Chinmay Chakraborty
Mohammad R. Khosravi *Editors*

Intelligent Healthcare

Infrastructure, Algorithms and Management

Springer

Intelligent Healthcare

Chinmay Chakraborty • Mohammad R. Khosravi
Editors

Intelligent Healthcare

Infrastructure, Algorithms and Management

Springer

Editors
Chinmay Chakraborty
Electronics & Communication
Engineering
Birla Institute of Technology
Ranchi, Jharkhand, India

Mohammad R. Khosravi
Computer Engineering
Persian Gulf University
Bushehr, Iran

ISBN 978-981-16-8149-3 ISBN 978-981-16-8150-9 (eBook)
https://doi.org/10.1007/978-981-16-8150-9

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

This book aims at promoting and facilitating exchanges of research knowledge and findings across different disciplines on the design and investigation of machine learning-based data analytics of intelligent healthcare infrastructures. This book also has an extensive focus on the emerging trends, strategies, and applications in healthcare data analytics and the related perspectives. The Internet of Medical Things (IoMT) systems will continuously generate massive data that requires big medical data processing techniques. Data analytics issued for healthcare to meet many technical challenges and issues that need to be addressed to realize this future healthcare systems. The advanced healthcare systems have to be upgraded with new capabilities such as data science, machine learning, intelligent decision-making, and distributed professional services. The IoMT helps us to design and develop intelligent healthcare solutions assisted by data analytics and computational intelligence. On the other hand, pervasive and ubiquitous computing still experiences new developments based on fusion-based and blind strategies for healthcare applications.

This book provides learning-based services, data-driven infrastructure design, analytical approaches, and technological solutions with case studies for smart health informatics. Among the required services, a smart and remote healthcare service will be crucial for smart cities to be realized. It is predicted that medical services will be provided remotely in an extensive platform, for instance, remote surgery, wearable sensing to predict illnesses, and intelligent medical helps based on artificial intelligence. Learning-based solutions with supervised and unsupervised methods are becoming so hot to be applied to various real-world problems. This book gives all the content into five main sections:

- Computational Intelligence
- Communications Technologies
- Security and Privacy
- Biomedical Signal and Image Processing
- Special Topics on COVID 19

As the last point, we would like to extend our sincere thanks to the contributing authors from industry, academia, and policy expertise to complete this work for aspiring researchers in this domain. We are confident that this book would play a key role in providing readers a comprehensive view of intelligent health informatics and developments around it and can be used as an e-learning resource for various examinations which deal with cutting-edge technologies.

Ranchi, Jharkhand, India Chinmay Chakraborty
Bushehr, Iran Mohammad R. Khosravi

Contents

About the Editors

Chinmay Chakraborty is a Assistant Professor at Birla Institute of Technology, Mesra, India, and Post-doctoral fellow of Federal University of Piauí, Brazil. He has published more than 150 conference presentations, journal papers, book chapters, and books and organized more than 20 special issues in various journals including IEEE, Springer, IGI Global, CRC Press, TechScience, MDPI, etc. His main research interests include the Internet of medical things, wireless body area networks, telemedicine, m-Health/e-health, and medical imaging.

Mohammad R. Khosravi is currently a researcher in the fields of communications, networking, and computing systems. He is now a research associate for multimedia and networking at the Department of Computer Engineering, Persian Gulf University, Iran, and a part-time research engineer and consultant in IEI Company, Iran. His main interests include statistical signal and image processing, medical bioinformatics, radar imaging and satellite remote sensing, computer communications, internet of things (IoT), wireless sensor networks, cyber-physical systems, multimedia networks, UAV networks, and information science (scientometrics).

Part I
Data Science in Intelligent Healthcare

Chapter 1
Distributed and Big Health Data Processing for Remote and Ubiquitous Healthcare Services Using Blind Statistical Computing: Review and Trends on Blindness for Internet of Artificially Intelligent Medical Things

Mohammad R. Khosravi

Abstract This chapter addresses a review and some relevant discussions about blind statistical computing in medical signal and image analysis for remote and pervasive medical systems through medical sensors in an internet of medical things (IoMT)-based intelligent healthcare platform. Blind computing as an outstanding keyword of this research is defined for IoT/IoMT nodes where statistical methods are investigated for making adaptive and high-performance blind computing. In addition, a taxonomy of different blind and non-blind computing techniques is illustrated with detailing various properties for IoMT applications. Then, a further discussion on statistical blind computing for adaptive data reconstruction is given to indicate power of statistical estimators to reach the high-performance blind computing. In the third part, some details and future trends regarding decision support systems based on statistical blind computing through IoMT are discussed to introduce interesting research points for prospective researchers in the topic of IoMT-assisted healthcare services.

Keywords Medical imaging · Blind computing · Medical data analysis · Internet of things (IoT) · Statistical computation · Pervasive computing · And cyber-physical systems (CPS)

M. R. Khosravi (✉)
Department of Computer Engineering, Persian Gulf University, Bushehr, Iran

Department of Electrical and Electronic Engineering, Shiraz University of Technology, Shiraz, Iran
e-mail: m.khosravi@sutech.ac.ir

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_1

1.1 Introduction

Nowadays, statistical methods are widely used in different aspects of medicine, science and engineering. Statistical approaches for high-performance, efficient and fast computing in medical data processing and analysis are now a hot topic of research [1–11]. In this research, the aim is to introduce some advances of statistical processing methods towards blind computing and distributed unsupervised recognition in remotely-accessed medical systems, from remote sensor-based diagnosis to actuator-based remote surgery. These methods which can also be combined with mathematical optimization techniques and heuristic methods in soft computing (e.g., bio/nature-inspired meta-heuristic and hyper-heuristic optimization using evolutionary computing/swarm intelligence, neural networks, and fuzzy logic), affective computational intelligence and artificial intelligence of things (AIoT), and information decomposition transforms (including transform domain computing, blind source separation (BSS), and compressive sensing/sparse representation) for solving complex problems of signals and images in medical diagnosis, sensing, computing and communications through cyber-physical medical systems (CPMS) and generally cyber-physical systems with various elements of industry and society [12–80].

Blind computing here indicates a wide range of computational methods that do not need any kind of external data fusion [70] and supervised machine learning platforms [21, 22]. The advantages behind this idea are: (1) there is no need to collect specific external data for fusion and to train machine learning algorithms (external data as training sets), (2) there is no dependency between the performance of computational systems and the external data that does not affect the outcome in different scenarios, and (3) to have lower complexity in real-time pervasive computing architecture through low-cost devices. In practice, each practical scenario will encounter a kind of main data for processing such that the data will have some specific features, thus in non-blind computing, if the external data is not selected properly as per the features of the main data, then the output of computing would not be acceptable. Although the blind strategies may have lower performance than the non-blind ones, their performance not only is independent from the main data features per scenario, namely, with changing test data we should not observe a great loss, but also they do not need external information to be performed (sometimes providing the training sets is very hard). Of course, independency of the main data features does not mean that a blind method must not be optimized according to the computational scenario and the main data features, optimization to enhance the final performance is always a key point which is towards adaptive computing and greediness. In the third section, more information on perspectives of blindness for ubiquitous unsupervised computing will be provided, more around collaborative/federated learning. Table 1.1 provides a taxonomy of blindness with presenting various aspects of real-world use of computational intelligence.

The expected applications of statistical blind computing contain many different challenging problems in medical diagnosis, remote/wireless patient monitoring, and health data retrieval, management, security, coding, and communications. For

Table 1.1 Taxonomy of computational blindness vs. other non-blind models for pervasive IoT nodes

Computational models / Properties/advantages/disadvantages	Blind computing (general unsupervised/non-fusion-based techniques)	Statistical blind computing	Semi-/supervised learning/machine learning	Outsourced fusion-based computing
Sensitivity as to external data fusion	No	No	Yes	Yes
Complexity for fast, low-power, and low-cost computing (real-time IoT pervasive devices)	Acceptable	Acceptable	Relatively high	Relatively high
Need to specific training sets	No	No	Yes	Yes
Adaptive computing capability (nonlinear filtering, content-aware, etc.)	Maybe	Mostly yes	Yes (data-related)	Yes (data-related)
General performance (pervasive IoT devices)	May be acceptable	Acceptable	Acceptable (better than blindness)	Acceptable (better than blindness)
Federated/collaborative learning capability (pervasive IoT devices)	N/A	Yes (unsupervised)	Yes (supervised)	N/A

instance, data processing can be useful for brain tumor and cancer detection, drug design, lesion evaluation and many other applications. As follows, some theoretical aspects of mathematical statistics are reviewed which may be applied to medical signal/image computing. Detection and estimation theories are two main aspects of statistical computing in multi-dimensional signal processing. These methods can be applicable into any form of medical imaging technology like positron emission tomography (PET), magnetic resonance imaging (MRI), computed tomography (CT), X-ray, and ultrasound, and also functional MRI (fMRI). They are also usable for biomedical signal processing (EEG, ECG, etc.). Another open problem in medical diagnosis is to use image segmentation and classification techniques based on statistical clustering, adaptive thresholding, and all forms of unsupervised/supervised learning in statistical pattern recognition. In addition, medicinal decision-making systems using different concepts of image classification such as hidden Markov model (HMM), support vector machine (SVM), statistical models in deep learning and so on are very hot areas of the current research. Combination of statistics and multi-resolution/decomposition transforms (wavelets, blind source separation techniques, e.g., independent component analysis (ICA)) for medical image analysis are highly investigated. However, for distributed and remote healthcare services based on biomedical imaging, mainly optical images can be captured for medical diagnosis through low-cost pervasive devices such as smartphones.

The statistical methods are also used in medical signal, image and video coding, security and privacy, and low-latency and ultra-reliable data transmission. Statistical image modeling based on sparse representation and compressed sensing techniques, and probability distributions is now very interesting for medical engineering and computer scientists. Computer methods for medical imaging in clinical studies can also benefit from statistical approaches. Performing suitable pre-processing such as noise reduction is vital in medical image analysis. Medical images (due to specific imaging technologies) often suffer from different intense noises including speckle, Gaussian and Rician. Thus, most of powerful denoising methods are being designed with using statistical computing. Denoising can improve quality of medical images and make medical diagnosis and prognosis more accurate.

As mentioned, the main idea of this research is to realize an insight onto blind statistical signal/image computing in CPMS and distributed nodes in IoMT platforms. Each distributed node in an IoMT-based joint computing/communication platform must be able to perform some processing aspects of images independently in order to pervasive computing-based medical diagnosis/prognosis, even if its hardware is very simple and there is a possibility of cloud/fog/edge computing through data transmission over internet. IoMT provides a backbone for computing and communications of medical images and other medical sensors, e.g., wearable cases. With integration of IoMT facilities with physical sensors from heartbeat sensors to imaging devices, a CPMS is created. In addition, some additional supports including control and cybernetics through human-machine interfaces (HMIs) and actuators, and cloud-based storage and analytics are required to integrate a highly reliable medical service as distributed and remotely available.

In this part of the first section, an outline of the given topics is presented. The second section compares two examples of reconstruction filters for making medical images high-resolution. Both classes of the filters are categorized as blind statistical computing strategy while one is providing adaptive computation but another one does not give. With comparing them, the importance of adaptation in statistical computing will appear, as addressed in Table 1.1. The third section gives us some perspectives on future trends of blind statistical computing for different applications of pervasive computing regardless of machine learning basis and the requirements from quality of experience (QoE), diagnosis, etc., in fact, it is closely a future scope for unsupervised federated learning using statistical decision-making. Moreover, the last section makes a conclusion on all the work.

1.2 Blind and Content-Aware Adaptive Computing: Statistical Optimization of Image Reconstruction Filters

Reconstructions filters for images are very important to be designed and implemented in order for different purposes such as medical diagnosis to be realized better. For example, interpolators as a very popular sort of these filters are used to recompress and magnify the digital images (a process of enhancing the spatial resolution). A main use of the filter in medical imaging is to use it for helping physician to have a more accurate decision about a disease. The reconstruction filters are mostly work in spatial domain, but sometime they are designed to be implemented in a transform domain such as fast Fourier transform (FFT), discrete cosine transform (DCT), and discrete wavelet transform (DWT). We can consider these filters as a dual performance mode for restoration filters which are used for noise level reduction (sometime as denoising). Both filter types will usually have a kernel/mask to apply a low-pass filters to the images to reach a final restored/ reconstructed output. On the other hand, magnification of medical images with a blind process does not include some steps that must be performed in a medical image super-resolution problem, e.g., supervised/fusion-based edge enhancement and de-blurring. Super-resolution is mostly used for high-order magnification (zooming or enlargement), thus with only the blind modes of operations, the output will not have an acceptable quality alongside its achieved resolution. However, the opinion of the author is to use only blind techniques for computations in a reconstruction filters for lower scales of magnifications (less than 4 times). Such filters are known mainly as image interpolators whose area of research has been constantly very hot in multimedia engineering since 1970. The design of the image interpolators has faced some revolutions and evolutional steps from its inception (from about 50 years ago until now). The first generation of interpolators was coming from numerical analysis in two-dimension (2D), particularly the topic of numerical interpolators, and later some aspects of signal processing theory had been added to them to create novel convolutional kernels for 2D filtering. The view behind this generation of interpolating filters was the king of image reconstruction area till around 2000 while the idea of edge-directed interpolation for digital images was born. This idea was solely for digital image processing on which such a view had not been seen in the classic image interpolation theory (coming from numerical analysis and pure signal processing). From now in this section, all the scientific findings discussed in the topic of reconstruction filters are towards blind computing.

The researchers had found out that all the past interpolators with a typical kernel shape can just adjust 2D distances in a reconstruction problem whereas the issue of edge preservation is being ignored. In fact, a new requirement was made in the area to go to the second generation of interpolators where two kinds of adaptation must be considered at the same time. Of course, in recent 20 years, most of the edge-directed interpolators are created for a fixed rescaling factor, thus since they may not need distance-based adaptation and then we may not observe an inherent tool in them to handle the issue of distance adaptation similar to the before 2000 interpolators. However, they normally use statistical ideas to make a kind of adaptation towards edge-aware reconstruction. The last saying does not mean that all the edge-directed (in some texts as edge-guided) should be presented with using statistical estimators, but this fact that most of them are statistically adaptive also exists. As mentioned, the edge-based adaption is a dedicated approach of interpolation in digital image processing, because it closely depends on local information in each image region related to the local gray-levels. Therefore, as a conclusion on the topic, we can clear that there are indeed two kinds of adaption for designing modern image reconstruction filters and interpolators: (1) classic view with a fixed kernel shape that creates linear image filters and only can adjust distances, (2) modern view with a variable spatial mask (without a fixed kernel shape) which results in non-linear filters and can apply edge preservation strategies to a constant reconstruction template of 2 times (with no need to distance-based adaption, this template is named quartered [14]). As follows, some existing statistical filters are qualitatively evaluated to show the recent advancements in the area of the edge-directed filters.

To create edge-directed adaptive interpolators, there are different ways. For example, a typical way is to make an expansion on the linear filters such as bilinear and bicubic such that the interpolator can consider local information of the edge at each sliding reconstruction mask, and consequently, the achieved filter will be adaptive for both aspects of distance-awareness and edge-guidance. Normally, heuristic ideas are utilized to make a kind of edge-guidance, but such ideas are not powerful where the adaptation from them is not impactful strongly. The only thing obtained in such ways is to have a non-fixed kernel and then a non-linear filter. However, if the edge-guidance is created by adaptive statistical estimators towards the concept of greedy computing for designing a non-linear filter, it will be most powerful. The main problem in this kind of edge-guided interpolators is to ignore the distance-based adaptation, thus they can mostly be used in the 2-time magnification problems (with a quartered template) although it does not need a kind of distance weighting, and is not free-sized or scalable. Fortunately, one of the most recent approaches could solve all the problems described here for both aspects such that it has presented a non-linear filter with distance-based adaptation based on bilinear and edge-guidance with using greedy, fair, and the most adaptive edge weighting, it was named BL-ALM [14]. Now, we focus on edge-based adaptation, or briefly edge-guidance, when pointing out the term of adaptive reconstruction filter/interpolator. For simplicity, all the discussion would be around the quartered template at this point.

The adaptive filters based on statistical weighting could attract much attention in recent two decades [12–14]. They consider statistical diversity and dispersion of input pixel values at every local mask separately, therefore each mask can have a different set of weights for itself while moving through the image to compute (= resample) all upsampled pixels during the enlargement process. For detailing the background, we here review three statistical interpolators qualitatively and provide their taxonomy properties. Two of them use adaptive weighting process and one is based on a simple averaging process and cannot compute missing values adaptively (with considering greediness, it is non-adaptive). The greediest finding must select the best possible weights at each level of computing, so if a technique ignore all or a part of greediness requirements in order to compute weights, it is not fully adaptive. If the greediness is applied partially in a technique, it is considered as partially adaptive (= semi-adaptive). On the other hand, if a technique forces all weights to be fixed at all reconstruction scenarios, it means it is against greediness and in fact is a non-adaptive filter. Table 1.2 describes these three methods with their properties.

Table 1.2 A comparison of some statistical reconstruction filters

Filters (interpolators)	Blind computing	Adaptive weighting for edge-guidance	Non-linear filtering	Grade of greediness	Neighbourhood system	Scalability (for distance adaptation)	Complexity description
FWQI [9]	Yes	No	No	0%	1st order	No (not needed[b])	Very low
LMMSE [70]	Yes	Yes	Yes	50%[a]	1st order	No (not needed[b])	More than FWQI
ALMMSE [12]	Yes	Yes	Yes	100%	1st order (the basic model)	No (not needed[b])	More than LMMSE
BL-ALM [14]	Yes	Yes	Yes	100%	1st order (the basic model)	Yes	More than ALMMSE

[a]Collinear weights have to get the same value, thus greediness is not complete, but orthogonal weights are selected adaptively
[b]The quartered templates basically do not need this kind of adaptation

As seen in Table 1.2, fixed weight quartered interpolator (FWQI) is not adaptive, because it is a kind of bilinear filtering for the quartered templates. It is also can be interpreted as the least complex form of linear minimum mean square error-estimation (LMMSE) and adaptive LMMSE (ALMMSE). On the other hand, LMMSE is semi-adaptive or half-greedy, but ALMMSE is fully adaptive and greedy. The greediness and adaptive weighting do not guarantee better performance of any technique for every test image because the image type, its texture and statistical features and some other content-based properties related to the image scene and imaging sensor are also very import to assess the performance of a blind reconstruction filter. In brief, the most impactful factors on the performance of blind filters are as follows:

- Energy of the image (related to the general variance and/or volume of darker areas)
- Diagonal filtering (to have it, or to ignore it (= 100% greediness))
- The order of neighborhood system (related to the number of correlated neighbors),

which may make one specific filter more suitable for an image whether from optical or non-optical imaging sensors for general use, medical imaging, and remote sensing systems. The idea behind LMMSE is coming from a general estimator design methodology in advanced statistics (inference issues) that says for having locally adaptive weighting, we need to minimize the variance of a linear estimator with several inputs. This method is mostly pointed out as a branch of minimum-variance unbiased estimation (MVUE) to provide inverse-variance weighting (a technique in meta-analysis or sensor fusion), however since inputs in an image are not random variables, therefore for computing of their variance, several heuristic ideas can be performed. One of them for LMMSE in [70] has been reviewed, it will be observable that the grade of greediness/adaptation is not complete (only 50%). On the other side, ALMMSE could provide a creative idea to complete the grade of greediness to be 100% [12]. Compared to FWQI that has a fixed reconstruction kernel, LMMSE and ALMMSE are very advanced approaches, however the idea of greediness in theory cannot guarantee a global optimum during the statistical optimization with MVUE-based weighting in complicated image data. Normally, we can try to see what happens when such ideas are applied to an input image on which having an expectation to reach a local optimum is perfectly logical and reasonable. Whereas FWQI, LMMSE, and ALMMSE are not scalable for distances, but as mentioned earlier, BL-ALM is adaptive for two different aspects of edge and distance [14]. BL-ALM is a modified version of ALMMSE towards scalability of zooming considering unequal distances.

1.3 Statistical Directions on Unsupervised Medical Diagnosis

Supervised machine learning-based computing for optimization [25, 48], estimation [74], prediction and time series analysis [54, 62, 69], detection and decision support systems [64], and identification/recognition [23, 24] with using statistical pattern recognition, neural networks and deep learning, and fuzzy classification is very helpful for real-world problems, however all computing models in the supervised mode are non-blind, and therefore suffer from the issues addressed in the first section. On the other hand, MVUE-based estimation provides blind high-performance computing towards fairness, adaptation and greediness along with the dedicated properties of blindness such as reliability for various types of data and multi-purpose use, fast implementation and easiness to use. Today, many sensorial data structures related to healthcare systems (and remote sensing) behaves like big data. Big data normally has five conditions to be met, i.e., Volume, Verity, Velocity, Veracity, and Value. While a huge volume of healthcare data with various types are used for critical applications of human health and needs reliable storage and fast processing and communications in a very accurate manner, thus the intelligent solutions for remote and pervasive healthcare services are not sometimes based on supervised machine learning with complicated prerequisites. In fact, adaptively blind computing can be much better, particularly for remotely distributed cheap nodes with less processing capacity, memory storage, energy (in wireless nodes), and even with low-cost and weaker communication links for internet access. An example of such devices among wearable sensors can be modern-day smart watches with a wide use among people with capabilities for health monitoring and predicting diseases (including heart beat processing and ECG analytics, blood pressure measurement (really?), and body temperature checking) such that we know although these devices are a kind of IoMT- and/or artificial intelligence of medical things (AIoMT)-enabled sensors, have less capacity for processing, storage, data transmission, and energy storage. In such cases, blind computing can provide more efficient computational tools.

