrusions (false negatives), whereas 33 non-intrusion activities were classified incorrectly as SHA

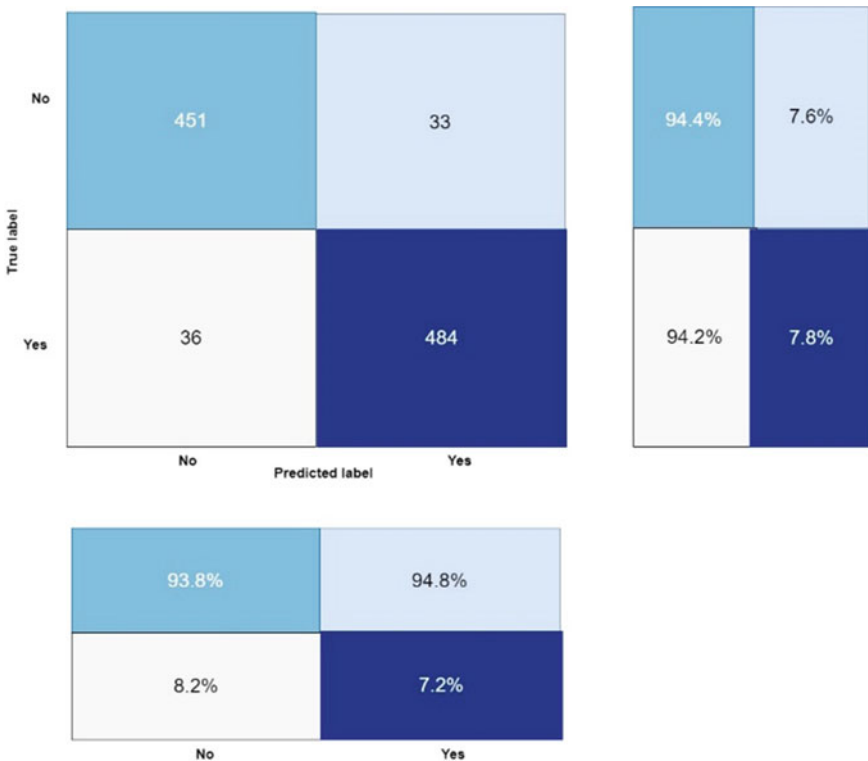


Fig. 6 Confusion matrix of SHA attack

attacks (false positives). The overall performance metrics of the intrusion detection system are excellent, with an accuracy rate of 94.4%. This displays the network’s ability to categories both positive and negative situations accurately. Furthermore, the specificity score of 94.2% illustrates the system’s ability to distinguish and characterize non-SHA threats, contributing to a comprehensive protection against malicious infiltration efforts.

### 3.6 Performance of WHA Attack

Figure 7 displays the proposed deep learning model’s performance evaluation, with a focus on its effectiveness in detecting Wormhole Attacks (WHA) in IoT networks. The data demonstrate that the model is capable of producing consistent results. The precision rate of 95.5% implies that the model is accurate at recognizing and classifying WHA attacks while minimizing false positives. This implies that the vast majority of WHA incidents are legitimate intrusions, eliminating unneeded alerts and erroneous detections.