For small and low-cost devices with lower processing capability (CPUs, GPUs, etc.), a solution is to use collaborative learning (generally as supervised machine learning approach) to be trained remotely and used in medical decision-making problems for anticipating illnesses prior to any difficulty and inevitable health issue. If an IoMT/AIoMT-enabled device is utilized remotely, we may need to update its prediction rules as per the on-demand requests, e.g., a new pandemic, this kind of learning may be very effective to keep the device updated. However, mostly making updates even with collaborative learning is very hard because running supervised learning techniques with a huge amount of training samples needs a relatively considerable computational source along with a strong access to internet (to be connected to other nodes in a smart home (as nodes for edge/fog [36, 39, 41, 43]), or even a cloud [36, 39, 41–43, 53, 55, 58, 63, 65, 76, 77]). Thus, a new model of this sort of learning is defined as unsupervised collaborative learning for such scenarios. It is understandable that most of the smart watches with several healthcare wearable sensors are not independent devices. They mainly rely on a smartphone, however their connection is highly range-limited, more with Bluetooth and Wi-Fi. Therefore, as IoMT nodes, they have access to internet for receiving some updates from a control infrastructure (e.g., cloud-based healthcare data center), nevertheless this access and their sources may not be sufficient for performing updates of supervised learning, and making decision any time. The solution seems to be unsupervised collaborative learning where updates are downloaded quickly as only some health control parameters through internet access without an emergency priority, but decision-making for diagnosis is not based on training sets, and would be faster accordingly whereas the computational power has not been strong. If in this case, a wearable sensor can easily use a part of computational sources of the smartphone or other devices in the home to make a prediction or healthcare monitoring. As unsupervised approaches need less computational sources, it is predicted that wearable sensors are able to make a medical processing solely based on their own processing capacity with a very low battery usage in most cases [36]. However, the ability of access and use of sources of other connected devices must remain because of unpredicted cases (e.g., the low battery alarm at wearable sensors). This process is a realization of unsupervised collaborative learning at distributed, ubiquitous, and remote healthcare nodes. It seems that regardless of the issue of training, all healthcare devices that need a persistent internet access (mainly for being connected to a cloud server [36, 39, 41–43, 53, 55, 58, 63, 65, 76, 77]) for decision-making and monitoring, are not reliable in practice.

Among statistical decision-making techniques, some techniques related to the statistical detection theory can be a good nominee to be used for unsupervised collaborative learning-based blind computing systems. These techniques similar to statistical (and non-statistical) clustering methods are unsupervised, in other words they are blind, but their theoretical fundamentals are completely different. The interesting point about them is to benefit from formulations of supervised statistical learning such as Bayesian methods, but they do not need to be trained with a training set. In fact, their supervisor is internal, and can be self-trained with using some spatial/time observations. These techniques are faster (than the supervised methods) and have been very popular in radar systems for warfare and remote sensing a long time ago, and now can be a reliable alternative for distributed cheap health monitoring devices. The detection methods are normally stronger than the clustering methods to reach a more accurate decision, in fact, they provide a kind of adaptively intelligent decision-making, similar to the estimators presented in the previous section. Both approaches are adaptive and blind with a strong root in advanced statistics, one for parameter estimation and another one for decision-making. Both can make the procedure of medical diagnosis more reliable. However, we must not expect or interpret them to be rivals of non-blind and supervised methods.

It is worthy to be mentioned that some blind parameter estimation techniques, e.g., bilinear, ALMMSE, and BL-ALM, may have been interpreted as a kind of supervised computing architecture with internal supervisor, this issue for bilinear as a polynomial numerical interpolator is clearer because the concept behind its processing is based on over-fitting which a direct form of supervision, however as there is no guide from outside, thus this supervision is not a kind of data fusion or supervised learning.

1.4 Conclusions

In this study, we reviewed some topics about the importance of blind statistical computing for medical systems with remote services. The study firstly was focused on defining some key terms such as blindness, adaptation and fair computing, and then some concepts related to IoT and CPS for medical systems. In total, a good framework for creating an internet of artificially intelligent medical things platform was illustrated in order for future healthcare services to be created. The main topic in IoMT/CPMS is computing or data processing jointly with sensing and communications [78–80]. As told throughout the text, the main subject here is blind computing for low-cost and low-power remote healthcare devices and gadgets. In this regard, in the second and third section, we extensively and deeply tried to draw a future guideline for different aspects of blind computing in medical applications.

In detail, the second section was about high-performance blind reconstruction techniques without any need to external supervision, whereas the third one was trying to provide some perspectives and trends on the use of blindness for reliable decision-making in medical diagnosis and decision support systems for health industry, mainly through pervasive wearable sensors as to ECG/EEG.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Khosravi, M. R. (2021). Signals and network applications for medical informatics, wireless body area systems and remotely-sensed e-health monitoring. *Current Signal Transduction Therapy, 16*(1), e050521193154.
2. Khosravi, M. R. (2021). Multimedia and information technology in healthcare systems, bio-signal communications and biometrics. *Current Signal Transduction Therapy, 16*(2), 92.
3. Khosravi, M. R., & Yazdi, M. (2018). A lossless data hiding scheme for medical images using a hybrid solution based on IBRW error histogram computation and quartered interpolation with greedy weights. *Neural Computing and Applications, 30*, 2017–2028.

4. Shahparian, N., Yazdi, M., & Khosravi, M. R. (2021). Alzheimer disease diagnosis from fMRI images based on latent low rank features and support vector machine (SVM). *Current Signal Transduction Therapy, 16*(2), 171–177.
5. Sun, J., Qi, L., Song, Y., Qu, J., & Khosravi, M. R. (2021). A dynamic programming approach for accurate content-based retrieval of ordinary and Nano-scale medical images. *International Journal of Nanotechnology*.
6. Li, G., Suna, J., Song, Y., Qub, J., Zhua, Z., & Khosravi, M. R. (2021). Real-time classification of brain tumors in MRI images with a convolutional operator-based hidden Markov model. *Journal of Real-Time Image Processing, 18*, 1207–1219.
7. Khosravi, M. R., & Samadi, S. (2019). Efficient payload communications for IoT-enabled ViSAR vehicles using discrete cosine transform-based quasi-sparse bit injection. *EURASIP Journal on Wireless Communications and Networking, 262*, 1.
8. Akbarzadeh, O., Khosravi, M. R., Halvaee, P., & Khosravi, B. (2020). Medical image magnification based on original and estimated pixel selection models. *Journal of Biomedical Physics and Engineering, 10*(3), 357–366.
9. Khosravi, M. R., et al. (2020). Spatial interpolators for intra-frame resampling of SAR videos: A comparative study using real-time HD, medical and radar data. *Current Signal Transduction Therapy, 15*(2), 144–196.
10. Attar, H. H., Solyman, A. A. A., Mohamed, A. F., Khosravi, M. R., Menon, V. G., Bashir, A. K., & Tavallali, P. (2020). Efficient equalizers for OFDM and DFrFT OCDM multicarrier Systems in Mobile E-health video broadcasting with machine learning perspectives. *Physical Communication, 42*, 101173.
11. Attar, H., Khosravi, M. R., Igorovich, S. S., Georgievan, K. N., & Alhihi, M. (2020). E-health communication system with multiservice data traffic evaluation based on a G/G/1 analysis method. *Current Signal Transduction Therapy, 16*(2), 115–121.
12. Khosravi, M. R., & Samadi, S. (2019). Data compression in ViSAR sensor networks using non-linear adaptive weighting. *EURASIP Journal on Wireless Communications and Networking, 2019*(1), 1–8.
13. Khosravi, M. R., & Samadi, S. (2020). Reliable data aggregation in internet of ViSAR vehicles using chained dual-phase adaptive interpolation and data embedding. *IEEE Internet of Things Journal, 7*(4), 2603–2610.
14. Khosravi, M. R., & Samadi, S. (2021). BL-ALM: A blind scalable edge-guided reconstruction filter for smart environmental monitoring through green IoMT-UAV networks. *IEEE Transactions on Green Communications and Networking, 5*(2), 727–736.
15. Khosravi, M. R., & Samadi, S. (2021). Frame rate computing and aggregation measurement towards QoS/QoE in video-SAR systems for UAV-borne real-time remote sensing. *The Journal of Supercomputing, 77*, 14565–14582.
16. Khosravi, M. R., et al. (2017). *An introduction to ENVI tools for synthetic aperture radar (SAR) image despeckling and quantitative comparison of denoising filters*. IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI;17).
17. Khosravi, M. R., et al. (2018). Enhancing the binary watermark-based data hiding scheme using an interpolation-based approach for optical remote sensing images. *International Journal of Agricultural and Environmental Information Systems, 9*(2), 53–71.
18. Khosravi, M. R., & Samadi, S. (2019). *Modified data aggregation for aerial ViSAR sensor networks in transform domain*. The 25th Int'l Conf on Parallel and Distributed Processing Techniques and Applications (PDPTA'19).
19. Khosravi, M. R., et al. (2020). A tutorial and performance analysis on ENVI tools for SAR image despeckling. *Current Signal Transduction Therapy, 15*(2), 215–222.
20. Khosravi, M. R. (2021). ACI: A bar chart index for non-linear visualization of data embedding and aggregation capacity in IoMT multi-source compression. *Wireless Networks*. https://doi.org/10.1007/s11276-021-02626-x

21. Tavallali, P., Yazdi, M., & Khosravi, R. (2018). Robust cascaded skin detector based on AdaBoost. *Multimedia Tools and Applications, 77*, 1–22. https://doi.org/10.1007/s11042-018-6385-7
22. Tavallali, P., & Yazdi, M. (2015). *Robust skin detector based on AdaBoost and statistical luminance features*. International Congress on Technology, Communication and Knowledge (ICTCK).
23. Tavallali, P., Yazdi, M., & Khosravi, M. R. (2017). *An efficient training procedure for Viola-Jones face detector*. Proc. of International Conference on Computational Science and Computational Intelligence (CSCI).
24. Tavallali, P., Yazdi, M., & Khosravi, M. R. (2020). A systematic training procedure for Viola-Jones face detector in heterogeneous computing architecture. *Journal of Grid Computing, 18*, 847–862.
25. Tavallali, P., Tavallali, P., Khosravi, M. R., & Singhal, M. (2021). An EM-based optimization of synthetic reduced nearest neighbor model towards multiple modalities representation with human interpretability. *Multimedia Tools and Applications*.
26. Tavallali, P., Tavallali, P., Khosravi, M. R., & Singhal, M. (2020). *Interpretable synthetic reduced nearest neighbor: an expectation maximization approach*. 27th IEEE International Conference on Image Processing (ICIP).
27. Alizadeh, A., Tavallali, P., Khosravi, M. R., & Singhal, M. *Survey on recent active learning methods for deep learning, transactions on computational science and computational intelligence (Springer Series), 2021*. Proceedings of the 26th Int'l Conf on Parallel and Distributed Processing Techniques and Applications (PDPTA'20), Part of CSCE'20.
28. Veer, K. (2018). Comparison of surface electromyogram signal for prosthetic applications. *Current Signal Transduction Therapy, 13*(2), 168–172.
29. Harikrishnan, A., & Veena, V. (2018). Therapeutic molecules for fumigating inflammatory tumor environment. *Current Signal Transduction Therapy, 13*(2), 129–152.
30. Nandi, S. (2018). Recent trends in design and developments of new drugs for the treatment of cancer, rheumatoid arthritis, and Parkinson's disease-associated to abnormal signal transduction. *Current Signal Transduction Therapy, 13*(2), 82–82.
31. Kala, R., & Deepa, P. (2018). Adaptive hexagonal fuzzy hybrid filter for Rician noise removal in MRI images. *Neural Computing and Applications, 29*(8), 237–249.
32. Chen, X., & Siau, K. (2020). Business analytics/business intelligence and IT infrastructure: impact on organizational agility. *Journal of Organizational and End User Computing, 32*(4), 24. https://doi.org/10.4018/JOEUC.2020100107
33. Huang, C. C. (2020). User's segmentation on continued knowledge management system use in the public sector. *Journal of Organizational and End User Computing, 32*(1), 19–40. https://doi.org/10.4018/JOEUC.2020010102
34. Ramu, N., Pandi, V., Lazarus, J. D., & Radhakrishnan, S. (2020). A novel trust model for secure group communication in distributed computing. *Journal of Organizational and End User Computing, 32*(3), 14. https://doi.org/10.4018/JOEUC.2020070101
35. Khosravi, M. R., Basri, H., Rostami, H., & Samadi, S. (2018). Distributed random cooperation for VBF-based routing in high-speed dense underwater acoustic sensor networks. *The Journal of Supercomputing, 74*(11), 6184–6200.
36. Abbasi, M., Yaghoobikia, M., Rafiee, M., Jolfaei, A., & Khosravi, M. R. (2020). Energy-efficient workload allocation in fog-cloud based Services of Intelligent Transportation Systems Using a learning classifier system. *IET Intelligent Transport Systems, 14*(11), 1484–1490.
37. Abbasi, M., Najafi, A., Rafiee, M., Khosravi, M. R., Menon, V. G., & Muhammad, G. (2020). Efficient flow processing in 5G-envisioned SDN-based internet of vehicles using GPUs. *IEEE Transactions on Intelligent Transportation Systems, 22*(8), 5283–5292. https://doi.org/10.1109/TITS.2020.3038250
38. Abbasi, M., Rezaei, H., Menon, V. G., Qi, L., & Khosravi, M. R. (2020). Enhancing the performance of flow classification in SDN-based intelligent vehicular networks. *IEEE*

Transactions on Intelligent Transportation Systems, 22(7), 4141–4150. https://doi.org/10.1109/TITS.2020.3014044
39. Abbasi, M., Pasand, E. M., & Khosravi, M. R. (2020). Workload allocation in IoT-fog-cloud architecture using a multi-objective genetic algorithm. *Journal of Grid Computing, 18*, 43–56.
40. Abbasi, M., & Khosravi, M. R. (2020). A robust and accurate particle filter-based pupil detection method for big datasets of eye video. *Journal of Grid Computing, 18*(2), 305–325.
41. Abbasi, M., Mohammadi-Pasand, E., & Khosravi, M. R. (2021). Intelligent workload allocation in IoT-Fog-cloud architecture towards mobile edge computing. *Computer Communications, 169*, 71–80.
42. Abbasi, M., Rafiee, M., Khosravi, M. R., Jolfaei, A., Menon, V. G., & Koushyar, J. M. (2020). An efficient parallel genetic algorithm solution for vehicle routing problem in cloud implementation of the intelligent transportation systems. *Journal of Cloud Computing, 9*, 6.
43. Abbasi, M., Yaghoobikia, M., Rafiee, M., Jolfaei, A., & Khosravi, M. R. (2020). Efficient resource management and workload allocation in fog-cloud computing paradigm in IoT using learning classifier systems. *Computer Communications, 153*, 217–228.
44. Abbasi, M., Moosavi, N., Rafiee, M., Khosravi, M. R., & Menon, V. G. (2020). A CRC-based classifier micro-engine for efficient flow processing in SDN-based internet of things. *Mobile Information Systems, 2020*, 7641073.
45. Abbasi, M., Rafiee, M., & Khosravi, M. R. (2020). Investigating the efficiency of multi-threading application programming interfaces for parallel packet classification in wireless sensor networks. *Turkish Journal of Electrical Engineering and Computer Sciences, 28*, 1699–1715.
46. Xu, X., Shen, B., Yin, X., Khosravi, M. R., Wu, H., Qi, L., & Wan, S. (2021). Edge server quantification and placement for offloading social Media Services in Industrial Cognitive IoV. *IEEE Transactions on Industrial Informatics, 17*(4), 2910–2918.
47. Solyman, A. A. A., Attar, H. H., Khosravi, M. R., et al. (2020). A low-complexity equalizer for video broadcasting in cyber-physical social systems through handheld mobile devices. *IEEE Access, 8*, 67591–67602.
48. Attar, H. H., Solyman, A. A. A., Khosravi, M. R., et al. (2021). Bit and packet error rate evaluations for half-cycle stage cooperation on 6G wireless networks. *Physical Communication, 44*, 101249.
49. Attar, H. H., Solyman, A. A. A., Alrosan, A., Chakraborty, C., & Khosravi, M. R. (2021). Deterministic co-operative hybrid ring-mesh network coding for big data transmission over Lossy channels in 5G networks. *EURASIP Journal on Wireless Communications and Networking, 2021*, 159.
50. Attar, H., Khosravi, M. R., Igorovich, S. S., Georgievan, K. N., & Alhihi, M. (2020). Review and performance evaluation of FIFO, PQ, CQ, FQ and WFQ algorithms in multimedia wireless sensor networks. *International Journal of Distributed Sensor Networks, 16*(6), 155014772091323.
51. Solyman, A. A. A., Attar, H., Khosravi, M. R., & Koyuncu, B. (2020). MIMO-OFDM/OCDM low complexity equalization under doubly Dispersive Channel in wireless sensor networks. *International Journal of Distributed Sensor Networks, 16*, 6.
52. Solyman, A. A. A., Attar, H. H., Khosravi, M. R., Menon, V. G., Jolfaei, A., Balasubramanian, V., Selvaraj, B., & Tavallali, P. (2020). A low-complexity equalizer for video broadcasting in cyber-physical social systems for handheld mobile devices. *IEEE Access, 8*, 67591–67602.
53. Xu, X., Mo, R., Yin, X., Khosravi, M. R., Aghaei, F., Chang, V., & Li, G. (2021). PDM: Privacy-aware deployment of machine-learning applications for industrial cyber-physical cloud systems. *IEEE Transactions on Industrial Informatics, 17*(8), 5819–5828.
54. Qi, L., Hu, C., Zhang, X., Khosravi, M. R., Sharma, S., Pang, S., & Wang, T. (2021). Privacy-aware data fusion and prediction with spatial-temporal context for Smart City industrial environment. *IEEE Transactions on Industrial Informatics, 17*(6), 4159–4167.

55. Meng, S., Huang, W., Yin, X., Khosravi, M. R., Li, Q., Wan, S., & Qi, L. (2021). Security-aware dynamic scheduling for real-time optimization in cloud-based industrial applications. *IEEE Transactions on Industrial Informatics, 17*(6), 4219–4228.
56. Xu, X., Shen, B., Yin, X., Khosravi, M. R., Wu, H., Qi, L., & Wan, S. (2020). Edge server quantification and placement for offloading social Media Services in Industrial Cognitive IoV. *IEEE Transactions on Industrial Informatics, 17*(4), 2910–2918.
57. Lin, W., Yin, X., Wang, S., & Khosravi, M. R. (2020). A Blockchain-enabled decentralized settlement model for IoT data exchange services. *Wireless Networks*.
58. Meng, S., Huang, W., Yin, X., Khosravi, M. R., Li, Q., Wan, S., & Qi, L. (2020). Security-aware dynamic scheduling for real-time optimization in cloud-based industrial applications. *IEEE Transactions on Industrial Informatics, 17*(6), 4219–4228.
59. Xu, X., Huang, Q., Yin, X., Abbasi, M., Khosravi, M. R., & Qi, L. (2020). Intelligent offloading for collaborative smart city services in edge computing. *IEEE Internet of Things Journal, 7*(9), 7919–7927.
60. Akbarzadeh, O., Baradaran, M., & Khosravi, M. R. (2021). IoT solutions for smart management of hospital buildings: A general review towards COVID-19, future pandemics and infectious diseases. *Current Signal Transduction Therapy, 16*(3), e070621193910.
61. Akbarzadeh, O., Baradaran, M., & Khosravi, M. R. (2021). IoT-based smart management of healthcare services in hospital buildings during COVID-19 and future pandemics. *Wireless Communications and Mobile Computing, 2021*, 5533161.
62. Salemi, H., Rostami, H., Talatian-Azad, S., & Khosravi, M. R. (2021). LEAESN: Predicting DDoS attack in healthcare systems based on lyapunov exponent analysis and echo state neural networks. *Multimedia Tools and Applications*.
63. Akrami, A., Rostami, H., & Khosravi, M. R. (2020). Design of a reservoir for cloud-enabled echo state network with high clustering coefficient. *EURASIP Journal on Wireless Communications and Networking, 2020*, 64.
64. Mokarram, M., Mokarram, M. J., Khosravi, M. R., Saber, A., & Rahideh, A. (2020). Determination of the optimal location for constructing solar photovoltaic farms based on multi-criteria decision system and Dempster–Shafer theory. *Scientific Reports, 10*, 8200.
65. Mokarram, M., & Khosravi, M. R. (2020). A cloud computing framework for analysis of agricultural big data based on Dempster–Shafer theory. *The Journal of Supercomputing, 77*(3), 2545–2565.
66. Abbasi, M., Shokrollahi, A., Khosravi, M. R., & Menon, V. G. (2020). High-performance flow classification using hybrid clusters in software defined Mobile edge computing. *Computer Communications, 160*(1), 643–660.
67. Abbasi, M., Rezaee, N., & Khosravi, M. R. (2021). Efficient resource-aware control on SIP servers in 802.11n wireless edge networks. *World Wide Web*.
68. Rezaee, K., Rezakhani, S. M., Khosravi, M. R., & Moghimi, M. K. (2021). A survey on deep learning-based real-time crowd anomaly detection for secure distributed video surveillance. *Personal and Ubiquitous Computing*.
69. Qi, L., Hu, C., Zhang, X., Khosravi, M. R., Sharma, S., Pang, S., & Wang, T. (2020). Privacy-aware data fusion and prediction with spatial-temporal context for Smart City industrial environment. *IEEE Transactions on Industrial Informatics, 17*(6), 4159–4167.
70. Khosravi, M. R., et al. (2017). MRF-based multispectral image fusion using an adaptive approach based on edge-guided interpolation. *Journal of Geographic information System, 9*, 114–125.
71. Abbasi, M., Rezaei, H., Menon, V. G., Qi, L., & Khosravi, M. R. (2020). Enhancing the performance of flow classification in SDN-based intelligent vehicular networks. *IEEE Transactions on Intelligent Transportation Systems, 99*, 1–10.
72. Gong, W., Lv, C., Duan, Y., Liu, Z., Khosravi, M. R., Qi, L., & Dou, W. (2020). Keywords-driven web APIs group recommendation for automatic app service creation process. *Software: Practice and Experience, 51*(11), 2337–2354.

73. Chen, C., Zhang, Y., Khosravi, M. R., Pei, Q., & Wan, S. (2020). An intelligent platooning algorithm for sustainable transportation Systems in Smart Cities. *IEEE Sensors Journal, 21*(14), 15437–15447.
74. Wu, X., Khosravi, M. R., Qi, L., Ji, G., Dou, W., & Xu, X. (2020). Locally private frequency estimation of physical symptoms for infectious disease analysis in internet of medical things. *Computer Communications, 162*, 139–151.
75. Liu, Q., Kamoto, K. M., Liu, X., Zhang, Y., Yang, Z., Khosravi, M. R., Xu, Y., & Qi, L. (2020). A sensory similarities approach to load disaggregation of charging stations in internet of electric vehicles. *IEEE Sensors Journal, 21*(14), 15895–15903.
76. Xu, X., Mo, R., Yin, X., Khosravi, M. R., Aghaei, F., Chang, V., & Li, G. (2020). PDM: privacy-aware deployment of machine-learning applications for industrial cyber-physical cloud systems. *IEEE Transactions on Industrial Informatics, 17*(8), 5819–5828.
77. Shynu, P. G., Nadesh, R. K., Menon, V. G., Venu, P., Abbasi, M., & Khosravi, M. R. (2020). A secure data deduplication system for integrated cloud-edge networks. *Journal of Cloud Computing, 9*, 61.
78. Wang, F., Zhu, M., Wang, M., Khosravi, M. R., Ni, Q., Yu, S., & Qi, L. (2020). 6G-enabled short-term forecasting for large-scale traffic flow in massive IoT based on time-aware locality-sensitive hashing. *IEEE Internet of Things Journal, 8*(7), 5321–5331.
79. Khosravi, M. R., & Menon, V. G. (2020). Intelligent and pervasive computing for cyber-physical systems. *The Journal of Supercomputing, 77*, 5237–5238.
80. Gaoa, Z., Yanga, Y., Khosravi, M. R., & Wan, S. (2021). Class consistent and joint group sparse representation model for image classification in internet of medical things. *Computer Communications, 166*, 57–65.

Chapter 2
Computer Techniques for Medical Image Classification: A Review

Oluwadare Adepeju Adebisi, Sunday Adeola Ajagbe, John Adedapo Ojo, and Matthew Abiola Oladipupo

Abstract Medical image reporting and interpretation play a significant role in the diagnosis and treatment of patients. Its introduction into healthcare systems has improved human health and promoted medical activity generally. Medical images are affected by noise, echo perturbations, fatigue, inter-observer variability, time-consuming demands, and yet, the results are subjective. Therefore, the need for the development of computer techniques to overcome the shortcomings of manual classification processes, which will serve as a second opinion for diagnosis, management, and treatment. This chapter aims at reviewing various stages of the development of Computer-Aided Diagnosis systems, computer techniques for medical image classification, identifying their strengths and shortcomings. However, we considered the post-processing of medical image stages as the area that requires more attention from researchers.

Keywords Deep learning · Feature extraction · Intelligence healthcare · Image classification · Image modality · Image processing · Medical images · Segmentation

2.1 Introduction

Classification techniques help in the development of Computer-Aided Diagnosis (CAD) systems, that help radiologists in the understanding of an image by evaluating the images and providing a second opinion for diagnosis. The CAD detects the earliest signs [1, 2] and evaluates information collected in a timely manner from medical imaging for effective identification and diagnosis of diseases [3]. Classification, which is one of the basic stages of CAD development of medical images plays a

O. A. Adebisi · S. A. Ajagbe (✉) · J. A. Ojo
Ladoke Akintola University of Technology, Ogbomoso, Nigeria
e-mail: oadebisi44@pgschool.lautech.edu.ng; saajagbe@pgschool.lautech.edu.ng; jaojo@lautech.edu.ng

M. A. Oladipupo
Salford University, The Greater Manchester, UK
e-mail: m.a.oladipupo@edu.salford.ac.uk

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_2

significant role in patients' diseases analysis. Classification of medical images is crucial in image processing as the development of computer-aided diagnosis systems provides a healthcare intelligence system that meets the needs of Twenty first-century healthcare delivery [4].

Traditionally, radiologists have been in charge of image interpretations in the medical field, and the activities were full of manual classification of medical images, this has proven to be challenging because the images are affected by noise, echo perturbations, fatigue, inter-observer variability, and time-consuming, which results to subjective interpretation. Therefore, the development of CAD for image classification is required to overcome the shortcomings of the manual classification of the medical images processes. The CAD system consists of image acquisition (image modalities), image preprocessing, feature extractions, feature selection, image segmentation, and feature classification [5]

2.1.1 Chapter Contribution

This chapter presents the stages of CAD system. The CAD assists in the interpretation of medical images and hence reduces unnecessary biopsy and false diagnoses in the health sector. The merits and demerits of each technique are also identified, which will help in the proper selection of appropriate classification techniques and hence minimize error in data reporting.

2.1.2 Organization of the Chapter

The following is the chapter's structure: Sect. 2.1 is the general introduction to CAD systems and computer techniques for medical image classification. Section 2.2 discusses the methods of image acquisition. Section 2.3 explains the way to improve medical images for further analysis and reduce data complexity. Section 2.4 describes the images segmentation methods. Section 2.5 discusses the image classification techniques. Finally, Sect. 2.6 conclusions the chapter and presents direction of future study in the medical image processing.

2.2 Image Modality

Image modality is the process by which images are acquired for various purposes. Usually, it is referred to as the technique used in acquiring the images from the body. Image acquisition or modalities is the process of getting the picture of an object for different purposes [6]. In this section, common medical image modalities are reviewed vis-à-vis their merits and demerits. The common medical image modality reviewed in this chapter are Ultrasonography, Computerized Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound, and X-ray. Different imaging techniques are described in Ref. [7].

In Ultrasonography, a transducer, that produces sound waves of high frequency is positioned against the patient skin [8]. Sound waves reflect differently which results in an image. Ultrasonography has become a commonly employed imaging method for the detection and diagnosis of diseases because it is non-invasive and cheaper [9, 10]. The computerized tomography (CT) scan reveals the pictures of the images with X-ray usually called a CT scan creates a detailed inside image(s) of the body using X-rays and computers. Unlike conventional X-ray, it creates a cross-section of internal body organs (A few examples are bones, internal organs, blood vessels, the brain, neck, spine, chest, and sinuses.). The CT scans present results relative is painless and non-invasive.

Magnetic resonance imaging is another medical image modality and it is a product of an intelligent healthcare system that gives detailed information of the body part using a magnetic field. The application of MRI is discussed in [11] and MRI is not painful and is safe but the scan envelopes the body and can make patients uncomfortable and irritating [12]. For ultrasound imaging, high-frequency waves are used by ultrasound equipment to display what is inside a body part. The probe on the gadget emits high-frequency sound waves and creates live images on the scanner between 15 and 45 min. It is used for diagnosis (internally and externally), surgeon guiding, and monitoring the images of unborn children in real-time [13, 14]. An X-ray uses X-ray radiation to obtain images. It is used to guide surgeons operating patients, broken bones detection, and bone tumor [15]. It has the advantage of covering a limited part of the patients' body therefore no anxiety in people with claustrophobia, also it is a fast-imaging modality.

2.3 Image Preprocessing

Many factors including noise affect the accuracy and efficiency of computer techniques in image processing, especially medical images. Therefore, most classification models require image preprocessing. Noise has been one of the limiting factors for the success of almost all the image processing techniques since it affects the accuracy of the image processing results. Various techniques have been developed to improve image quality [16]. Noise removal and enhancements are the common techniques to improve the qualities of medical images. Noise degrades medical images and makes the interpretation of the images difficult for the radiologist. The techniques to remove image noise depend on the types of noise [17]. The common types of noise in medical images are Gaussian noise, salt, pepper noise, and Quantization Noise [18]. It is an additive noise, which is not dependent on the intensity of pixel value at each point. Kulik and Spodarev [19] defined Gaussian random variables as

$$PG(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(z-\mu)}{2\sigma^2}} \tag{2.1}$$

where z is the variable, μ is the average number and σ is the standard deviation**.** The majority of Gaussian noise comes from poor illumination of the sensor during image acquisition [20]. Speckle noise is a random granular 'noise' the reduces medical image qualities [21]. The images suffer from speckle noise as an output of the interference of the returning wave at the transducer aperture [22, 23]. Quantization noise occurs when continuous data is transformed to discrete values during digital acquisition. This results in a uniform degradation in data resolution [24, 25]. Quantization noise results from little variations between the sampled analog input and the resolution of the analog-to-digital converter [26]. Salt and pepper noise results from a sharp interruption in an image caused by faulty sensors and defective memory location [27]. The median filter is commonly used to remove salt and pepper noise [28, 29].

An Image enhancement is a way of improving images for better output or analysis [30]. It involves different methods of enhancing an image or changing the image to a better form for easier interpretation. Morphological image processing is an enhancement method that involves a set of non-linear operations that *extract image components* based on shapes [31]. Morphological operations applied ordering of pixel values for binary processing. Morphological operations work on the basis of set theory [32]. The significant features to be considered are size, shape, and origin.

Weiner filter reduces noise by comparing the received signal with an estimation of a desired noiseless signal [33–35]. The Median filter is popularly used to eliminate noise from signals or images. The filter can remove noise without affecting the edges. The operation is determined by arranging the pixel value of the environment neighborhood into numerical ordering and placing the considered pixel as the middle one [36, 37]. Histogram Equalization is a method that enhances medical images by adjusting the intensities of the image. Histogram Equalization changes the value of the image intensity to make the output image histogram approximately matches a specified histogram. The intensities of digital images are spread over the histogram the portion of local contrast. Different types of Histogram equalization have been applied to enhance image contrast [38]. Unlike ordinary histogram equalization, Adaptive Histogram Equalization (AHE) develops many histograms that are related to a different portion of an image and relocate the image lightness [38].

2.3.1 Feature Extraction

During feature extraction, specific attributes are extracted from the image [39]. It is used to determine future sets that can accurately differentiate between stages of image malignancy. In machine learning, several features like textural features, morphological features, and random features are considered and make the

Table 2.1 Information about the texture of an image

Statistics	Description
Homogeneity	The differences of the element values in the GLCM and GLCM diagonal
Contrast	Differences in GLCM
Energy	Addition of those squared values elements an in the GLCM.
Correlation	Measure joint probability occurrence of the specified pixel

Source: Roomi, 2012 Ref. [46]

classification model reason like human-being, which is referred to as a intelligence system, and when medical images are been considered, it can be called healthcare intelligence systems [40]. The common features that are commonly considered for classification include textural features, Morphological Feature, Wavelet features, and Randon Transform Features.

Textural features provide the spatial arrangement characteristics of the image. Texture features have been used to obtain features that are not easily visually extracted but are diagnostically important [41, 42]. The texture features are the representation of a mutual relationship between neighboring pixels' intensity values and present a detailed symbolic description of the image. Textural features can be represented as Gray-Level Co-occurrence matrix (GLCM), Linear Binary Pattern (LBP), and Fuzzy Local Binary Patterns (FLBP) [41, 43, 44] extract textural features using for classification of ultrasound liver image [45] (Table 2.1)

Morphological Feature describes the size and shape, which are useful for extracting relevant image components for processing [47]. Shapes have a different probability of malignancy and size also has its own feature [48]. Naz et al. [49] evaluated different morphological features for the characterization of thyroid nodules by using high-frequency ultrasound. A wavelet is an oscillation with an amplitude starting from zero, increasing, and decreasing to zero. Wavelets are used in representing data or other functions and processing data at different scales and resolutions. Wave- let comes in different sizes and shapes; morletdaubeches, coiflets, biorthogonal, Mexican hat, and zymlets. The number close to each wavelet name represents the number of vanishing moments for the subclass of wavelet [50]. Continuous wavelet transform (CWT) is an execution of the wavelet transform using almost arbitrary wavelets and arbitrary scales. A two-variable function is created by comparing the signal to the wavelet at various scales. The CWT is a complex-valued scale and position function. The CWT refers to the complex function of scale and location if the wavelet is complex [31].

The Discrete Wavelet Transform (DWT) is the development of a wavelet transform with wavelet scales and translations following some set of laws. The transform decomposes the signal into an orthogonal set of wavelets. A scaling function can be used to create wavelet transform [51]. To decompose signals into low-pass and high-pass components, the DWT employs filter banks made up of finite impulse response filters. The low-pass component contains information about slow varying signal features, whereas the high-pass component contains information about fast variable signal features. Medical images contain several directionality patterns. The encoding of the patterns can be obtained using Random Transform Features [52]. The image intensity is projected at several angles such as 0, 45, 90, and 135 degrees. Savelonas et al [53] used random transform features to produce energy-based feature sets for texture classification in a large image database [54].

2.3.2 Feature Selection

Feature selection is an important part of artificial intelligence and indeed provides an effective way of solving the issue of high-dimensional data analysis by removing irrelevant features. Feature selection presents raw images in the simplest form to help in decision-making during detection, classification, or recognition. An efficient feature selection algorithm improves learning accuracy and reduces computation time. Feature selection methods include particle swarm optimization, filter model, wrapper model, and hybrid model [55]. The particle swarm optimization (PSO) is based on population neighborhoods and inspired by the flocking and Schooling patterns [54]. The filter feature selection approach employs a statistical measure to assign a score to each feature and rank them according to the score in order to determine whether or not they should be kept in the dataset. The approach analyses each feature separately, evaluates them, and selects the best feature subset (s) [52]. The wrapper model uses a learning algorithm technique to find features that increase image processing model learning performance. The method evaluates the set of features and their combination using an appropriate score for prediction [56]. The hybrid method usually combines both the filter model and the wrapper model. Popular hybrid methods include LASSO and Elastic Net.

2.4 Image Segmentation

Image segmentation is a method of dividing an image into parts and change the representation of the image into a more meaningful one that can be analyzed easily. The segmentation techniques convert complex images into simple images based on patterns, texture, shape, color etc. Image segmentation performs a significant role in the automatic segmentation of important regions in medical images [53, 57]. The contraction reveals a decrease in spatial information but information on characteristics was increased. U-net has a sum of 23 convolutional layers. The network avoids the use of a fully connected layer but utilizes only the convolution layers. Badrinarayanan et al. [13] created a deep fully CNN for semantic segmentation known as SegNet. SegNet also consists of both encoder and decoder networks. SegNet was trained with different segmentation dataset.

Albelwi and Mahmood [58] developed an Xception network in which inception modules were replaced with depth wise separable convolutions. Xception has 23 million parameters. Szegedy et al. [59] designed Inception –v4 which consists of 43 million parameters. Inception –v3 was improved by changing the stem module Xia et al. [60] presented ResNet-50 which consists of 25million parameters. The number of ResNet-50 towers was increased to 32. The steps for classification of medical images using transfer learning include; Loading of Pretrained Network, Replacing of the final layers, Training of Network, Prediction of Network Accuracy, and Classification of the validation Images. The convolution layers extract features that are necessary for image classification by the layers that can learn and the final classification layer to classify the input images. The classification layer is replaced with new unlabeled layers. In the review of segmentation methods by [2], noise and perturbation were identified as major issues in medical image segmentation. Some of the segmentation techniques are Edge Based Segmentation, Otsu Thresholding, Back Propagation Neural Networks, and Self-Organizing Maps

Edge detection is one of the most popular approaches for the discontinuities detection method. The important features such as curves, corners, and lines can be extracted from the edges of an image. Edge detection algorithms are usually less complex and can be used to detect and links edge pixels to form contours [61]. Backpropagation is a technique used in artificial neural networks (ANN) to determine a gradient, which is required to calculate the weights to be used in the network [43]. It is popularly used to train neural networks over one hidden layer· The backpropagation algorithm applied delta rule or gradient descent to look for the minimum value of the error function in the weight. A self-organizing map (SOM) is a kind of intelligence system that is trained by unsupervised learning to reduce datasets of high dimensions into lower- dimensional ones. SOM is usually applied for high-dimensional reduction. SOM utilized appropriate learning to maintain the properties of the input space. The nodes are connected to the input, and there is no connection between the nodes. The steps of SOM algorithm implementation given by [44] are as follow:

1. Initialize each node's weights with a random number between 0 and 1
2. SOM should be presented with a random input vector from the training dataset.
3. Calculate the Best Matching Unit (BMU) from the distance between the input vector and each node weight. The distance (Dist) between the input vector (V_i) and the weights of node (W_i) is expressed as

$$Dist = \sqrt{\sum_{i=0}^{i=n} (V_i - W_i)^2} \tag{2.2}$$

4. Determine the radius of the environment near the BMU.

$$W(t+1) = W(t) + \Theta(t)L(t)(V(t) - W(t)) \tag{2.3}$$

where t = time, L = Learning rate

5. Adjust the BMU node weight

The decay of learning rate $L(t)$ is determined for each iteration as:

$$L(t) = L_0 \exp\left(-\frac{t}{\lambda}\right) \tag{2.4}$$

The influence rate is given as

$$\Theta(t) = \exp\left(-\frac{dist^2}{2\sigma^2(t)}\right) \tag{2.5}$$

where σ = width of the lattice at time t
$\Theta(t)$ = influence rate

Another important traditional technique for segmentation is Otsu algorithm. Dorathi and Malathi [62] developed a thresholding algorithm that calculates the optimum threshold by dividing two parts to make the intra variance part and the inter variance parts with the assumption that the image is divided into two groups of pixels. This is one of the innovative ways that make image processing algorithms an intelligence system. Most of the conventional algorithms require the development of feature algorithms and feature selection algorithm by the domain expert. The accuracy of the segmentation system depends on the accuracy of the features extracted and selected.

Deep learning helps to learn data directly from data thereby avoiding erroneous handcrafted features leading to better accuracy. However, the challenge in segmentation using deep learning is small data, lack of annotation of some medical images, legal and ethical issues. Data augmentation has been applied to multiply medical images. Each image is multiplied by rotation and flipping to increase the number. Data augmentation methods include elastic deformations [42] principal component analysis, and histogram matching. The Fully Convolutional Network (FCN) was created by altering classifiers for dense prediction and replacing the last completely connected layers from classification networks with fully convolutional layers [40, 63]. The network is fully trained from start to finish. Basic components of FCN networks include convolution and pooling layers, as well as activation functions.< examples>

Ronneberger et al. [15] developed the U-net encoder–decoder architecture for medical image segmentation. The network is built on a full CNN that was developed. Long et al. [14] which has been tweaked to function with fewer training images and generate more accurate segmentation. On a recent computer, segmenting a 512×512 picture takes less than a second. GPU stands for Graphics Processing Unit (GPU). The u-shaped design of the U-net is made up of a contracting path (encoder) and an expansive path (decoder). The contracting path is a conventional convolutional network, consisting of two 3×3 convolutions that are applied repeatedly, each followed by a rectified linear unit (ReLU) and a 2×2 max pooling operation with stride 2 for downsampling. Badrinarayanan et al. [13] developed SegNet, a deep fully CNN for semantic segmentation. The SegNet is made up of an encoder network, a decoder network, and a pixel-by-pixel classification layer [12].

2.5 Image Classification Techniques

The classification algorithms classify into different classes based on patterns on the extracted features. Several classifiers have been used to characterize medical images as benign or malignant. There are various computer techniques such as artificial neural network, Gaussian mixture model, Decision Tree (DT), Support Vector Machine (SVM),K-Nearest Neighbor (KNN), Adaboost classifier, Naives Bayes Classifier (NBC), and Fuzzy Sugeno mode. Table 2.2 shows the advantages and disadvantages of different classification methods.

An artificial neural network (ANN) is a technique that makes a machine learn from training data. A neural network processes the data in a similar way to the human nervous system [64]. It has the input layer that provides the networks with features that are forwarded to the hidden layers and bring output that mimics human reasoning. ANN consists of the input, hidden, and output layers. The input layer accepts the explanatory characteristics for each observation as input. The number of explanatory variables is the same as that of input nodes in the input layer. The input values inside the network are transformed by the hidden layers and the result is passed to the output layer for necessary action. There is a proper connection between the inputs signal and hidden layers. After processing, the variables in the hidden layers are passed to the output layer. This computing technique has proven to be useful to the radiologist working on medical images dataset to enhance healthcare delivery as it provides a second opinion to radiological work.

Probabilistic Neural Networks (PNNs) is a member of the radial basis networks family. The PNN is a neural network that combined the Bayes decision theory and Parzen's method of density evaluation. The PNN calculates a decision boundary that is not linear in which the error is minimized based on optimal decision rules. The PNN for group j is expressed in Eq. (2.6)

Table 2.2 Merits and demerits of different classification techniques

Classification methods	Merits	Demerits
Decision tree (DT) classifier	The algorithm is simple to interpret Less training time	Often leads to overfitting Not suitable for a large dataset the result is affected by noise
Support vector machine	Perform well when there is a clear margin between Two classes	Not suitable for large data Low performance with noisy data
K-nearest neighbor	Simple to interpret Easy to interpret the output	Sensitive to noisy data outliers not suitable for large data
Naives Bayes classifier	Easy to implement require small data	Zero frequency Feature-dependence assumption
Deep learning	High classification accuracy Can easily be adapted to a new problem Flexible to be adapted to solve new problems	The method requires a large dataset

$$g_j(x) = \frac{1}{(2\pi)^{P/2}\sigma P N_j}\sum_{i=1}^{N_j} e^{-\left(x-x_{ij}\right)\quad\left(x-x_{ij}\right)^T/2\sigma^2} \tag{2.6}$$

x stands for testing vector, x_{ij} represents the i-th training vector of a j-th family, N is the number of patterns in family j, σ is a smooth value, and p represents the values of the feature involved in the characteristics vector [65]. PNNs are usually applied to classify data into different classes. The input layer which has a node for each feature of input data computes distances between the input and training input vector which results in a vector that represents the nearness of the input to a training input. For the pattern layer, each pattern node represents a particular raining pattern. The squared distances (Euclidean) between the input vector and the training vectors are calculated. The modification of the distances of the value obtained by the activation function evaluates the distance between the input and the training vector. The overall output layer is the addition of a pattern layer that comprises neurons for each member in which, the node's output is added. The neuron activation for a group is the same as the estimated density function for the same group. The addition of the neurons is sent to the output neuron in the output layer (last layer) [66].