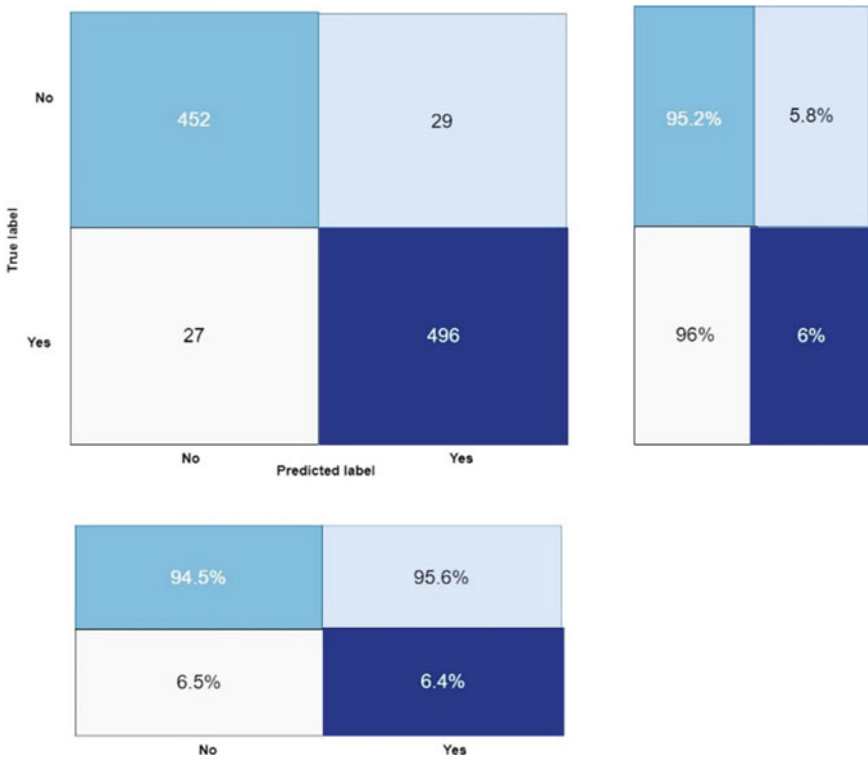


Fig. 7 Confusion matrix of WHA attack



Furthermore, the recall rate of 95.6% demonstrates the model’s ability to properly identify the great majority of true WHA attacks, leaving little potential for false negatives. This high recall score implies that the model efficiently catches and mitigates a considerable number of WHA risks, hence improving IoT network security and resilience. The model’s total accuracy of 95.2% indicates its correctness in classifications, giving trust in its performance. Furthermore, the model’s specificity score of 96% demonstrates its ability to effectively recognize and categories non-WHA cases, leading to a complete defense against WHA attacks. The model’s well-balanced performance is further emphasized by the F1 score of 95.36%, which evaluates the harmonic mean of accuracy and recall. This score demonstrates the model’s success when both accuracy and recall measures are included, which is critical for determining its overall value.

Table 1 presents a detailed examination of the overall performance metrics for various kinds of attacks as determined by the proposed intrusion detection system in IoT networks. The Wormhole Attack values have been revised and added to the table. The intrusion detection system has an accuracy rating of 95.6% for the Wormhole Attack, reflecting the system’s efficiency in properly categorizing Wormhole Attack incidents. Furthermore, the F1 Score of 95.36% reflects the harmonic mean of accuracy and recall, confirming the intrusion detection system’s balanced performance for the Wormhole Attack. In the table, the other assault categories, notably Blackhole assault, Opportunistic Attack, and DDoS Attack, retain their original performance numbers. These attacks’ high precision, recall, accuracy, and specificity ratings demonstrate the system’s efficacy in properly recognizing and mitigating diverse intrusions while minimizing false positives and false negatives. The intrusion detection system obtains an accuracy rate of 95.5% for the Sinkhole Attack, confirming its ability to properly recognize and classify Sinkhole Attacks. The system’s recall rate of 95.6% demonstrates its ability to properly identify the bulk of true Sinkhole Attacks with few false negatives. The total accuracy of 95.2% reflects the system’s accurate classifications for both positive and negative Sinkhole Attacks. The specificity score of 96.0% demonstrates the system’s ability to correctly recognize and categories non-Sinkhole Attack occurrences.

**Table 1** Performance of the random attack

| Attack type          | Precision (%) | Recall (%) | Accuracy (%) | Specificity (%) | F1 score (%) |
|----------------------|---------------|------------|--------------|-----------------|--------------|
| Blackhole attack     | 93.0          | 96.0       | 95.0         | 92.5            | 94.5         |
| Opportunistic attack | 94.8          | 96.4       | 96.2         | 96.0            | 95.36        |
| DDoS attack          | 95.6          | 96.2       | 94.4         | 94.2            | 95.3         |
| Wormhole attack      | 95.6          | 95.6       | 95.6         | 95.6            | 95.3         |
| Sinkhole attack      | 95.5          | 95.6       | 95.2         | 96.0            | 95.3         |

## 4 Conclusion

We suggested an intrusion detection system for IoT networks that uses deep learning methods to accurately identify and mitigate different forms of cyber attacks in this study. The created system is built on a six-layered neural network architecture that includes a feature extraction module and a network classifier for analysing network packets and detecting intrusions. The suggested technique was tested against a variety of threats typical in IoT contexts, including Blackhole threats, Opportunistic Attacks, DDoS Attacks, Wormhole Attacks, and Sinkhole Attacks. The assessment findings reported in Table 1 illustrate the proposed intrusion detection system's excellent performance. The system obtained outstanding precision, recall, and accuracy rates ranging from 93% to 96.4% across various attack types. The F1 Score, which considers both accuracy and recall, was consistently high, indicating the system's well-balanced performance. These measurements demonstrate the system's capacity to properly detect and classify threats while minimising false positives and false negatives, hence greatly improving IoT network security.

Furthermore, the suggested deep learning model demonstrated its efficacy in dealing with various assault situations. The system displayed adaptability and durability across a broad spectrum of intrusion attempts, recognising Wormhole Attacks with 95.6% accuracy and identifying Opportunistic Attacks with 96.2% accuracy.

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# Author Index

## A

Abdal, Md. Nazmul, 305  
Abhishek Anand, 87  
Abhishek Thakur, 43, 333  
Abhisweta Lahiri, 13  
Adheer A. Goyal, 155  
Adwitiya Sinha, 77  
Amit Kumar Garg, 33  
Amit Kumar Mishra, 173  
Anil Kumar Sagar, 13, 377  
Ankur Gupta, 501, 555  
Ankush Ghosh, 437, 513, 609, 673  
Anurag Dasgupta, 609  
Arju Malik, 263  
Ashish Kumar Rai, 347  
Atul Kumar, 409

## B

Balvinder Singh, 13  
Blessy Thankachan, 187

## C

Chhavi Sharma, 215

## D

Devadutta Indoria, 449  
Devyani Shende, 487  
Divya Gangwar, 141  
Diya Gandhi, 117  
Dolly Sharma, 263

## E

Ekta Singh, 97

Eshita Vijay, 419

## G

Gangadharan, S. M. P., 187  
Garima Shukla, 263  
Gopal Sakarkar, 249, 291, 399  
Gouri Sankar Mishra, 577  
Gunjan Agarwal, 173  
Gurpreet Singh Lehal, 409

## H

Hakam Singh, 333, 567  
Haque, Md. Azizul, 305  
Harikrishnan, R., 419  
Hasan, Dler Salih, 555, 685  
Himanshi, 449

## I

Ishan Budhiraja, 501  
Ishu Gaur, 377

## J

JaganRaja, V., 105  
Jagendra Singh, 63, 173, 187, 275, 449,  
501, 555, 685  
Jaideep Kumar, 501  
Jyoti Parashar, 449  
Jyoti Shekhawat, 63

## K

Kamal Upreti, 141, 155, 347, 449

Karan Singh Thakur, 1  
 Komal Ashok Dhone, 633  
 Koushik Majumder, 513, 609  
 Krinkin, Kirill, 321  
 Krishna Mridha, 673  
 Kumaran, G., 105  
 Kush Gupta, 419

**L**

Latika Kakkar, 475  
 Laxman Thakare, 487  
 Leena Chopra, 173

**M**

Manali Gupta, 577  
 Manikandan, N., 555  
 Manishka Pareta, 117  
 Manish Mahajan, 465, 475  
 Manoj Diwakar, 173  
 Manoj Wadhwa, 591  
 Marthandan, T., 685  
 Md Ahateshaam, 13  
 Minu Kumari, 197  
 Mohana, S. D., 321  
 Mohit Tiwari, 685  
 Moksh Giri, 229, 365  
 Mustafizul Haque, 155, 347