The Gaussian mixture model (GMM) consists of multiple probability distributions with the assumption that data are formed from Gaussian distributions with unknown values [67]. The decision tree (DT) divides the training data in a recursive way so that a particular class has dominant samples. The tree is used for evaluating the classes rules, which are used to classify it [68, 69]. A support vector machine (SVM) is an algorithm that is usually to classify data. SVM can also be used for regression [70, 71] SVM is supervised learning with a hyperplane or a group of hyperplanes to separate separation between the two classes [72–75].

K-Nearest Neighbor (KNN) classifies data using its *k nearest neighbors*. Classification is achieved by comparing the unknown and known samples based on distance [68, 76]. The collection of neighbors can be thought of as the classifier's training samples, as the correct classification is known. The similarity is defined based on a distance metric between two data points. The Adaboost classifier unlike other classifiers is a meta-classifier that helps weak classifiers perform better. The classifier employs an ML algorithm that repeatedly feeds the input training set to a weak learner algorithm. The algorithm retains and updates a dataset of weights for the training dataset for each of these repetitions. The technique starts with all weights being the same value, then updates them after each call so that the weights of erroneously categorized samples are increased [77].

The Naives Bayes Classifier (NBC) is based on the Bayes theorem and posits that the existence of one feature of a class is unrelated to the presence of another feature-and that each feature is assigned the same weight or relevance. The maximum likelihood method is used to estimate parameters in the Naives Bayes model [78]. Han & Kamber [78] developed the Sugeno model, which involves the generation of fuzzy rules from a given input-output dataset. If the first and second input is x and y respectively, the output is expressed as $z = ax + by + c$. The output remains

Table 2.3 Deep learning applications

Author/ Year	Application	Architecture/ Algorithm	Classification performance
Wang et al. [80]	Breast cancer classification	Convolutional neural networks	92%
Albelwi & Mahmood [58]	Brain tumor classification	Deep neural network	96.97%
Christ et al. [13]	Liver and tumor Segmentation	Cascaded fully Convolutional network	94%
Adebisi et al. [2]	Lung nodules classification	Modified Alexnet	*Accuracy of 95%, sensitivity 94.73%, and specificity of 98.38%.*
Ajagbe et al. [12]	Alzheimer disease Classification (multiple classifications)	Deep convolutional neural network approaches	Accuracy of 71.02% for CNN, 77.06% for VGG 16 and 77.66% for VGG 19

the same for a zero-order model. When the input is 1 and 2 for AND operation and firing strength w_i. The result is the weighted mean of rule outputs determined from:

$$Final\ \ output \frac{\sum_{i=1}^{N} W_i N_j}{\sum_{i=1}^{N} W_i} \tag{2.7}$$

fuzzy approaches have been applied in the classification of medical images in Refs. [79, 80].

One of the most recent popular methods of classification of the image is deep learning. In deep learning, a model learns features and tasks from data using a neural network. It can handle high-dimensional data and concentrates on the right features, unlike other ML algorithms [81]. Table 2.3 shows the review of deep learning medical applications. A CNN is a deep learning algorithm that consists of multiple layers with different functions. CNN is a class of deep neural networks that takes an input image, assign learnable weights and biases to classify images [82]. The CNN has the potential to learn how to filters on its own, unlike primitive techniques where filters are hand- engineered and training data. Set of filters in the convolutional layers extract features from input. Filters detect acts features from the original input image.

The ReLU is preferable to other activation functions because it mapping negative values to zero and preserving positive values, which enables faster and more effective training [82]. The pooling layer performs nonlinear downsampling [58]. A deep neural network can be fine-tuned to classify a new collection of images. This process is known as transfer learning. Transfer learning (TL) is typically considerably quicker and less difficult than training a new network because the learned characteristics can be applied to a new task with fewer training images. Pre-trained models are typically used to achieve TL. Most pre-trained models used in

TL are based on CNN. The TL has been used to classify medical images in [4] with an improved result Common pretrained models include LeNet-5, AlexNet, VGG-16, GoogLeNet, ReseNet-50, U-net, SegNet, and Xception [12, 59]

AlexNet is a CNN developed by Krizhevsky et al. [83], the network has learned rich feature representations from different images. The network has an image input size of 227 × 227 and can classify images into 1000 groups. AlexNet consists of

8 layers with 60 million parameters. The last three layers the configured for 1000groups and can be fine-tuned to solve a new problem. Simonyan and Zisserman [60] designed DCNN for large-scale image recognition known as VGG-16. The network consists of 13 convolutional and 3 fully-connected layers with ReLU introduced by AlexNet. The VGG-16 network stacks more layers onto AlexNet. The network is made up of 138 million parameters and can occupy about 500MB of storage space. Szegedy et al. [84] designed a CNN that is 22 layers deep known as GoogLeNet (Inception-v1). The network was trained on ImageNet and can group the images into 1000 object categories. GoogLeNet has an image input size of 224 × 224 with 5 million parameters. The network was built using dense modules instead of stacking convolutional layers. Increasing the number of CNN layers results in better performance. However, with network depth increasing, accuracy gets saturated and decreases rapidly. ReseNet-50 (2015) developed by He et al. [85] solved the problem of degrading accuracy while building a deeper network (152 layers) with the use of skip connections (shortcut connections).

Ronneberger et al. [15] created U-net for biomedical image segmentation. The network is based on the fully CNN developed by Long (2014), which was modified to work and the fewer training image dataset and produce more precise segmentation. Segmentation of a 512 × 512 image takes less than a second on a recent Graphics Processing Unit (GPU). It consists of contracting and expansive parts, encoder and decoder respectively. The contraction reveals a decrease in spatial information but information on characteristics was increased. U-net has a sum of 23 convolutional layers. The network avoids the use of a fully connected layer but utilizes only the convolution layers Badrinarayanan et al. [13] created a deep fully CNN for semantic segmentation known as SegNet. SegNet also consists of both encoder and decoder networks. SegNet was trained with different segmentation datasets. Albelwi & Mahmood [86] developed an Xception network in which inception modules were replaced with depth-wise separable convolutions. The Xception has 23 million parameters. Szegedy et al. [87, 88] designed Inception –v4 which consists of 43 million parameters. Inception –v3 was improved by changing the stem module Xia et al. [89] presented ResNet-50 which consists of 25million parameters. The number of ResNet-50 towers was increased to 32 [90]. The steps for classification of medical images using transfer learning include; Loading of Pretrained Network, Replacing of the final layers, Training of Network, Prediction of Network Accuracy, and Classification of the validation Images [91, 92]. The convolution layers extract features that are necessary for image classification by classifying the input images, there are two layers: a learnable layer and a final classification layer. The classification layer is replaced with new unlabeled layers.

2.6 Conclusion and Future Direction

Many computer techniques algorithms have been developed for the development of CAD systems. High accuracy of the computer techniques will improve the development of an intelligent healthcare system and reduces unnecessary biopsy and false diagnoses in the health sector. Support Vector Machine has a good performance when there is a clear distinction between two classes but its performance is low with the noisy and large dataset. Although, Decision Tree and K-nearest Neigbor are simple to interpret and require less time for training, they are sensitive to noise and not suitable for large dataset. Generally, the conventional machine learning techniques require domain experts to develop an algorithm for feature extraction and selection. The performance of such classification systems depends on the accuracy of the features extracted or selected. Deep learning techniques eliminates these handcrafted features which lead to better performance than other machine learning techniques. Furthermore, a deep learning network can handle high dimensional data, efficient in focusing on the right features and requires less preprocessing. However, deep learning requires a lot of images for training, and the availability of medical images is a challenge due to ethical reasons. Data augmentation has been introducing to populate and multiply dataset to avoid overfitting of the neural network and improve classification performance. Transfer learning, which is also a recent development in deep learning allows learned features to be adapted to classify the new set of images with fewer images. Computer techniques algorithms research need expansion on postprocessing techniques such as adjusting exposure, applying curves, and frequency separation. Also, due to few available medical images, more research is needed in the area of unsupervised learning for image classification.

Conflict of Interest

There is no conflict of interests.
Funding There is no funding support.

Data Availability Not applicable.

References

1. Lostumbo, A., Suzuki, K., & Dachman, A. H. (2010). Flat lesions in CT colonography. *Abdominal Imaging, 35*(5), 578–583.
2. Adebisi, O. A., Ojo, J. A., & Bello, T. O. (2020). Computer-aided diagnosis system for classification of abnormalities in thyroid nodules ultrasound images using deep learning. *IOSR Journal of Computer Engineering (IOSR- JCE), 22*(3), 60–66.
3. Taki, A., Kermani, A., Ranjbarnavazi, S. M., & Pourmodheji, A. (2017). *Computing and visualization for intravascular imaging and computer-assisted stenting* (pp. 106–118). Elsevier Academic Press.
4. Venkatakrishnan, S., & Kalyani, C. V. (2019). Basic of image processing technologies. *International Journal of World Research, 34*(1), 55–58. Retrieved from www.apjor.com

5. Adebisi, O. A., & Ojo, J. A. (2020). A review of various segmentation methods for ultrasound thyroid images. *International Journal of Advanced Research in Science, Engineering and Technology (IJARSET), 7*(8), 14577–14582.
6. Nam, D., Barrack, R. L., & Potter, H. G. (2014). What are the advantages and disadvantages of imaging modalities to diagnose Wear-related corrosion problems? *Clinical Orthopaedics Related Research, 472*, 3665–3673. https://doi.org/10.1007/s11999-014-3579-9
7. Ganguly, D., Chakraborty, S., Balitanas, M., & Kim, T. (2010). Medical imaging: A review. In *Proceedings of the International Conference on Security-Enriched Urban Computing and Smart Grid (SUComS)*, *78*, pp. 504–516. Daejeon, Korea.
8. Sahuquillo, P., Tembl, J. I., Parkhutik, V., Vázquez, J. F., Sastre, I., & Lago, A. (2012). The study of deep brain structures by transcranial duplex sonography and imaging resonance correlation. *Ultrasound in Medicine & Biology, 39*(2), 226–232. https://doi.org/10.1016/j.ultrasmedbio.2012.09.008
9. Ovland, R. (2012). Coherent plane-wave compounding in medical ultrasound imaging (unpublished master thesis). Norwegian University of Science and Technology.
10. Szabo, T. L. (2004). *Diagnostic ultrasound imaging: Inside out*. Elsevier Academic Press.
11. Sivasubramanian, M., Hsia, Y., & Lo, L. (2015). Nanoparticle-facilitated functional and molecular imaging for the early detection of cancer. *Frontiers in Molecular Biosciences, 1*(15), 1–16. https://doi.org/10.3389/fmolb.2014.00015
12. Ajagbe, S. A., Amuda, A. A., Oladipupo, M. A., Afe, O. F., & Okesola, K. I. (2020). Multi-classification of Alzheimer disease on magnetic resonance images (MRI) using deep convolutional neural network (DCNN) approaches. *International Journal of Advanced Computer Research, 11*(53), 51–60. https://doi.org/10.19101/IJACR.2021.1152001
13. Badrinarayanan, V., Kendall, A., & Roberto-Cipolla, R. (2015). SegNet: A deep convolutional encoder-decoder architecture for image segmentation, computer vision and pattern recognition. *Neural and evolutionary computing*. arXiv:1511.00561 Retrieved from https://arxiv.org/abs/1511.00561
14. Long, J., Shelhamer, E., & Darrell, T. (2015). Fully convolutional networks for semantic segmentation. *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* (pp. 3431–3440). IEEE.
15. Ronneberger, O., Fischer, P., & Brox, T. (2015). U-net: Convolutional networks for biomedical image segmentation. In *International conference on medical image computing and computer-assisted intervention (MICCAI).9351* (pp. 234–241). Springer.
16. Thanh, D. N., Hien, N. N., Kalavathi, P., & Surya-Prasath, V. B. (2020). Adaptive switching weight mean filter for salt and pepper image Denoising. *Third International Conference on Computing and Network Communication (CoCoNet'19).171*, pp. 292-301. Procedia Elsevier. doi: https://doi.org/10.1016/j.procs.2020.04.031.
17. Shah, A., Bangash, J. I., Khan, A., Ahmed, I., Khan, A., Khan, A., Khan, A. (2020). Comparative analysis of median filter and its variants for removal of impulse noise from gray scale images, *Journal of King Saud University - Computer and Information Sciences,* Elsevier, doi: https://doi.org/10.1016/j.jksuci.2020.03.007.
18. Thanh, D. N., Dvoenko, S. D., & Dinh, V. S. (2016). A mixed noise removal method based on Total variation. *Informatica, 40*, 159–167.
19. Kulik, R., & Spodarev, E. (2020). Long range dependence of heavy tailed random functions. Retrieved from arXiv.org > math > arXiv:1706.00742v4.
20. Brahnam, S., Jain, C., Nanni, L., & Lumini, A. (2013). *Local binary patterns: New variants and applications* (pp. 273–286). Springer Nature.
21. Shruthi, B., Siddappa, M., & Renukalatha, S. (2015). Speckle noise reduction in ultrasound images-A review. *International Journal of Engineering Research, 1*, 1042–1046.
22. Sharma, A., & Singh, R. P. (2015). A review on synthetic aperture radar. *International Journal of Innovative Research in Advanced Engineering, 2*(12), 2349–2763.
23. Brandt, T., & Mather, P. (2009). *Classification methods for remotely sensed data* (pp. 37–38). CRC Press.

24. Vaseghi, S. V. (2008). *Advanced signal processing*. John Wiley and Sons Ltd.. Retrieved from https://adminimages.muhandes.net/content/library/749fef5085f840b6ad6801e90c fec251.pdf
25. Sedano, F., Lisboa, S., Duncanson, L., Ribeiro, N., Sitoe, A., Sahajpal, R., Hurtt, G., & Tucker, C. (2020). Monitoring intra and inter annual dynamics of forest degradation from charcoal production in Southern Africa with Sentinel – 2 imagery. *International Journal of Applied Earth Observation and Geoinformation, 92*, 102184. https://doi.org/10.1016/j.jag.2020.102184. Elsevier.
26. Sontakke, M. D., & Kulkarni, M. S. (2015). Different types of noises in images and noise removing technique. *International Journal of Advanced Technology in Engineering and Science, 3*(1), 2348–7550. Retrieved from www.ijates.com
27. Li, F., & Fan, J. (2009). Salt and pepper noise removal by adaptive median filter and minimal surface inpainting. *22nd International Congress on Image and Signal Processing* (pp. 1–5). Tianjin.
28. Chan, R. H., Chung-Wa, H., & Nikolova, M. (2005). Salt-and-pepper noise removal by median-type noise detectors and detail-preserving regularization. *IEEE Transactions on Image Processing, 14*(10), 1479–1485.
29. Balamurugan, E., Sengottuvelan, P., & Sangeetha, K. (2013). An empirical evaluation of salt and pepper noise removal for document images using median filter. *International Journal of Computer Applications, 82*, 17–20.
30. Pitas, I. (2000). *Digital image processing algorithms and applications* (pp. 2419–2431). John Wiley & Sons, Inc..
31. Chang, C., Huang, H., & Chen, S. (2009). Thyroid nodule segmentation and component analysis in ultrasound images. In *Proceedings of Asia-Pacific Signal and Information Processing Association Annual Summit and Conference* (pp. 910–917). Sapporo, Japan.
32. Rani, S., Bansal, D., & Kaur, B. (2014). Detection of edges using mathematical morphological operators. *Open Transactions on Information Processing*, 17–26.
33. Brown, R. G., & Patrick, Y. C. (2017). *Introduction to random signals and applied Kalman filtering with Matlab exercises* (4th ed.). John Wiley & Sons.
34. Jensen, J. R., & Schill, S. R. (2000). Contrast enhancement, lecture notes. In *Department of Geography University of South Carolina.*
35. Al-amri, S. S., Kalyankar, N. V., & Khamitkar, S. D. (2010). Linear and non- linear contrast enhancement image. *International Journal of Computer Science and Network Security, 10*(2), 139–143.
36. Arce, R. G. (2005). *Nonlinear signal processing: A statistical approach*. John Wiley & Sons.
37. Archana, J. N. (2016). A review on the image sharpening algorithms using unsharp masking. *International Journal of Engineering Science and Computing (IJESC), 6*(7), 8729–8733.
38. Dorothy, J. R., Rathish, R. J., Prabha, S. S., & Rajendran, S. (2015). Image enhancement by histogram equalization. *International Journal of Nano Corrosion Science and Engineering, 2*(4), 21–30.
39. Santhi, V., Acharjya, D. P., & Ezhilarasa, M. (2016). *Emerging technologies in intelligent applications for image and video processing*. IGI Global. Retrieved from https://www.worldcat.org/title/emerging-technologies-in- intelligent-applications-for-image-and-video-processing/oclc/923790989
40. Onieva, J., Andresen, L., Holsting, J. Q., Rahaghi, F. N., Ballester, M. A., Estepar, R. S., Román, K. L.-L., & de La Bruere, I. (2018). 3D pulmonary artery segmentation from CTA scans using deep learning with realistic data augmentation. *Image Analysis for Moving Organ, Breast, and Thoracic Images, 11040*, 225–237.
41. Keramidas, E., Iakovidis, D., Maroulis, D., & Karkanis, S. (2007). Efficient and effective ultrasound image analysis scheme for thyroid nodule detection. In *4th International Conference on Image Analysis and Recognition, CIAR 2007* (pp. 1052–1060). DBLP. https://doi.org/10.1007/978-3-540-74260-9_93
42. Milletari, F., Navab, N., & Ahmadi, S. A. (2016). V-Net: Fully convolutional neural networks for volumetric medical image segmentation. Retrieved from arXiv:1606.04797.

43. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning* (pp. 1Gavri96), Press MIT; Nielsen, M. A. (2015). *Neural networks and deep learning*. Retrieved September 3, 2018, from http://neuralnetworksanddeeplearning.com/.
44. Sayad, S. (2010). *Self-organizing maps*. Retrieved August 3, 2018, from https://www.saedsayad.com/clustering_som.htm
45. Aborisade, D. O., Ojo, J. A., Amole, A. O., & Durodola, A. O. (2014). Comparative analysis of textural features derived from GLCM for ultrasound liver image classification. *International Journal of Computer Trends and Technology (IJCTT), 11*(6), 239–244.
46. Roomi, M. M., & Saranya, S. (2012). Bayesian classification of fabrics using binary co-occurrence matrix. *International Journal of Information Sciences and Techniques (IJIST), 2*(2), 9.
47. Sujata, S., & Arora, K. (2014). A study analysis on the different image segmentation techniques. *International Journal of Information & Computation Technology, 4*(14), 1445–1452. Retrieved from http://www.irphouse.com
48. Koundal, D., Gupta, S., & Singh, S. (2012). Computer aided diagnosis of thyroid nodule: A review. *International Journal of Computer Science & Engineering Survey (IJCSES), 3*(4), 71–82.
49. Naz, K. N., Khyani, M., Baloch, M. A., Ansari, M. A., & Khan, Q. S. (2014). Morphological evaluation of thyroid nodules on ultrasound. *Pakistan of Journal of Otolaryngology, 30*, 3–6.
50. Ardakani, A., Gharbali, A., & Mohammadi, A. (2015). Application of texture analysis method for classification of benign and malignant thyroid nodules in ultrasound images. *Iranian Journal of Cancer Prevention, 8*(2), 116–124.
51. Bhirud, P., & Prabhu, N. (2014). Performance evaluation of filters of discrete wavelet transforms for biometrics. *International Journal of Informatics and Communication Technology, 3*(2), 97–102.
52. Raghavendra, U., Gudigar, A., Maithri, M., Gertych, A., Meiburger, K. M., Yeong, C. H., Madla, C., Kongmebhol, P., Molinari, F., Ng, K. H., & Acharya, U. R. (2018). Optimized multilevel elongated quinary patterns for the assessment of thyroid nodules in ultrasound images. *Computers in Biology and Medicine, 95*, 55–62. https://doi.org/10.1016/j.compbiomed.2018.02.002
53. Savelonas, M. A., Iakovidis, D. K., Legakis, I., & Maroulis, D. (2009). Active contours guided by echogenicity and texture for delineation of thyroid nodules in ultrasound images. *IEEE Transactions on Information Technology in Biomedicine, 13*, 519–527.
54. Seal, A., Ganguly, S., Bhattacharjee, D., Nasipuri, M., & Gonzalo-Martin, C. R. (2015). Feature selection using particle swarm optimization for thermal face. *Advances in Intelligent Systems and Computing Recognition*, 25–35.
55. Sathua, S. K., Dash, A., & Behera, A. (2013). Removal of salt and pepper noise from gray-scale and color images: An adaptive approach. *International Journal of Computer Science Trends and Technology (IJCST), 5*(1), 117–126.
56. Chandraka, C., Sharma, M., & Singha, I. (2012). Survey of image contrast enhancement methods. *International Journal of Electronics, Communication and Instrumentation Engineering Research and Development (IJECIERD), 2*(3), 56–63.
57. Savelonas, M. A., Lakovidis, D. K., Dimitropoulos, N., & Maroulis, D. (2007). Computational characterization of thyroid tissue in the radon domain. *IEEE International Symposium on Computer-Based Medical Systems* (pp. 189–192). IEEE.
58. Albelwi, S., & Mahmood, A. (2017). A framework for designing the architectures of deep convolutional neural networks. *Entropy, 19*(6), 242.
59. Lee, M. W. (2014). Fusion imaging of real-time ultrasonography with CT or MRI for hepatic intervention. *Ultrasonography, 33*(4), 227–239.
60. Szegedy, C., Liu, W., Jia, Y., Sermanet, P., Reed, S., Anguelov, D., Dumitru, E., Vincent, V., & Rabinovich, A. (2015). Going deeper with convolutions. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* (pp. 1–9). IEEE.

61. Deserno, J. T., Burtseva, L., Secrieru, I., & Popcova, O. (2009). Computer aided sonography of abdominal diseases: The concept of joint technique impact. *Computer Science Journal of Moldova, 17*(3), 278–297.
62. Dorathi Jayaseeli, J. D., & Malathi, D. (2020). An efficient automated road region extraction from high resolution satellite images using improved cuckoo search with multi-level thresholding schema. *Procedia Computer Science, 167*(4), 1161–1170. https://doi.org/10.1016/j.procs.2020.03.418
63. Ajagbe, S. A., Idowu, I. F., Adesina, A. O., & Oladosu, J. B. (2020). Accuracy of machine learning models for mortality rate prediction in a crime dataset. *International Journal of Information Processing and Communication, 10*(1), 150–160.
64. Sukhadeve, A. (2017). *Understanding neural network: A beginner's guide*. Retrieved August 6, 2017, from www.datasciencecentral.com/profiles/blogs/understanding-neural-network-a-beginner-s-guide.
65. Walls, A. C., Park, Y., Tortorici, M. A., Wall, A., McGuire, A. T., & Veesler, D. (2020). Structure, function, and antigenicity of the SARS-CoV-2 spike Glyco- protein. *Cell, 181*(2), 281–292.e6. https://doi.org/10.1016/j.cell.2020.02.058. Elsevier.
66. Specht, D., & Vinodchandra, S. (2017). Probabilistic neural network inferences on oligonucleotide classification based on oligo. *Verlad*, 77–84.
67. Pedregosa, F., Varoquaux, G., Gramfort, A., & Micheal, V. (2011). Scikit-learn: Machine learning in python. *Journal of Machine Learning Research, 12*, 2825–2830.
68. Larose, D. T. (2004). *Discovering knowledge in data: An introduction to data mining* (pp. 90–106). Wiley Interscience.
69. Tsantis, S., Dimitropoulos, N., Cavouras, D., & Nikiforidis, G. (2009). Morphological and wavelet features towards sonographic thyroid snodules evaluation. *Computerized Medical Imaging and Graphics, 33*, 91–99.
70. Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science, 2*, 160. https://doi.org/10.1007/s42979-021-00592-x
71. Vlacic, L. (2002). Learning and soft computing, support vector machines, neural networks, and fuzzy logic models, Vojislav Kecman; MIT Press, Cambridge, MA, 2001, ISBN 0-262-11255-8, 2001, pp. 578. ISBN 0-262-11255- 8, 2001. *Neurocomputing, 47*(1–4), 305–307. https://doi.org/10.1016/s0925-2312(01)00685-3
72. Kecman, V. (2002). *Learning and soft computing: Support vector machines, neural networks, and fuzzy logic models* (1st ed.). MIT Press.
73. Muller, K. R., Mika, S., Ratsch, G., Tsuda, K., & Schölkopf, B. (2001). An introduction to kernel-based learning algorithms. *IEEE Transactions in Neural Networks, 12*(2), 181–202. https://doi.org/10.1109/72.914517
74. Heinrich, L., Funke, J., Pape, C., Nunez-Iglesias, J., & Saalfeld, S. (2018). *Synaptic cleft segmentation in non-isotropic volume electron microscopy of the complete drosophila brain*. Cornell University.
75. Ray, S. (2017). *Understanding support vector machine algorithm from examples*. Retrieved October 2, 2018, from www.Analyticsvidhya.5com/Blog/2017/09/Understaing-Support-Vector-machine-example-code/.
76. Chinmay, C., Gupta, B., & Ghosh, S. K. (2015). Identification of chronic wound status un- der tele-wound network through smartphone. *International Journal of Rough Sets and Data Analysis, Special issue on: Medical Image Mining for Computer-Aided Diagnosis, 2*(2), 56–75. https://doi.org/10.4018/IJRSDA.2015070104
77. Adebisi, O. A., Ojo, J. A., & Oni, O. M. (2020). Comparative analysis of deep learning models for detection of COVID-19 from chest X-Ray images. *International Journal of Scientific Research in Computer Science and Engineering (IJSRCSE), 8*(5), 28–35. ISSN: 2320-7639.
78. Han, J., & Kamber, M. (2006). *Data mining: concepts and techniques*. Morgan Kaufmann.
79. Dhawan, A. P., & Dai, S. (2008). Clustering and pattern classification. In *Principles and advanced methods in medical imaging and image analysis* (pp. 229–265). World Scientific Publishing Co. Pte. Ltd..

80. Wang, H., & Fei, B. (2009). A modified fuzzy C-means classification method using a multiscale diffusion filtering scheme. *Medical Image Analysis, 13*(2), 193–202.
81. Bengio, Y., LeCun, Y., & Hinton, G. (2015). Deep learning. *Springer Nature, 521*, 436–444.
82. Saha, S. (2018). *A comprehensive guide to convolutional neural networks — The ELI5 way*. Retrieved October 2, 2018, from https://towardsdatascience.com/a-comprehensive-guide-to-convolutional–neuralnetworks-the-eli5-way-3bd2b1164a53
83. Simonyan, K., & Zisserman, A. (2014). Very deep convolutional networks for large-scale image recognition. *International Conference on learning Representation (ICLR) Banff* (pp. 1–14). Canada.
84. He, K., Zhang, X., Ren, S., & Sun, J. (2015). Deep residual learning for image recognition. *2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* (pp. 770–778). IEEE. doi:https://doi.org/10.1109/cvpr.2016.90.
85. Xia, J., Huling, C., Quang, L., Zhou, M. Z., Limin, C., Zhennao, C., Yang, F., & Hong, Z. (2017). Ultrasound-based differentiation of malignant and benign thyroid nodules: An extreme learning machine approach. *Computer Methods and Programs in Biomedicine, 147*, 37–49.
86. Priya, M., Sand, K., & Nawaz, G. (2017). Effective morphological image processing techniques and image reconstruction. In *Effective Morphological Image Processing Techniques and Image Reconstruction, Proceedings of National Conference on "Digital Transformation – Challenges and Outcomes"*. St. Anne's First Grade College for Women.
87. Chinmay, C., Gupta, B., & Ghosh, S. K. (2014. ISSN: 2213-9095). Mobile metadata assisted community database of chronic wound. *Elsevier International Journal of Wound Medicine, 6*, 34–42. https://doi.org/10.1016/j.wndm.2014.09.002
88. Kanevsky, M. B. (2008). *Radar imaging of the ocean waves*. Elsevier Science.
89. Frangi, A. F., Schnabel, J. A., Davatzikos, C., Alberola-López, C., & Fichtinger, G. (2018). Medical Image Computing and Computer Assisted Intervention – MICCAI 2018. *Lecture Notes in Computer Science*, 317–325. doi: https://doi.org/10.1007/978-3-030-00934-2.
90. Chinmay, C., & Sanjukta, B. (2021). Ch. 1: Healthcare data monitoring under internet of things. In *CRC: Green computing and predictive analytics for healthcare* (1st ed., pp. 1–18). Chapman and Hall/CRC.
91. Ahmed, S., Hossain, M. F., Kaiser, M. S., Noor, M. B. T., Mahmud, M., & Chakraborty, C. (2021). Artificial intelligence and machine learning for ensuring security in smart cities. In C. Chakraborty, J. C. W. Lin, & M. Alazab (Eds.), *Data-driven mining, learning and analytics for secured smart cities* (Advanced sciences and technologies for security applications). Springer, .. https://doi.org/10.1007/978-3-030-72139-8_2
92. Tomakova, R., Komkov, V., & Emelianov, E. (2017). The use of Fourier descriptors for the classification and analysis of peripheral blood smears image. *Scientific Research Publishing, 8*(11), 1563–1571.

Chapter 3
Optimal Feature Selection for Computer-Aided Characterization of Tissues: Case Study of Mammograms

John Adedapo Ojo, Temitope Olugbenga Bello, Peter Olalekan Idowu, and Ifeoluwa David Solomon

Abstract Feature extraction and selection are very important stages in pattern recognition and computer vision solutions with far-reaching effects on their performance. In computer-aided diagnosis (CADx) systems, efficiency is affected by its subjectivity to the accuracy of the region of interest (ROI) extraction technique, which is largely dependent on the features extracted. Optimization algorithms are often used to improve the selection of discriminative features which thereby leads to improve accuracy of the CADx systems. This work considers the effects of optimizing selected features in the performance of breast tissue characterization in mammograms. It uses Whale Optimization Algorithm (WOA) to optimize Otsu fitness function of Gray Level Co-occurrence Matrix (GLCM) in extracting the region of interest (ROI). The extracted features were classified into BIRADS scales 1, 2 and 5 using Multiclass Support Vector Machine (MSVM). The performance of the developed algorithm was evaluated using specificity, sensitivity as well as accuracy and compared with other techniques namely Texture Signature (TS), Pixel-Based Morphological (PBM), Natural Language Processing (NLP), and Interactive Data Language (IDL). The result of the developed WOA-Otsu-GLCM-MSVM CADx algorithm for specificity, sensitivity, and accuracy are 96%, 92% and 94%, respectively. The developed algorithm gave an accuracy of 94.4% as against 81.0%, 85.7%, 93.0% and 82.5% for TS, PBM, NLP and IDL methods, respectively. The characterization of the breast tumour using the developed CADx algorithm performed better compared with the conventional methods.

J. A. Ojo · P. O. Idowu (✉) · I. D. Solomon
Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria
e-mail: jaojo@lautech.edu.ng; poidowu@pgschool.lautech.edu.ng

T. O. Bello
Department of Radiology, LAUTECH, Ogbomoso, Nigeria
e-mail: tobello@lautech.edu.ng

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_3

Keywords Mammogram · Breast tumour · Fatty tissue · Whale optimization algorithm · Dense tissue · Gray level co-occurrence matrix · Multi-support vector machine · Pectoral muscle

3.1 Introduction

Pattern recognition (PR) refers to techniques used in computer vision (CV) to recognize distinct patterns in images for classification or grouping. PR is used to determine where an image belong to in a group, it finds use in tasks such as recognition, clustering and classification. It has been employed for applications such as; voice, object, tumour and face detection and recognition among others [1]. Feature extraction and selection are very important stages in PR solutions with far-reaching effects on performance. This implies that the performance of a PR system depends mainly on how well the features are extracted, selected and analyzed to distinguish one class from another.

In biomedical imaging, images of internal organs are captured using several modalities for diseases detection, diagnosis and study. Biomedical imaging types are magnetic resonance imaging (MRI), single-photon emission computed tomography (SPECT), computed tomography (CT), X-ray and Ultrasound among others [2]. Mammograms employ low dose X-rays to scan and capture breast tissues for screening and diagnosis purposes. Computed aided diagnosis (CADx) is a system that analysis biomedical images through feature extraction and pattern recognition technique(s) for diagnostic purposes [3, 4].

CADx usually plays a supporting role rather than substituting doctors or radiologists. The aim of CADx systems is the detection of early abnormality signs in patients which human professionals might miss, such as mammogram architectural distortion. Early detection of diseases, tumours, and other medical conditions can be the difference between life and death, hence, the importance of CADx cannot be overemphasized [5].

Breast tumour is a mass that occurs in the breast region, it turns to cancer when the tumour becomes malignant. Breast tumours have been confirmed to occur mostly in the fibroglandular region of the breast, it is depicted as white spots or patches on the mammogram [3]. Tumours are classified as either benign (unharmful) or malignant/cancerous (harmful). The malignant one is a rapidly growing type which can spread to neighbouring tissues and can sometimes result into metastasis (consequential malignant growth far from the origin cancer). Hence, the malignant type needs urgent care to guard against its spread through metastasis [6]. Cancer results from uncontrolled growth of cluster cells in the human body, this cluster can develop into tumour (a noticeable mass). Malignant breast tumour (cancer) is responsible for a high rate of death among women, efficient CADx system with the help of mammogram can result in early detection which consequently helps reduce this rate [7]. Symptoms of breast cancer may include nipple inversion, rapid change in breast skin or colour, dimpling of the skin and spontaneous discharge of one breast among others [8]. The development of breast tumour detection and classification systems remains a topical issue in the CADx research world [9–11].

In the area of medicine, the pink ribbon serves as a symbol to raise public awareness of breast cancer. One of the primary reasons of women's high mortality rates is breast cancer [12]. BRCA1, BRCA2 (two genes), obesity, birth control pill inhalation, irregular menstrual cycles, higher radiation therapy exposure, and estrogen hormone are all high-risk factors for breast cancer [10, 13, 14]. These factors are to blame for causing cell mutations, which resulted in unrestrained cell growth. Breast soreness is the most common sign of breast cancer, which can be fatal if not detected early. Other symptoms include skin irritation, redness, discomfort, and swelling, which turn ominous with the erosion of nipples or sudden watery discharge from the nipples [10, 14].

Radiologists are saddled with the task of reading mammograms for the identification of possible irregularities. In computer-aided diagnosis (CADx) systems, efficiency is affected by its subjectivity to the accuracy of the region of interest (ROI) extraction technique, which is largely dependent on the features extracted. Earlier researches on breast tumour detection CADx systems adopt manually chosen thresholds for ROI extraction and many are not Breast Imaging Reporting and Data System (BIRADS) based. Optimization algorithms are often used to improve the extraction and selections of discriminative features and consequently result in improved outcomes [11, 15, 16].

This work considers the effects of optimizing Otsu algorithm for ROI extraction to enhance features selection for breast tissue characterization using mammograms. It uses Whale Optimization Algorithm (WOA) to optimize Otsu fitness function producing WOA-Otsu, an automatic ROI extraction technique. GLCM is employed to extract discriminative features from the ROI images to form feature vectors which are then passed on to MSVM for classification. The developed CADx system is WOA-Otsu-GLCM-MSVM algorithm for optimal feature selection of breast tissue for tumour detection and classification.

3.2 Literature Review

The breast consists of dense tissue known as fibro-glandular tissue (which is made up of glandular with connective tissue) and fatty tissue. The dense tissue appears bright, while fatty tissue appears dark on a mammogram [17]. Tumours do originate from the breast tissue (lobules: milk-producing glands) and ducts that connect it to the nipple. Breast is prevalent in women and the malignant type often leads to death. Tumour (malignant or Benign) occurs as a result of uncontrolled cell mutation in the breast which is felt as a lump or visible on X-ray. Timely detection can lead to effective solutions that can curb mastectomy (surgical breast tissue removal) and consequently decrease re-occurrence probability and mortality rate [18].Breast image is a discrete bi-dimensional function, $m(a, b)$, where m, a and b are amplitude and spatial 2D coordinates, respectively. The function represents the intensities at the corresponding points on the image. The breast image is captured using different imaging modalities as aforementioned.

MRI uses a strong magnetic flux to rearrange the hydrogen atoms of the water in the body to produce hundreds of images representing slices or cross-sections in three-dimensional space. Breast MRI is a potential alternative to mammograms, but the cost is higher than other imaging methods and not widely available as ultrasound and mammography [19]. MRI is the technique of choice in breast tumour diagnosis for women with established cases of breast cancer [20]. MRI images depict the true nature of the established breast tumour, but they come in slices which make the analysis challenging. MRI is not suitable for screening examination by itself because it misses some tumours that mammography (that is screening mammography) can depict [18].

Breast ultrasound is primarily useful in differentiating a solid mass from a cyst and discovering an unnoticeable palpable abnormality on mammogram. It provides a better view of a lesion that is not visible on mammograms. Despite this advantage, ultrasound is not accurate imaging modality in detecting breast microcalcifications. In most inconclusive cases ultrasound serves as a follow up after mammography [21].

Mammograms are X-rays of the breast which displays high intensities region as potential tumours. It has the ability to depict subtle fine scale signs due to its high spatial resolution from low dose X-rays [22]. Full Field Digital Mammography (FFDM) is a type of mammography that uses an electronic device in the place of X-ray film to produce better quality mammograms with lower radiation doses. This enables better picture quality with a lower radiation dose. It is an advanced and reliable technique that could lead to better treatment through early detection of breast tumours [23].

Breast tumours are mostly uncovered after symptoms are noticed, however, many females with the ailment shows no symptoms [22]. Therefore, constant breast tumour check-up is so important. The ability of the radiologist to easily detect breast tumours on a mammogram highly depends on how dense the breast is. Several researches have been done in the area of CADx system development, examples of such are given herein.

Three pre-trained networks (VGG16, VGG19, and ResNet50) behavior were analyzed in [24] for magnification independent breast cancer classification. The result for transfer learning was compared to the fully-trained network on the histo-pathological imaging modalities. At the same time, the impact of training–testing data size on the performance of the considered networks was investigated. A fine-tuned pre-trained VGG16 with logistic regression classifier produced the best results, with 92.60% accuracy.

A method that employs preprocessing, data augmentation, deep neural network architecture (VGG-16), and gradient boosted trees classifier was presented by Ref. [25]. The system returns 87.2% accuracy on 4-class classification task. For a 2-class classification task on carcinomas detection, it gave 93.8% accuracy, 96.5 sensitivity and 88.0% specificity at the high-sensitivity operating point.

The use of Convolutional Neural Networks (CNNs) to classify hematoxylin and eosin-stained breast biopsy images was proposed by Ref. [26]. Images were categorized into four categories: normal tissue, benign lesion, in situ carcinoma, and invasive carcinoma, as well as two categories: carcinoma and non-carcinoma. The network's architecture is intended to retrieve information at various scales, including nuclei and overall tissue organization. This design enables the proposed system to be extended to whole-slide histology images.A Support Vector Machine classifier was trained using the features extracted by the CNN. The accuracy for four classes is 77.8%, and for carcinoma/non-carcinoma is 83.3%. The approach has a sensitivity of 95.6% for cancer cases.

Using a Faster region convolutional neural network (Faster R-CNN) and deep CNNs, [27] provide a multistage mitotic cell identification approach. In our research, two available datasets of breast cancer histology (international conference on pattern recognition (ICPR) 2012 and ICPR 2014 (MITOS-ATYPIA-14)) were employed. The method delivers state-of-the-art values of 0.876 precision, 0.841 recall, and 0.858 F1-measure for the ICPR 2012 dataset, and 0.848 precision, 0.583 recall, and 0.691 F1-measure for the ICPR 2014 dataset, which are higher than some earlier methods.

A multiclass CADx system capable of diagnosing breast cancer into four categories was proposed by [28]. The method involves normalizing the hematoxylin and eosin stains to enhance colour separation and contrast. Then, two types of novel features—deep and shallow features—are extracted using two deep structure networks based on DenseNet and Xception. Finally, a multi-classifier method based on the maximum value is utilized to achieve the best performance. The proposed method is evaluated using the BreakHis histopathology data set, and the results in terms of diagnostic accuracy is 92%.

3.2.1 ROI Extraction Techniques

The Breast Imaging Reporting and Data System (BIRADS) categorises findings of expert radiologists about tumours into classes numbered 0 via 6. This is the standard system used by medical doctors or oncologists to report mammograms results or findings. A recommendation was put forward by [29] that each breast should be examined separately and diagnosed in accordance to BIRADS. The summary of BIRADS categorization is described in Tables 3.1 and 3.2.

Table 3.1 Summary of breast density categorization [17, 30]

Category	Percentage density
Type 1	Fatty breast (contains 0–10% dense tissue).
Type 2	Fibro glandular (contains 25–20% dense tissue).
Type 3	Heterogeneously dense (contains 50–75% dense tissue).
Type 4	Dense and homogeneous (contains 75–100% dense tissue)

Table 3.2 Summary of BIRADS categories [29]

Category	Assessment
BIRADS 0	Incomplete
BIRADS 1	Normal
BIRADS 2	Benign
BIRADS 3	Probably benign
BIRADS 4	Suspicious abnormality
BIRADS 5	Probably malignant
BIRADS 6	Malignant

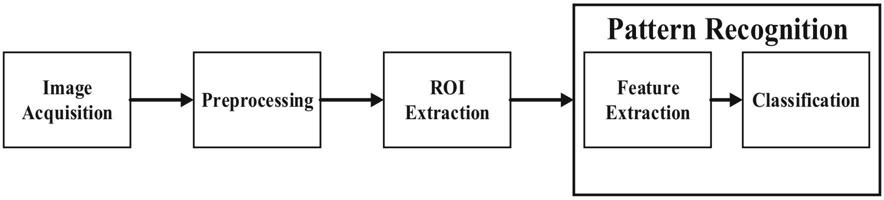


Fig. 3.1 CADx block schematics

The precise ROI extraction or segmentation of the breast regions in mammograms is a vital processing phase in computer analysis of mammograms. This allows for accurate recognition of irregularities as the undue influence of the mammograms background or irrelevant regions would have been removed. It also facilitates enhancements of methods like comparative analysis, that is the automatic comparison of mammograms pairs. The borderline of the breast gives substantial information concerning distortion in pairs of mammograms and this serves as the basis for linking nipple position relative to the skin surface [31].

The exactness of ROI extraction technique (otherwise known as segmentation) determines how accurate and efficient a CADx system is. Pectoral muscle presence makes ROI extraction challenging; hence it must be removed from the mammogram for accurate segmentation [32]. The main approaches or procedures of research exploration embedded in the components of the CADx system comprises image acquisition, preprocessing, ROI extraction, features extraction and classification stages as shown in Fig. 3.1.

Mammographic images (mammograms) are readily available in databases of some organizations such as; Mammography Image Analysis Society (MIAS), Medical Information Data Analysis System (MIDAS) database and Digital Database for Screening Mammogram (DDSM) among others.

The segmentation process separates the image pixels into different groups according to their similarities. It is concerned with the demarcation of image portions to communicate and mathematically interpret hidden information. Mammography segmentation is dependent on the motion, shape, colour, spatial configuration and texture of the breast image or its components [33, 34]. Detection of images or their constituents is difficult to attain in many real-world settings. Segmentation of mammograms is made up of duo stages: breast contour outline and pectoral region removal. The pectoral area denotes a high-intensity region in most mammograms and can influence the output image processing. Two preprocessing algorithms are often incorporated, one for breast outline extraction and the other for pectoral area removal [35].

3.2.2 Optimization Algorithms

Optimization algorithms are techniques that can be used to maximize the best threshold value(s) to split the image into object and background. They are used to optimize Otsu thresholding techniques in this work, to improve the outcome to attain optimal thresholding value. The optimal thresholds are found through between-class variance maximization or within-class variance minimization of the regions which are labelled as thresholds [36]. Optimization algorithms available in the literature are particle swamp optimization (PSO), artificial bee colony (ABC), cat swarm optimization (CSO), whale optimization algorithm (WOA) and genetic algorithm (GA) among others.

WOA is a meta-heuristic algorithm that perform optimization based on the humpback whales bubble net hunting strategy [37]. Validation of WOA was performed using 29 optimization problem mathematical benchmarks with its performance evaluated via comparison with conventional techniques such as PSO, Gravitational Search Algorithm, Fast Evolutionary Programming and Differential Evolution. WOA is shown to outperform most of the compared popular meta-heuristic techniques.