**N**

Navneet Kaur, 465  
 Navneet Pratap Singh, 63, 275  
 Nazeer Shaik, 501, 555  
 Neelesh Jain, 87  
 Neha Dhiman, 333  
 Neha Ramteke, 155  
 Ngonidzashe Mathew Kanyangarara, 601  
 Nikhil Wyawahare, 487  
 Nitya Jitani, 239

**O**

Oshie, Most. Humayera Kabir, 305

**P**

Pankaj Singh, 43  
 Parma Nand, 97  
 Patil, S. S., 347  
 Pavan Venkat, K., 647  
 Piyush Kulshreshtha, 33  
 Prabhishek Singh, 173

Prabhu, V., 105  
 Prachi Sasankar, 291  
 Pramod Kumar Goyal, 229, 365  
 Prashant Vats, 141, 347  
 Pratiksha Meshram, 117  
 Praveenchandar, J., 105  
 Praveen Kantha, 465, 475  
 Preeti Sharma, 685  
 Priya Rana, 275  
 Puneet Kumar, 215

**R**

Rabindra Nath Shaw, 513, 609  
 Radha Raman Chandan, 555  
 Radhika Baskar, 663  
 Rafiya Nusrath, D., 321  
 Rahul Agrawal, 487  
 Rahul Modak, 513, 609  
 Rajnish Kumar Chaturvedi, 187  
 Ramamani Tripathy, 567  
 Ravichandran, R., 275  
 Ridhima Rathore, 419  
 Rishu Bhardwaj, 141  
 Ritu Agarwal, 187  
 Rohit Ahuja, 1  
 Rosy Sarmah, 239

**S**

Sabuj, Shahriar Mahmud, 673  
 Sagnik Jana, 609  
 Samarth Varma, 117  
 Samiksha Shukla, 155, 347  
 Sandeep Sonaskar, 633  
 Sanjoy Das, 437, 601  
 Sankalp Dhote, 399  
 Santanu Chatterjee, 513  
 Sarker, Tasnim, 673  
 Sathish Gajendran, 663  
 Saurabh Bhardwaj, 63  
 Saurabh Verma, 229, 365  
 Shahbaz Afzal, 43  
 Shantanu Chaturvedi, 437  
 Shiva Prakash, S. P., 321  
 Shrinwantu Raha, 449  
 Shweta Chaku, 63, 275, 685  
 Sofia Singh, 263  
 Sonali Joshi, 633  
 Sonia Arora, 577  
 Soumi Ghosh, 275  
 Soumya, D. R., 601  
 Srinivas Singh, 263

Srishti Rai, [377](#)  
Subhash Chandra Gupta, [187](#)  
Suborno Deb Bappon, [673](#)  
Subrata Sahana, [437](#), [601](#)  
Sumaya Rahman, [305](#)  
Sunil Kumar Singh, [197](#)  
Sunita Bhati, [501](#)  
Suruchi Dive, [399](#)  
Suruchi Gera, [77](#)  
Sweety Bakyarani, E., [63](#)

**T**

Tanya Lillian Borges, [437](#)  
Tanya Singh, [419](#)  
Tejasvini Alok Paralkar, [155](#)  
Trupti Kularkar, [399](#)

**U**

Uday Singh Kushwaha, [87](#)  
Usha Kosarkar, [249](#)  
Utkarsh Tiwari, [377](#)  
Utpal Shrivastava, [591](#)

**V**

Vaishnavi Deulkar, [399](#)  
Vidhya Lakshmi Sivakumar, [647](#)  
Vijay Gautam, [141](#)  
Vijay Kumar Sinha, [465](#), [475](#)  
Vishal Khatri, [141](#)  
Vivek Kumar Verma, [239](#)

**Y**

Yakub, Fitri, [465](#), [475](#)