A liver segmentation in MRI images using WOA was proposed in [38]. The technique used WOA for image cluster extraction to aid the segmentation approach. The system was tested with a dataset of 70 radiologists' approved MRI images. The segmented images were validated using Similarity Index (SI) and Structural Similarity Index Measure (SSIM) among others. The experimental result gave an accuracy of 97.5% using SI and 96.75% using SSIM.

A feature selection technique based on WOA was proposed by [37]. The technique was validated using 18 typical benchmark data sets gotten from UCI respiratory and was compared to three wrapper feature selecting techniques namely GA, PSO and ALO. WOA was found to be better in terms of accuracy and average selection size.

An improved Otsu thresholding based pre- and post-processing technique for soft tissue sacromas (STS) segmentation on MRI images with malignant tumours was reported in [39]. The result of WOA in optimizing Otsu algorithm was evaluated with other techniques such as Differential evaluation, PSO and Grasshopper Optimization. Though the results are close to each other, WOA happen to give better result than others with high robust performance.

WOA was used for clustering by [15] and compared with PSO, ABC, GA, DE and K-means clustering. The proposed method was evaluated with seven standard UCI repository benchmark and one artificial dataset. The results show that WOA based algorithm was the most effective, most robust and easiest to implement of the compared approaches.

WOA was used for feature selection in conjunction with Fuzzy based Relevance Vector Machine (FRVM) classifier by Ref. [16]. This process was compared with PSO-based and other techniques for disease diagnosis. WOA-based technique was shown to converge quicker than the compared techniques to produce a better solution.

A new Image segmentation technique based on multilevel thresholding was proposed by Ref. [1]. WOA was used to optimize thresholding values used for ROI extraction. The obtained results showed that the proposed method performed better in solving multilevel thresholding problems for ROI extraction and produces faster convergence. It is evident from previous studies that WOA outperforms most of the metaheuristic optimization algorithm as it is robust, give faster convergence and higher performance. Hence, this proves promising if implemented on realistic datasets such as MIDAS, MIAS or DDSM.

Mirjalili and Lewis developed a contemporary meta-heuristic optimization algorithm known as WOA [15, 16]. The algorithm comprises of three mathematical models, namely, prey search, prey encircling and bubble-net attacking. These models mimic humpback whales' traits to perform optimization.

3.2.3 Feature Extraction

Several techniques have been used to analyse, detect or extract features from mammogram images. Feature extraction translates pixel information into a higher degree depiction of motion, colour, shape, spatial configuration and texture of the breast image or its components. The mined is used for succeeding expression characterization. Feature extraction generally reduces the dimensionality of the input by representing raw images in a reduced form to enable efficient detection or classification [40].

Feature extraction and selection are essential for efficient dimensionality reduction, improved data presentation, prediction performance improvement, data storage requirement reduction, computational requirement reduction and by extension, cost reduction. In a situation where the classifier can get optimal accuracy using the

Table 3.3 Texture features [23]

Feature	Expression
Contrast (c)	$C = \sum_{i,j} \lvert i - j \rvert^2 \mathrm{p(i,j)}$
Uniformity (U)	$U = \sum_{p=0}^{n-1} P^2$
Entropy (E)	$E = \sum_{i} P\left(\frac{i}{d}\right).logP\left(\frac{i}{d}\right)$
Energy (e)	$e = \sum_{L-0}^{L-1} [P(i)]^2$

extracted features, feature selection might not be required [39]. Table 3.3 shows the texture features expressions.

A co-occurrence signifies the angular spatial and distance relation on an image subsection of a specific size. GLCM is a matrix obtained from a grayscale image, it is how frequent a pixel with intensity value "i" occurs vertically (90°), horizontally (0°) or diagonally (45° or 135°) with respect to neighbouring pixels with intensity value j. Statistical texture features can be of either first, second or higher-order. The GLCM technique is a method used in mining second-order statistical features [41–43]. It is a technique developed by Haralick, which is regularly employed in image feature extractions for the detection and categorization of tumours in mammograms [42, 44, 45].

Many features and classification techniques have already been developed to detect and categorize the lesions as malignant or benign, among others are Artificial Neural Networks (ANN), Hybrid Neural Network Classification (HNN), Support Vector Machines (SVM), K-Nearest Neighbours (KNN), Relevant Vector Machine (RVM), and Fuzzy approaches. But the capacity of SVM to outdo several famous developed methods for the broadly studied problem of microcalcification detection suggests that it is a promising method for object characterization in medical imaging applications [46, 47].

3.2.4 Evaluation of CAD System

CADx system performance depends on disease, image type and organ. The CADx system findings can be categorised as False Negative (FN), True Positive (TP), True Negative (TN) and False Positive (FP) depending on the presence of abnormality or otherwise. The true or false denotes how CADx decision agrees with actual clinical state and positive or negative represents the decision made by the algorithm [48].

CADx performance is evaluated using several objective evaluation parameters such as sensitivity, accuracy and specificity among others. Equations 3.1, 3.2 and 3.3 are the mathematical definition for sensitivity, specificity and accuracy respectively. The parameter score of a CADx system is directly proportional to its performance.

$$\text{Sensitivity} = \frac{TP}{TP + FN} \tag{3.1}$$

Higher sensitivity indicates low false negative detection.

$$\text{Specificity} = \frac{TN}{TN + FP} \tag{3.2}$$

Higher specificity indicates low false positive detection.

$$\text{Accuracy} = \frac{TP + TN}{TN + TP + FP + FN} \tag{3.3}$$

CADx of breast cancer over the years has greatly contributed to the medical diagnosis development as it is constantly being used by radiologists [9]. CADx accuracy can be improved by reducing FP and FN of the system. Despite advancements in CAD detection systems, there is still a need for optimization of the existing algorithms to produce a more reliable system as there is no one-fit all method. This research tends to detect and characterize breast tumors based on BIRADS scheme of ACR using an optimized segmentation approach.

3.3 Methodology

The developed method consists of the data acquisition stage, the image preprocessing stage, the WOA-Otsu RoI extraction stage, the feature extraction stage, and the classification stage. The block diagram of the proposed CADx system is shown in Fig. 3.2. All the stages involved were carried out in Python using Jupyter notebook of Anaconda distribution.

MIAS database was used to test the developed system. The database consists of 161 pairs (left and right) of mammography images, out of which 115 were abnormal (64 benign and 51 malignant). The images were also classified into Dense-Glandular (112 images), Fatty (106 images) and Fatty-Glandular (104 images) based on the radiologist report in the database.

Image preprocessing was used for the reduction of image noise. The noises in the images were removed for successful segmentation, image artefact removal, and pectoral region removal. In this study region descriptive method [49] was used to remove pectoral muscle, artefact and high-intensity noise. The median filter was used to filter noise and smoothen the mammograms.

The bilateral comparison stage was done using Breast Images Bilateral Comparison (BIBC) derived from the work of [50]. The left breast and right were set in the same orientation and the BIBC values of each image were computed using Eq. (3.8). BIBC was used to detect asymmetric distortion between the left and right breast. The difference between the breast tissues was compared with a choosing value (0.05). The breasts with higher values than 0.05 are suspected to be with abnormalities. BIBC is derived as shown in Eqs. (3.4) to (3.8).

$$\text{if } \mathrm{P}\left(\mathrm{Im}_{\mathrm{R}}^{\mathrm{I}}\right) \tag{3.4}$$

$$\text{sum } \mathrm{P}\left(\mathrm{Im}_{\mathrm{R}}^{\mathrm{I}}\right) = \text{sum } \mathrm{P}\left(\mathrm{Im}_{\mathrm{R}}^{\mathrm{I}}\right) + 1 \tag{3.5}$$

$$\text{if } \mathrm{P}\left(\mathrm{Im}_{\mathrm{R}}^{\mathrm{I}}(\mathrm{i},\mathrm{j})\right) > 161 \tag{3.6}$$

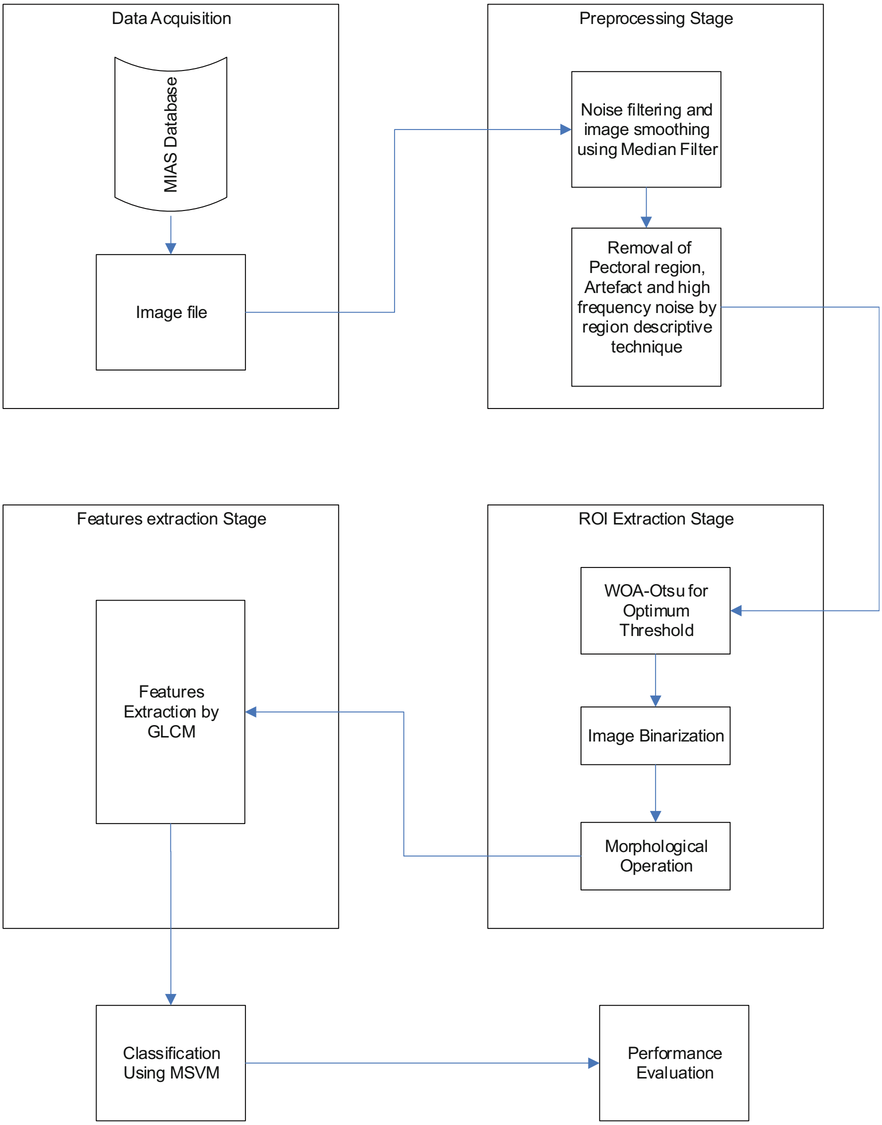


Fig. 3.2 Block diagram of the computer aided diagnosis system of breast tumour

$$\text{sum P}\left(\text{Im}_\text{R}^\text{I}\right) = \text{sum P}\left(\text{Im}_\text{R}^\text{I}\right) + 1 \tag{3.7}$$

$$\text{BIBC} = \frac{\left|\sum \text{P}\left(\text{Im}_\text{R}^\text{I}\right) - \sum \text{P}(\text{Im}_\text{L})\right|}{1024^2} \tag{3.8}$$

where Im_L is the left breast image, $\text{Im}^\text{I}{}_\text{R}$ is the flipped right breast image and BIBC, is the breast image bilateral comparison difference value.

The breast density evaluation stage uses Breast Density Distribution Function (BDDF) defined as in Eq. (3.9):

$$\mathrm{BDDF} = \frac{\sum_{1}^{i} \sum_{1}^{j} p_{ij}}{N} \quad (3.9)$$

where: i, j are the spatial coordinates of the function p_{ij}, p_{ij} is the intensity values greater than 172, N is the total pixels in the images.

The preprocessed images were categorized into fatty and dense breasts using Eq. (3.9). Optimum intensity (threshold) value of 172 was chosen to arrive at a reduced false-positive value and better true negative values, which resulted in an improved classification. The mammograms are categorized using BDDF values. Images with BDDF values less than 0.1 are classified as fatty while others are classified as dense breasts.

The denser the breast tissue is, the difficult it is for radiologists to detect breast cancer. Hence CADx systems for automatic breast tumour detection are more efficient on fatty images.Images with BIBC values less than 0.05 were fed as input into the breast density evaluation stage.

The proposed technique flowchart is shown in Fig. 3.3. The method used WOA to optimize Otsu algorithm for automatic selection of best thresholding values. These optimal values were used to segment the mammograms. The fitness functions used Otsu's maximum class variance criterion of algorithm to enhance the accuracy of the ROI extraction via two-level thresholding. This improves the accuracy of the classification stage. The input to the proposed WOA-Otsu algorithm is the region descriptive preprocessed mammograms.

The feature extraction stage employed statistical features and GLCM. This technique was applied to the segmented images to extract relevant intensity and texture features such as contrast, uniformity, homogeneity, mean, standard deviation of the object among others. The GLCM features (homogeneity, correlation, contrast and energy) were extracted at 8 different distances and angular orientations (0, 45°, 90°, 135°). In addition, statistical features (mean, standard deviation, variance and median) were added to the bank of features. The combined features were fed into the MSVM.

The classification of the extracted feature vectors was done using the MSVM following BIRADS scale system. The relevant feature vectors were subdivided into train and test data sets in the ratio 0.75 to 0.25 respectively. The appropriate MSVM classifier was trained and tested to categorize the imputed images into normal, benign or malignant tissues based on the BIRADS system.

The system algorithm was implemented in Python using Jupyter notebook IDE of Anaconda distribution version 5.0 on Hewlett Packard (Hp) computer system with processor Intel(R) Core (TM) i3-2350M CPU @ 2.30 GHz and 6.00GB RAM.

The computer system has 750G HDD capacity, 64-bit Operating System (OS), and x64-based processor on Windows 10 professional edition.

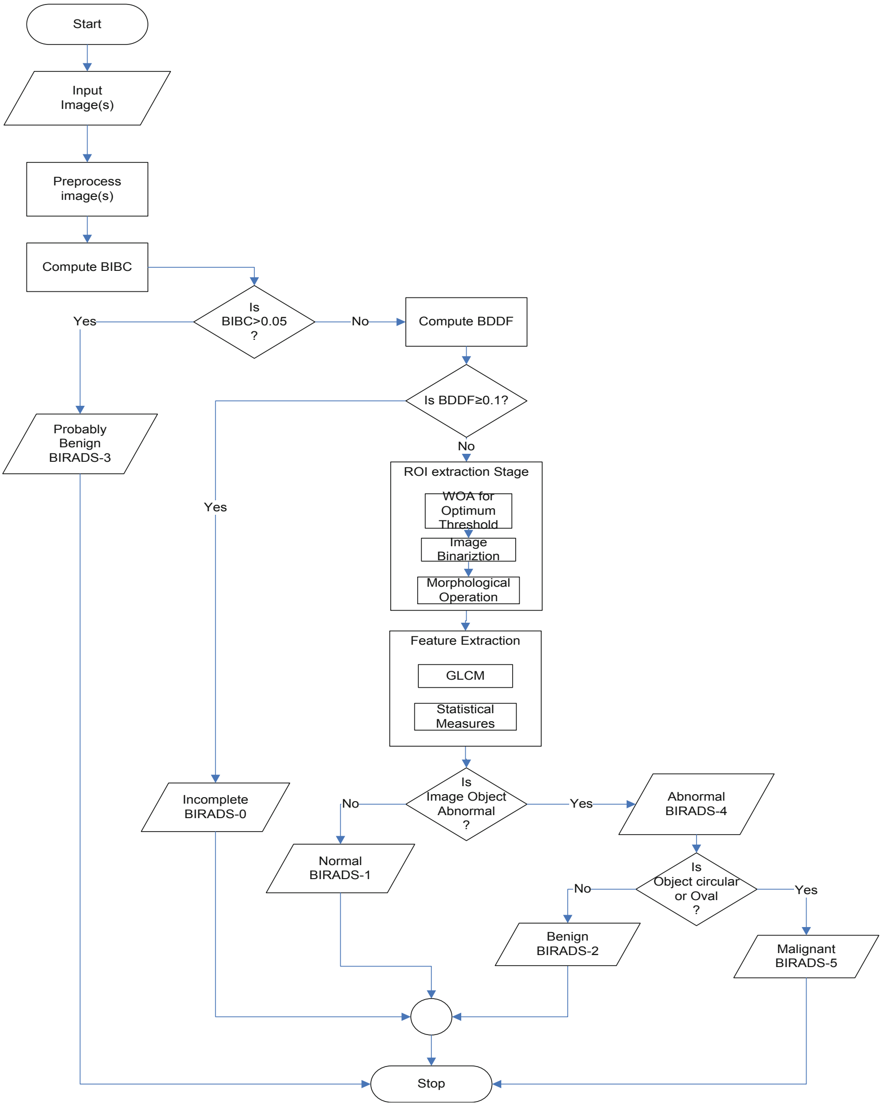


Fig. 3.3 Flow chart of the breast tumor categorization system

The performance of the developed computer-aided diagnosis system was evaluated using specificity, sensitivity, and accuracy.

The parameters TP, TN, FN and FP was derived from the contingency table of the developed system. TP is when the system correctly classified a lesion mammogram, TN is when the system correctly classified a non-lesion mammogram, FN is when the system classified a lesion mammogram as non-lesion and FP is when the system classified a non-lesion mammogram as lesion.

3.4 Results and Discussions

The 322 mini-MIAS database images were preprocessed using region descriptive method [49] and median filter to eradicate high-frequency noise, artefact and pectoral muscle region. The result achieved in this stage is presented in Table 3.4. The processing stage took 202.32 seconds for the whole 322 images in the database to be preprocessed in Python 3.7.3 using Jupyter notebook of Anaconda Distribution version 5.0, which is approximately 0.6283 s processor time per image this faster preprocessing time compare to time took to obtain the same result in MATLAB as indicated in [50]. The stage successfully processed all the mammograms (322 images). The results of the preprocessed mammograms are shown in Fig. 3.4.

The breast images with BIBC values greater than 0.05 were grouped as BIRADS 3 (suspicious breast tissue) to be examined by an expert radiologist for further diagnosis. A total of 161mammograms out of 322 were classified as BIRAD 3.

The breast BDDF values were used to group the fed-in mammograms (161) into fatty (BDDF value $<$0.1) and dense (BDDF value $\geq$0.1) breast images. The dense images were labelled BIRADS 0, which implies that there is a need for additional imaging evaluation. Right and Left breast fatty and dense images are shown in Fig. 3.5.

The images with BDDF values $<$0.1 (51 fatty breast images) were passed as input into the WOA-Otsu algorithm. The algorithm automatically segments input images into object and background (ROI extraction). It was observed that the normal images were almost completely black as the background (in this case), while the abnormal (benign and malignant) were having various shapes of white masses. Figure 3.6 shows the segmented images, with (a) as a normal mammogram, (b) as benign tumour and (c) as malignant tumour respectively. The segmented images were fed as input into the feature extraction stage.

The feature vector obtained from GLCM at various angular orientations and distances were 128 intensity features extracted, 32 features each contrast, homogeneity, energy and uniformity respectively. Additional texture features were extracted from statistical measures, these are mean, median, standard deviation and variance. The total feature vector extracted is 132 combined features per image, these are fed into the MSVM classifier for training and testing.

The feature data set was divided into train and test data in the ratio 0.75 to 0.25. The 51 mammograms (fatty breast tissues), that consist of 23 normal, 16 benign and 12 malignant gave 39 train and 12 test datasets. The training dataset was used to train the MSVM. The trained system was used to classify the test dataset into malignant, benign and normal. The performance metrics are presented in Table 3.6 which is derived from Table 3.5. The GUI of the model build in Python using the tkinker

Table 3.4 Results of the preprocessed mammograms

Subjective inspection	Results (%)	Sample image(s)
Successful	299 (92.86)	Fig. 3.4a
Accepted	13(4.04)	Fig. 3.4b
Unaccepted	10(3.10)	Fig. 3.4c

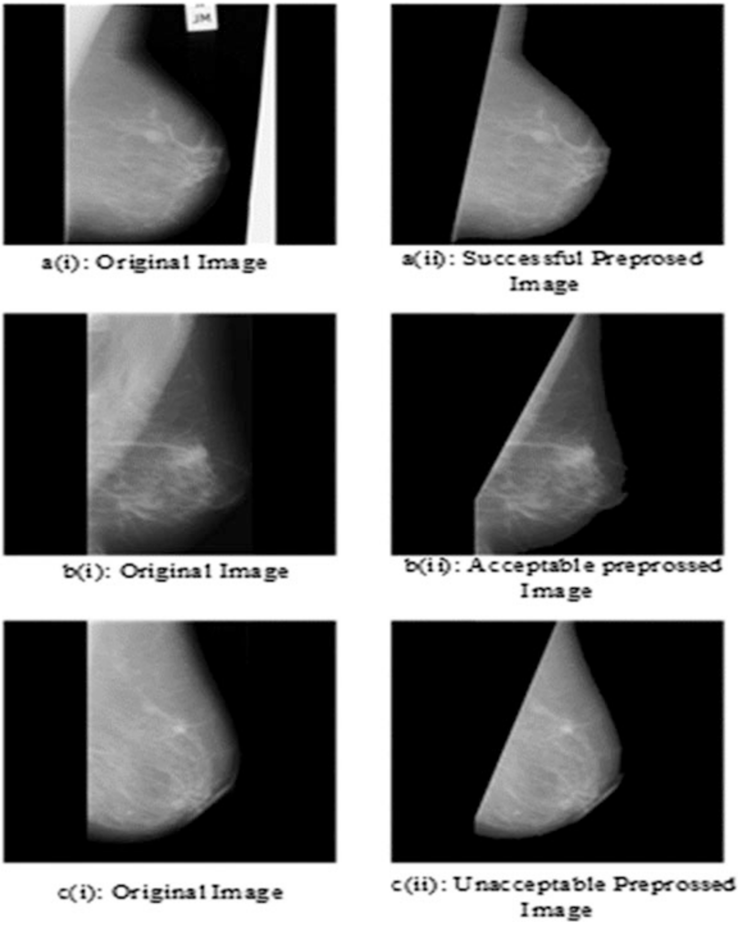


Fig. 3.4 The preprocessed images

library is shown in Figs. 3.7, 3.8, and 3.9 as normal image, benign and malignant respectively.

The mini-MIAS database mammograms were used in the development of the computer-aided diagnosis (CADx) system. Both subjective and objective methods of performance evaluation were used to evaluate the system.

The preprocessed image(s) were subjected to visual inspection and compared with the consultant radiologist report presented in the readme file of the database. The results were categorized as successful, acceptable and unacceptable as shown in Fig. 3.4. The results obtained are shown in Table 3.4, 299 images out 322 images (92.86% of the total samples) were successful, 13 images (4.04% of the total samples) were acceptable and 10 images (3.10% of the total samples) were unacceptable.

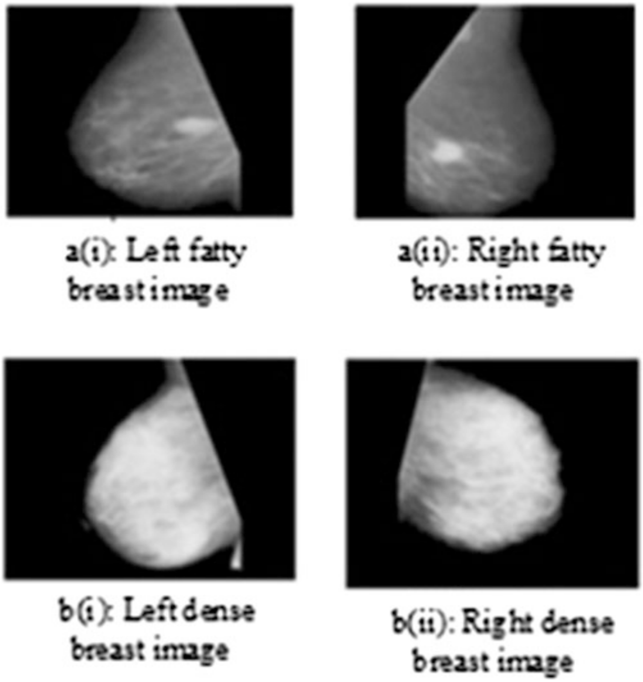


Fig. 3.5 Fatty and dense breast image

The mammograms in the bilateral comparison stage with higher BIBC values that were classified as BIRADS3, implies that they are considered to be suspicious images, that is, they are architecturally asymmetrical with their breast pair when set in the same orientation and compared. Since their BIBC value is greater than 0.05, the images were suspected for microcalcification and a follow-up is recommended.

The density evaluation stage used BDDF values to categorize the images into fatty and dense breast image(s). Figure 3.5a, b illustrate samples of fatty and extremely dense breast tissue respectively. The mammograms with BDDF greater than 0.1 that were categorized as BIRADS0 were considered incomplete (inconclusive) diagnoses, that is, there is a need for additional imaging evaluation. The reason being that these mammography images are heterogeneously dense and appears brightly coloured as a potential tumour will appear on a mammogram, hence they are grouped for other imaging evaluation as the radiologist will recommend.

The segmentation stages used the optimum threshold value obtain from WOA-Otsu algorithm to automatically segment the images into objects and background as shown in Fig. 3.6. The mammography images without tumours also known as normal mammograms were observed to dark as the background region of the mammogram after segmentation. This shows an absence of tumour as usually appear white on mammogram after segmentation, Fig. 3.6a shows the output of a

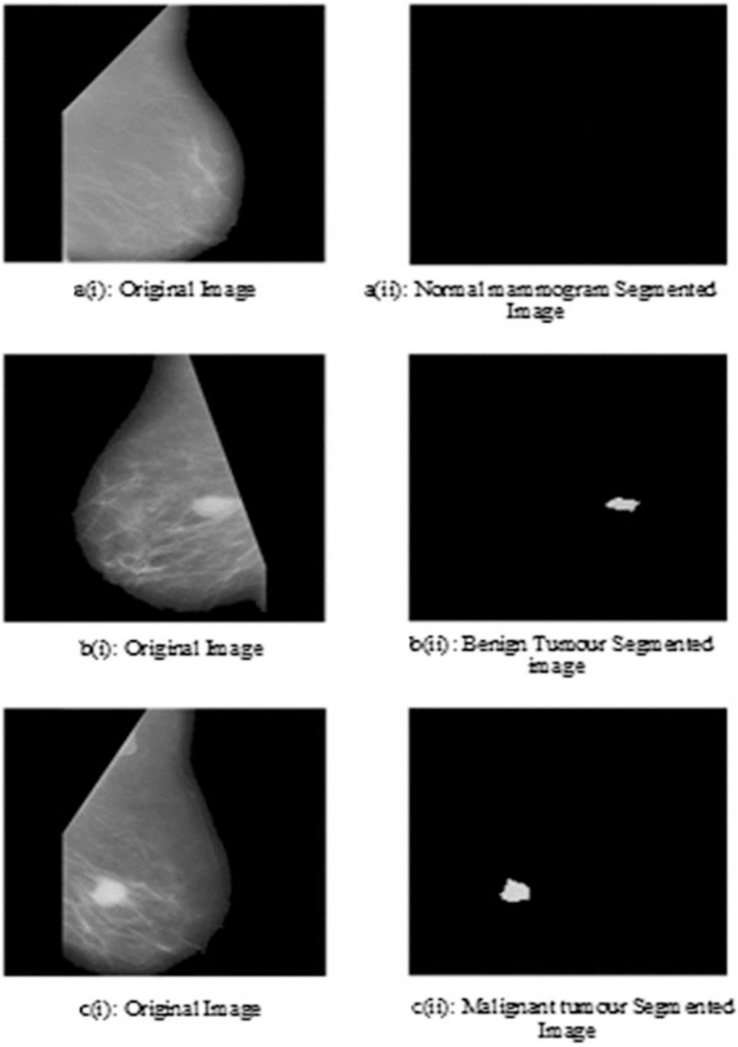


Fig. 3.6 Images of segmentation stage

Table 3.5 Test result confusion matrix

	Actual		
Predicted	Normal	Benign	Malignant
Normal	5	0	0
Benign	0	3	1
Malignant	0	0	3

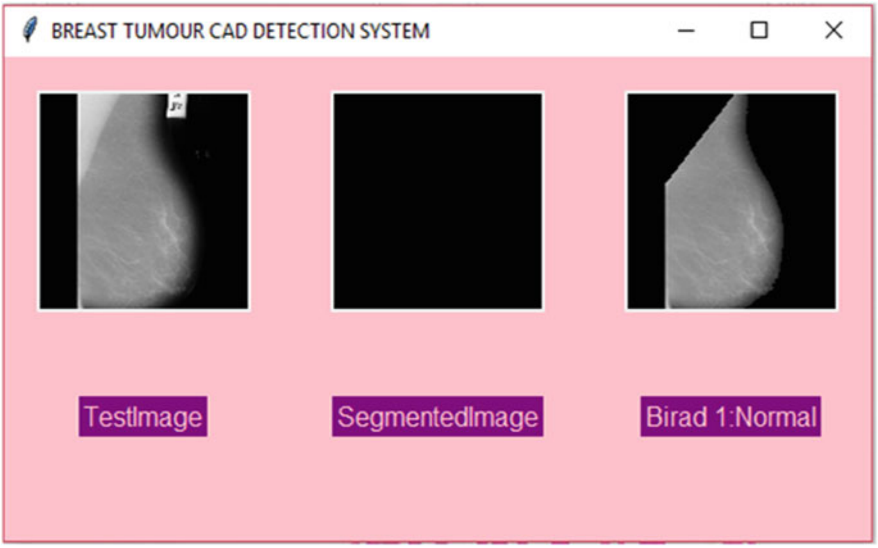


Fig. 3.7 Normal breast tissue

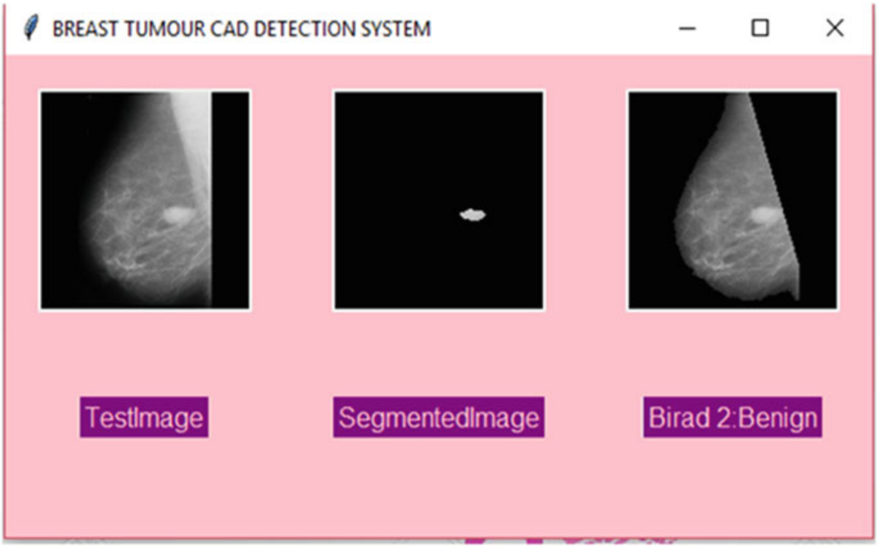


Fig. 3.8 Benign breast tissue

normal mammogram. The mammography image with benign cyst were observed to be circumscribed in shape as indicated in Fig. 3.6b while the mammograms with malignant tumours were observed to be speculated in shape as depicted in Fig. 3.6c.

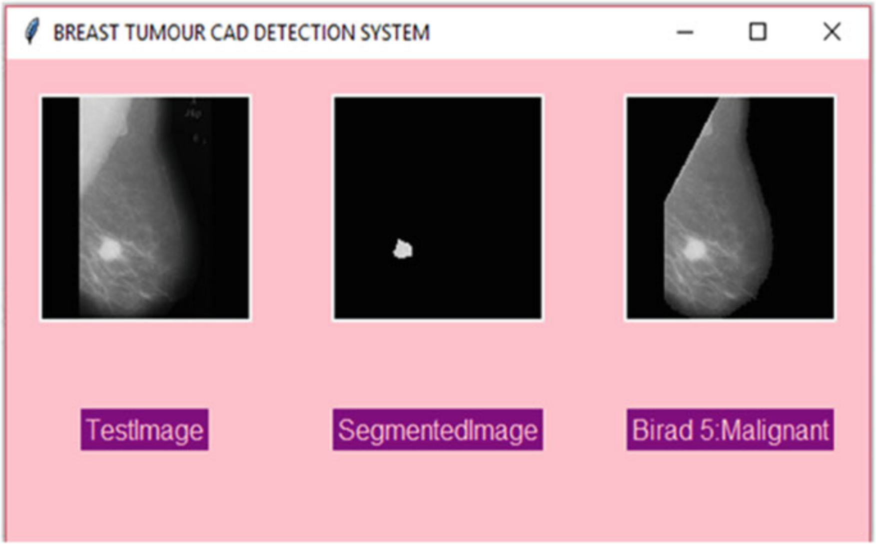


Fig. 3.9 Malignant breast tissue

The features mined from the GLCM and statistical measure to the obtained relevant intensity and texture features that were fed into the MSVM classifier were considered, as a hybridized feature that combines two or more techniques is adopted to achieve higher truthfulness [23]. The hybridize features technique adopted combines texture-based and intensity-based features and the total extracted feature for each mammogram is 132 features.

The MSVM was used to categorize the mammography images into BIRADS1, that is normal mammogram, BIRADS2, a benign tumour (non-cancerous abnormality) and BIRADS5, a malignant tumour (cancerous abnormality). The confusion matrix obtained from the classification is shown in Table 3.5. The performance of the system was tested using specificity, sensitivity, and accuracy. Table 3.6 shows the performance of the system derived from the confusion matrix. The system returns specificity of 0.96, sensitivity of 0.92 and accuracy of 0.94.

The CADx System develop in this study was compared with others in the literature that used BIRADS scheme and SVM classifier for mammograms classification including Novel Texture Signature (TS) Based approach proposed by [53], Pixel-Based Morphological Technique (Otsu) technique developed by [18], Natural Language Processing (NLP) method proposed by [52], and Interactive Data Language (IDL) method proposed by Ref. [51]. Table 3.7 shows the performance accuracy of the system as compared with other methods in literature. Figure 3.10 shows the bar chart of the comparison and it observed that the system gave better performance compared to others in the literature with an accuracy of 94.44%.

Table 3.6 Performance evaluation of the developed system

Performance evaluation metrics	Results (%)
Specificity	95.93
Sensitivity	91.67
Accuracy	94.44

Table 3.7 Performance (Accuracy) of developed system and others in the literatures using BIRADS and SVM classifier

Author(s)	Database	Method	Overall Acc
Proposed	mini-MIAS	WOA-Otsu	0.9444
Mohammed et al. [51]	SMDS	IDL	0.8250
Castro et al. [52]	Locally source	NLP	0.9300
Adepoju et al. [18, 50]	mini-MIAS	PBMT	0.8571
He et al. [53]	mini-MIAS	TS	0.8100

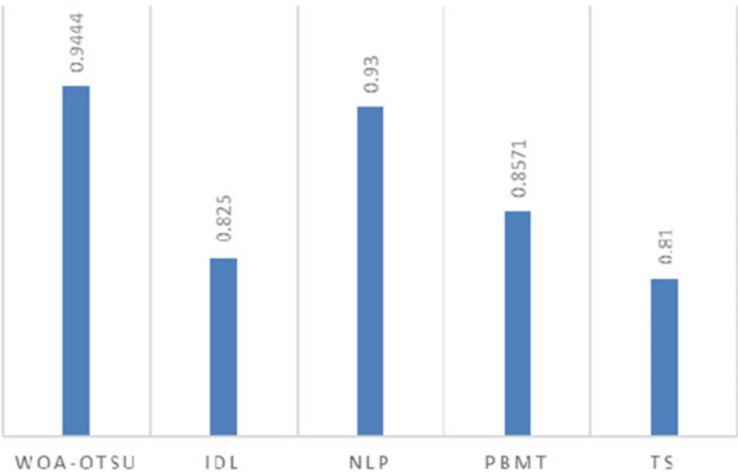


Fig. 3.10 Bar chart showing accuracies of different methods

3.5 Conclusion

A CADx system to detect the existence or absence of breast tumour have been developed. The use of a median filter for noise elimination at the preprocessing stage proved to be successful for the mammograms' enhancement. In addition, WOA-Otsu algorithm has resulted in successful automatic detection and segmentation of breast tumours. This has led to a better classification of the breast tissues into normal, benign or malignant by the system.

A novel segmentation technique has been developed that can automatically segment mammograms mitigating the problem of overfitting. This work reiterates that conventional methods coupled with optimization can produce results comparable with deep learning techniques. The developed CAD technique can automatically detect and classify tumours in breast images. The developed WOA-Otsu algorithm can be adopted for tumour detection and categorization in other medical image databases such as liver, kidney, thyroid, and brain among others.

The use of other optimization algorithms in conjunction with WOA-Otsu is suggested. Further research work into how the system can be used to detect and categorize tumours on more dense mammography images is recommended.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. El Aziz, M. A., Ewees, A. A., Hassanien, A. E., Mudhsh, M., & Xiong, S. (2018). Multi-objective whale optimization algorithm for multilevel thresholding segmentation. In *Advances in soft computing and machine learning in image processing* (Studies in computational intelligence) (Vol. 730, pp. 23–39). Springer.
2. Hassanpour, H., Samadiani, N., & Salehi, S. M. (2015). Using morphological transforms to enhance the contrast of medical images. *The Egyptian Journal of Radiology and Nuclear Medicine, 46*(2), 481–489.
3. Wang, C., Brentnall, A. R., Cuzick, J., Harkness, E. F., Evans, D. G., & Astley, S. (2017). A novel and fully automated mammographic texture analysis for risk prediction: Results from two case-control studies. *Breast Cancer Research, 19*, 114.
4. Priyanka, D., & Chinmay, C. (2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence, 1*, 1–24.
5. Chinmay, C. (2019). Performance analysis of compression techniques for chronic wound image transmission under smartphone-enabled tele-wound network. *International Journal of E-Health and Medical Communications (IJEHMC), 10*(2), 1–15.
6. Saidin, N., Ngah, K. U., Shuaib, L. I., & Sakim, H. A. M. *Segmentation of breast regions in mammogram based on density: A review*. Imaging & Computational Intelligence Group (ICI).
7. Chakravarthi, R., Nandhitha, N. M., Roslin, S. E., & Selvarasu, N. (2016). Tumour extraction from breast mammographs through hough transform and DNN hybrid segmentation technique. *Biomedical Research, 27*(4), 1188–1193.
8. Krishnan, M., Chinmay, C., Banerjee, S., Chakraborty, C., & Ray, A. K. (2009). Statistical analysis of mammographic features and its classification using support vector machine. *Expert Systems with Applications, 37*, 470–478.
9. Kaur, P., Singh, G., & Kaur, P. (2019). Intellectual detection and validation of automated mammogram breast cancer images by multi-class SVM using deep learning classification. *Informatics in Medicine Unlocked, 16*, 100151.

10. Ganesan, K., Acharya, U. R., Chua, C. K., Min, L. C., Abraham, K. T., & Kwan-Hoong, N. (2013). Computer-aided breast cancer detection using mammograms: A review. *IEEE Reviews in Biomedical Engineering, 6*, 77–98.
11. Pavol, Z., Peter, K., Karol, K., Zuzana, D., Hubert, P., Tibor, B., Erik, K., Marek, S., Alena, L., Dominika, V., Tatiana, K., Igor, S., Veronica, H., Jan, B., Zuzana, L., Dietrich, B., Mariusz, A., Walther, K., Jan, D., & Olga, G. (2019). Why the gold standard approach by mammography demands extension by multiomics? Application of liquid Biopsis miRNA profiles to breast cancer disease management. *International Journal of MolecularSciences, 20*(12), 2878.
12. Siegel, R. L., Miller, K. D., Fedewa, S. A., Ahnen, D. J., Meester, R. G. S., Barz, A., & Jemal, A. (2017). Colorectal cancer statistics. *CA: a Cancer Journal for Clinicians, 67*(3), 177–193.
13. Ford, D., Easton, D. F., Stratton, M., Narod, S., Goldgar, D., Devilee, P., Bishop, D. T., Weber, B., Lenoir, G., Chang-Claude, J., Sobol, H., Teare, M. D., Struewing, J., Arason, A., Scherneck, S., Peto, J., Rebbeck, T. R., Tonin, P., Neuhausen, S., . . . Eyfjord, J. (1998). Genetic heterogeneity and penetrance analysis of the BRCA1 and BRCA2 genes in breast cancer families. *American Journal of Human Genetics, 62*, 676–689.
14. Kallenberg, M., Petersen, K., Nielsen, M., Ng, A. Y., Diao, P., Igel, C., Vachon, C. M., Holland, K., Winkel, R. R., Karssemeijer, N., & Lillholm, M. (2016). Unsupervised deep learning applied to breast density segmentation and mammographic risk scoring. *IEEE Transactions on Medical Imaging, 35*(5), 1322–1331.
15. Sayed, G. I., Darwish, A., Hassanien, A. E., & Pan, J.-S. (2017). Breast cancer diagnosis approach based on meta-heuristic optimization algorithm inspired by the bubble-net hunting strategy of whales. In *Genetic and evolutionary computing* (Advances in intelligent systems and computing). Springer.
16. Nasiri, J., & Khiyaban, F. M. (2018). A whale optimization algorithm (WOA) approach for clustering. *Cogent Mathematics & Statistic, 5*, 1483565.
17. Yogapriya, J., Saravanabhavan, C., & Ila, V. (2018). Medical image retrieval system using local binary patterns,whale optimization & relevance vector machine algorithms. *Tagajuornal, 14*, 3164–3191.
18. Adepoju, T. M., Ojo, J. A., Omidiora, E. O., & Olabiyisi, O. S. (2015). Pixel-based morphological technique for breast tumour detection. *International Journal of Scientific & Engineering Research, 6*(6), 1416–1420.
19. ACS. (2017). *Breast cancer early detection and diagnosis*.
20. Jalalian, A., Mashohor, S., Mahmud, R., Karasfi, B., Saripan, M. I. B., & Ramli, A. R. B. (2017). Review article: Foundation and methodologies in computer-aided diagnosis systems for breast cancer detection. *EXCLI Journal, 16*, 113–137.
21. Saslow, D., Boetes, C., & Burke, W. (2007). American Cancer Society guidelines for breast screening with MRI as an adjunct to mammography. *CA: A Cancer Journal for Clinicians, 57*(2), 75–89.
22. Raj, J. R., Rahman, S. M. K., & Anand, S. (2016). Preliminary evaluation of differentiation of benign and malignant breast tumors using non-invasive diagnostic modalities. *Biomedical Research, 27*(3), 596–603.
23. Adeyemo, T. T., Adepujo, T. M., Sobowale, A. A., Oyediran, M. O., Omidiora, E. O., & Olabiyisi, S. O. (2017). Feature extraction techniques for mass detection in digital mammogram (review). *Journal of Scientific Research & Reports, 17*(1), 1–11.
24. Shallu, R. M. (2018). Breast cancer histology images classification: Training from scratch or transfer learning? *ICT Express, 4*, 247–254.
25. Rakhlin, A., Shvets, A., Iglovikov, V., & Kalinin, A. A. (2018). Deep convolutional neural networks for breast cancer histology image analysis. In *Lecture notes in computer science* (Vol. 10882, pp. 737–744). Springer.
26. Arau'jo, T., Aresta, G., Castro, E., Rouco, J., Aguiar, P., Eloy, C., et al. (2017). Classification of breast cancer histology images using convolutional neural networks. *PLoS One, 12*(6), e0177544.

27. Tahir, M., Muhammad, A. M. O., Min, B. L., & Kang, R. P. (2020). Artificial intelligence-based mitosis detection in breast cancer histopathology images using faster R-CNN and Deep CNNs. *Journal of Clinical Medicine, 9*, 749.
28. Alkassar, S., Jebur, B. A., Abdullah, M. A. M., Al-Khalidy, J. H., & Chambers, J. A. Going deeper: Magnification invariant approach for breast cancer classification using histopathological images. *IET Computer Vision, 15*, 151–164.
29. Adepoju, T. M., Adeyemo, T. T., Fagbola, T. M., Omidiora, E. O., & Olabiyisi, S. O. (2016). Histogram normalization technique for preprocessing of digital mammographic images. *LAUTECH Journal of Engineering and Technology, 10*(1), 82–87.
30. Corinne, B., Salma, A., Kim, V. N., Daniel, V., Clarisse, D., & Robert, S. (2007). BIRADSTM classification in mammography. *European Journey of Radiology, 61*, 192–194.
31. Rampun, P., Morrow, J., Scotney, B. W., & Wang, H. (2020). Breast density classification in mammograms: An investigation of encoding techniques in binary-based local patterns. *Computers in Biology and Medicine, 122*, 1–18.
32. Aghdam, H., Puig, D., & Solanas, A. (2013). A probabilistic approach for breast boundary extraction in mammograms. *Computational and Mathematical Methods in Medicine, 10*, 17–26.
33. Suguna, S. K., & Ranganathan, R. (2017). A new Evolutionanary – Based optimization algorithm for mammogram image processing. *International Journal of Pure and Applied Mathematics, 117*(17), 241–247.
34. Cruz, C. F. (2011). *Automatic analysis of mammography images: Enhancement and segmentation techniques*. Port University.
35. Karakoyun, M., Baykan, N. A., & Hacibeyoglu, M. (2017). Multi-level thresholding for image segmentation with swarm optimization algorithms. *International Research Journal of Electronics & Computer Engineering, 3*(3), 654–658.
36. Kumar, T. G., Murugan, D., & Manish, T. I. (2018). An analysis on road extraction from satellite image using Otsu method and genetic algorithm techniques. *WSEAS Transactions on Computers, 17*, 42–51.
37. Mirjalili, S., & Lewis, A. (2016). The whale optimization algorithm. *Advances in Engineering Software, 95*, 51–67.
38. Zidan, M., Hassanien, A. E., Hefny, H. A., & Houseni, M. (2017). Liver segmentation in MRI images based on whale optimization algorithm. *Multimedia Tools and Applications, 76*, 24931–24954.
39. Ozturk, Ş., Akdemir, B., Ozkaya, U., & Seyfi, L. (2017). Soft tissue sacromas segmentation using optimized otsu thresholding algorithms. *International Journal of Engineering Technology, Management and Applied Sciences, 5*, 9.
40. Mafarja, M. M., & Mirjalili, S. (2017). Hybrid Whale Optimization Algorithm with simulated annealing for feature selection. *Neurocomputing, 260*, 302–312.
41. Kowsalya, S., & Priyaa, D. S. (2015). A survey on diagnosis methods of breast cancer using mammography. *International Journal of Engineering Technology Science and Research, 2*, 100–107.
42. Guyon, I., & Elisseeff, A. (2003). Special issue on variable and feature selection. *Journal of Machine Learning Research, 3*, 1157–1182.
43. Mohanaiah, P., Sathyanarayana, P., & GuruKumar, L. (2013). Image texture feature extraction using GLCM approach. *International Journal of Scientific and Research Publications, 3*(5), 1–5.
44. Punithavathi, V., & Devakumari, D. (2020) *Detection of breast lesion using improved GLCM feature based extraction in mammogram images*.
45. Jagadesh, B. N., & Kumari, L. K. (2021). A GLCM based feature extraction in mammogram images using machine learning algorithms. *International Journal of Current Research and Review, 13*(5), 145–149.
46. Mahdi, F. (2015). Application of GLCM technique on mammograms for early detection of breast cancer. *Journal of Babylon University/Pure and Applied Sciences, 23*(2), 885–890.

47. Chinmay, C. (2019). Computational approach for chronic wound tissue characterization. *Elsevier: Informatics in Medicine Unlocked, 17*, 1–10.
48. Mryka, H. B. (2017). *GLCM texture: A tutorial*. University of Calgar.
49. Ojo, J. E., Adepoju, T. M., Omidiora, E. O., Olabiyisi, O. S., & Bello, O. T. (2014). Pre-processing method for extraction of pectoral muscle and removal of artefacts in mammogram. *IOSR Journal of Computer Engineering (IOSR-JCE), 16*(3), 06–09.
50. Adepoju, T. M., Ojo, J. A., Omidiora, E. O., Olabiyisi, O. S., & Bello, O. T. (2015). Detection of tumour based on breast tissue categorization. *British Journal of Applied Science & Technology, 11*(5), 1–12.
51. Mohamed, S. E., Wahbi, T. M., & Sayed, M. H. (2018). Automated detection and classification of breast cancer using mammography images. *International Journal of Science, Engineering and Technology Research (IJSETR), 7*, 4.
52. S. M. Castro, E. Tseytlin, O. Medvedeva, . K. Mitchell, S. Visweswaran, T. Bekhuis and R. S. Jacobson, "Automated annotation and classification of BI-RADS assessment from radiology reports, Journal of Biomedical Informatics" 67, 177–187, 2017.
53. He, W., Denton, E. R., & Zwiggelaar, R. (2010). Mammographic image segmentation and risk classification using a novel texture signature based methodology. *IWDM, 6136*, 526–533.

Chapter 4
Breast Cancer Detection Using Particle Swarm Optimization and Decision Tree Machine Learning Technique

Jesutofunmi Onaope Afolayan, Marion Olubunmi Adebiyi, Micheal Olaolu Arowolo, Chinmay Chakraborty, and Ayodele Ariyo Adebiyi

Abstract Cancer of the breast is one of the deadliest diseases encountered by women and requires early diagnosis. Although more time is required for the traditional diagnostic process, a realistic and straightforward approach may be achieved through machine learning approaches to detect ailment. Advances in technology, however, generate different kinds of high-dimensioned data, majorly cancer or medical data. Staggeringly high data makes it harder for them to obtain insight knowledge; unrepresentative knowledge can contribute to skewed outcomes in classification. The feature selection process may be used to enhance classification performance to solve any of these challenges. In this article, Particle Swarm Optimization (PSO) is suggested to optimize the efficiency of the classification with the Decision Tree algorithm on a Wisconsin Breast Cancer dataset. The findings reveal that the performance of the system was 92.26% accuracy likened to the state-of-the-art. In conclusion, the system will help minimize the existence of breast cancer disease by creating an early detection system for diagnosis based on a machine learning approach, and it will help health practitioners in decision-making.

Keywords Machine learning · Breast cancer · Particle swarm optimization · Diagnosis · Algorithms · Evaluation · Health · Decision tree

---

J. O. Afolayan · M. O. Adebiyi · M. O. Arowolo (✉) · A. A. Adebiyi
Department of Computer Science, Landmark University, Omu-Aran, Nigeria
e-mail: Marion.adebiyi@lmu.edu.ng; arowolo.olaolu@lmu.edu.ng; ayo.adebiyi@lmu.edu.ng

C. Chakraborty
Department of Electronics and Communication Engineering, Birla Institute of Technology, Jharkhand, India
e-mail: cchakrabarty@bitmesra.ac.in

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_4

4.1 Introduction

As the average life expectancy rises, so does the requirement for healthcare services to be provided and improved. The advancement of communication and information technology has caused the creation of smart cities with numerous components. Smart Health (s-Health) is one of those components, used to improve healthcare by as long as a variety of amenities for example patient monitoring, initial disease diagnosis, among others. There are numerous machine learning approaches available now that can help with s-Health services. Machine learning methods in healthcare use the growing amount of medical information collected offered by the Internet of Things to improve clinical outcomes. These methodologies focus on providing significant advantages and also unique challenges. The machine learning component is utilized in medical and genetic knowledge. Many of these areas focus on diagnosis, detection, and prediction. An increase in the capability of medical products generally collects information but an infrastructure needed is largely uncontrollable not really in place to identify utilize such relevant information.

In the world of bioinformatics or medical research, correct diagnosis of vital data such as medical, among others, are crucial concerns [1]. In the world of medicine, disease diagnosis is a demanding and challenging activity, a vast rate of medical diagnosis evidence accessible in various hospitals, diagnostic centers, research centers, as well as website repositories, to enable the system automated and rapid disease diagnosis, it is necessary to classify them. The patient preparation officer's expertise and skill in the medical profession are generally used to identify the disease. Consequently, there are cases of defects, unwanted biases, and accurate disease detection takes a long time. Amongst females across the globe, cancer of the breast is leading cancer. The best strategy to maximize the chances of cure and longevity is to diagnose cancer early. Data mining has been a common method for discovering new information in social science, finance, marketing, and medicine with promising outcomes [2, 3]. The unwanted sprouting of breast cancer is caused by some cells in the breast. In other to achieve a proper diagnosis of cancer of the breast, many methods have been developed. Mammography or breast screening [4] is a breast-related cancer detection procedure. It is used via X-rays to verify the status of women's nipples. Also, due to the small number of cancerously viewed cells, it is nearly difficult to detect breast cancer at the initial level. Cancer can be detected by mammography at an initial phase, and this procedure takes only a few minutes. Early identification and diagnosis are crucial to reducing this cause of death. In the case of breast cancer, there are two early warning strategies: early diagnosis and screening. This fatality rate can be reduced by improved medical equipment and techniques. The new advancement of breast cancer diagnosis enables cancer cells to be identified; as the testing instruments become more reliable, identification and prediction will be made more effective [5].

According to the American Cancer Society [6], relative to all other cancers currently introduced, breast cancer affects women. The estimate shows that approximately 252,710 women would be affected by intrusive breast cancer, and about sixty-three thousand, four hundred and ten (63,410) women would be diagnosed in the United States in 2017 in situ breast cancer. Men have an advanced chance of having breast cancer too. A prediction made for men in 2017 started that nearly 2470 people in the United States will be affected by this disease. Another prediction estimates that around 41,070 people would die of cancer disease in 2017. According to recent data from the United Kingdom, 41,000 women had breast cancer last year, with only three hundred males impacted.

Mammography, along with a surgical biopsy and fine needle aspirate (FNA), is a traditional way to diagnose breast cancer. The outcomes of this diagnosis of malignant lumps method are mammography, sensitivity results 68–79%, 65–98% fine needle aspirate, and the surgical biopsy is nearly 100% [7]. A surgical biopsy is an expensive medical technique, but its efficacy is greater. The Fine Needle Aspiration biopsy involves the isolation of cell samples from the lump and microscopic visual examination. After cancer of the breast, detection has been made; the prognosis is then calculated to forecast breast cancer cells' potential growth and attributes [8].

There have been several attempts to cut expenses and intensify breast cancer patients' care quality. Existing therapy procedures are both expensive and aching in patients' bodies [9]. Preventative steps must be taken before cancer progresses. Consider using machine learning to forecast a breast cancer diagnosis. This technology is reasonably inexpensive and simple to use, in addition to providing early prevention.

Machine learning techniques have many possible medical uses and have been utilized in a significant number of oncology functions, such as cancer susceptibility estimation, survival rates, and therapies. Machine Learning (ML) is a subset of Artificial Intelligence (AI) that permits electronic computers to learn with or without no human being's involvement. ML is one of the most popular models in the field of AI, which has been quickly implemented to train machines and develop predictive models for effective decision-making [10]. Machine learning approaches are the leading choice to produce a better outcome in classification and prediction problems. The ML strategies for cancer detection and prediction could be used in breast cancer studies. If cancer is malignant or benign [11] may be predicted by these ML approaches. In this paper, Feature selection is suggested by exploiting the algorithm of Particle Swarm Optimization on our raw breast cancer dataset to get a reduced subset free of noises, and it will be analyzed and evaluated using the Decision Tree machine algorithm for classification. The dataset is split into two, 25% for testing and 75% for training. The major contribution in this study suggests an innovative PSO for selecting relevant features in breast cancer data, which helps in evaluating the classification performance using the decision tree.

The remaining aspects of this paper are expressed: Sect. 4.2 summarizes the related work. Section 4.3 discusses the materials and methods. In Sect. 4.4, discussed the results. Finally, Sect. 4.5 concluded this work and proposed possible areas of further research.

4.2 Related Works

In machine learning and data mining, an essential and crucial responsibility is classification. To categorize Breast Cancer, many studies have been done using machine learning techniques and data mining on various medical datasets. Many of them have a high level of categorization precision. Several new systems for diagnosing breast cancer have been developed as medical science has progressed. The following is a summary of the research in this field.

Sakri et al. [12] based on improving the precision performance, Particle Swarm Optimization (PSO) feature selecting algorithm along with Reduced Error Pruning (REP) tree, K-NNs, and Naïve Bayes (NB) machine learning algorithms. Their job viewpoint represents the issue of breast cancer in Saudi Arabian women, and according to their report, it is one of Saudi Arabia's main problems. Their studies show that the primary victims of this malicious disease are women above 46 years. In line with this sentiment, the developers of [12] have introduced five analysis techniques of WBCD dataset phase-based data. A relativity study between classifications with a method of feature selection and a method exclusive of feature selection has been published. For K-NNs, NB, and RepTree, 66.3%, 70%, and 76.3% precision were established accordingly. Weka tool was used for processing data. PSO was used to identify four attributes that serve a good function for this classification role. As a result, they received 75%, 80%, and 81.3% precision values for K-NNs, NB, and Reptree with PSO, respectively.

Silva et al. [13] investigated four machine learning approaches in predicting breast cancer recurrence type. Support Vector Machine (SVM), GRNN, Naïve Bayes (NB), and J48 are the four classifiers employed. The results demonstrate that GRNN and J48 surpass the other two classifiers in terms of accuracy of 91%.

Borges and Rodrigues [14] compared two machine learning classifiers to analyze the cancer of the breast dataset. The classifiers used are Naïve bayes and the J48. After vigorous evaluation and analyses, Naïve Bayes gave 97.80% accuracy, considered the highest, while the J48 gave 96.06% accuracy.

Ahmed et al. [15] used various ML classification methods in predicting a target class successfully and enhance the prediction by examining the efficiency of specific features from the initial Wisconsin Breast Cancer dataset (WDBC) for predicting breast cancer laboratory identification. Immediately the classifiers run the dataset completely, they were compared to discover the top-performing method, and then the dataset's effective attributes were examined to increase performance even more. Five algorithms, namely Naïve Bayes, Multilayer Perceptron (MLP), Support Vector Machine (SVM), J48, and Random Forest, were compared in this article. The employed performance metrics to compare the results include Accuracy, Precision, Recall, F-Measure, Kappa Statistics, PRC Area, ROC Area, and MCC. Among the algorithms utilized, the Naïve Bayes classifier produced the best results based on the indication of performance values. In other to improve efficiency, a model was proposed, and an evaluation of advanced procedures was made on the same dataset; different academics have presented alternative solutions.

Asri et al. [16] worked on the WDBC; their research compares the performance of four algorithms of ML such as Decision Tree (C4.5), Support Vector Machine (SVM), k Nearest Neighbors (k-NN), and Naïve Bayes (NB). The major objective is to appraise the validity of each algorithm's classification accuracy, sensitivity, precision, and specificity as regards the effectiveness and efficiency. The results of the experiments demonstrate that SVM has the error rate, which is the lowest, and the 97.13% accuracy, considered the highest. The WEKA, a data mining tool, is used to execute all of the tests in a simulated environment.

Kumar et al.'s research [17] focuses on applying several data mining classification methods to predict benign and malignant cancer of the breast. The UCI repository's Breast Cancer Wisconsin data collection was utilized as the experimental and investigational dataset, with attribute clump thickness as the assessment group. On this data set, the performance of the following twelve algorithms is examined: Ada-Boost, Logistics Regression, Decision Table, J-Rip, Random tree, Multiclass Classifier, Lazy IBK, Multilayer–Perceptron, Lazy K-star, J48, Random Forest, and Naïve Bayes.

Ojha and Goel [18] highlight the selection parameters for applying data mining techniques to anticipate the likelihood of recurrence of breast cancer. The publications show how clustering and classification procedures are utilized. For the experimental dataset, the author claims that classification techniques performed better than clustering. EM, PAM, K-Means, Mean and Fuzzy c-mean were used as clustering procedures, whereas Nave Bayes, KNN, SVM, Mean, and C 5.0, were utilized as classification methods.

In Srikanth et al. [19], the performances of several techniques of machine learning were compared, including J48 (C4.5 decision tree) Sequential Minimal Optimization (SMO), Naïve Bayes (NB), K-Nearest Neighbors (k-NN), and K-Means. The Wisconsin Breast Cancer (Original) dataset was used to assess the performance of various algorithms. The major goal is to assess each algorithm's competency concerning precision, specificity, sensitivity, and accuracy. The findings reveal SMO is the best regarding the low fault rate and correctness. The WEKA tool is used to carry out and implement all of the tests.

Musa and Aliyu [20] aim to use specific techniques of descriptive statistics and decision tree classifiers, considered as machine learning algorithms to evaluate the model's performance in forecasting the likelihood of metastasis cancer in late-presenting patients. The illness dataset was obtained from the Usmanu Danfodiyo University Teaching Hospital's Department of Radiotherapy and Oncology in Sokoto, Nigeria. There are 259 instances and 10 attributes in this dataset. 88% sensitivity, 75% specificity, and 98% accuracy. Findings from this study, a machine learning algorithm utilizing decision tree classifiers, indicated that 87% of the tumors would reach stage IV, suggesting that cancer could extend to several other tissues of the body.

The goal of Ganggayah et al. [21] is to use quality and acceptable machine learning approaches to develop explainable prognostic models to discover the major prognostic parameters impacting the rate of survival of women with breast cancer in the Asian environment. Prediction models were created using a decision tree, SVM and random forest, neural networks, logistic regression, and extreme boost to determine the major breast cancer survival rate predictive factors. The information was then grouped using breast cancer patients' receptor status through immunohistochemistry to undertake sophisticated random forest modeling. The crucial variable quantities were then ranked using random forest variable selection methods. Ultimately, decision tree algorithms were developed and validated the use of survival analysis. All algorithms reached similar conclusions in terms of model correctness and setting measure, with the decision tree yielding 79.8% accuracy, which is considered the lowest, and the random forest presented the 82.7% accuracy, which is considered the highest. In addition, the study found that cancer step classification, tumor dimensions, the number of positive lymph nodes, total axillary lymph nodes removed, the types of main treatment, and finding methodologies were all essential variables.

Autsuo Higa [22] for breast cancer prediction, two robust classification procedures, Artificial Neural networks, and decision trees, were deployed in the research investigation. According to experimental results, the algorithms mentioned above have an auspicious result for this reason, with comprehensive forecast accuracy of 94% and 95.4%, sequentially. Both algorithms were utilized as intelligent approaches for breast cancer detection in this study, cancer detection in the ten studies, both systems accurately classified more than 92% of the cases. On average, however, the algorithm of Neural Network had a higher accuracy rate of prediction (actual predictions rate). The categorization rate is 95.9%.

Bellaachia and Guven [23] give an investigation of data mining strategies for predicting the survivorship rate of breast cancer patients in this research. SEER Public-Use Data was used as the source of information. The preprocessed data collection contains 151,886 records that include all of the SEER database's 16 fields. The Naïve Bayes, C4.5 decision tree algorithms, and back-propagating neural networks were examined as data mining tools. These algorithms were used in several experiments. The results of the prediction are comparable to those of existing approaches. Nevertheless, the reference observed that the C4.5 algorithm beats the other two approaches significantly.

Hasan et al. [24] devised a statistical model focusing on the symbolism regression of multi-gene genetic programming in breast cancer prognosis. The ten-fold method is intended to discourage overfitting. It shows a quantitative analysis as well. The stop criteria were established for the model; however, the generation level was not higher than zero. The model has obtained a precision of 99.28% with a precision rate of 99.26%.

Ronak et al. [25] present a decision tree-based data mining method for breast cancer timely detection. Breast cancer is classified as benign (cannot enter nearby tissue) or malignant (can invade nearby tissue) (can invade neighboring tissue) malignancies of the breast. This research also looks at a variety of data mining approaches used to identify breast cancer and a general overview of the disease (risk factors, types, treatment, and symptoms).

The original WDBC (1992) from the UCI ML Repository was used in Saputra and Prasetyo [26]. This research aimed to determine which features would be employed and how to deal with class imbalances so that the C4.5 algorithm could perform better in the classification process. To solve class imbalances, PSO and bagging are utilized as feature selection approaches. To determine the accuracy of the classification, the confusion matrix was used to test it. According to the findings of this study, using PSO as a feature selection and bagging method to solve class imbalances with the C4.5 algorithm increased accuracy by 5.11%, from 93.43% to 98.54%.

The goal of Park et al. [27] was to create a breast reconstruction decision tree model and test its prediction. Ethnographic decision tree modeling was employed in a mixed approach design. Individual and focus group interviews were used to collect data for the qualitative stage, which was then processed to create a decision tree model. The questionnaire was prepared in the quantitative stage with questions based on the qualitative stage's defined criteria. In 2017, 61 women with breast cancer took part in the study. The five key determinants impact recurrence, recommendations, body image recovery, physician confirmation, and financial possessions. Nine prediction pathways were also included in the model. It was out that the model correctly projected 90% of decisions to undertake breast rebuilding or not to undertake breast rebuilding. The data suggest that the five criteria are important in deciding whether to have breast rebuilding or not. As a result, more wide-ranging topics, such as the five criteria mentioned above, must be considered in breast reconstruction therapy for breast cancer patients to make the finest option possible.

Bhise et al. [28] propose a Machine Learning model for doing automated breast cancer diagnoses. CNN was used as a Recursive Feature Elimination (RFE), and the classifier model was used to choose features. The research also compares five algorithms: Random Forest, SVM, KNN, Nave Bayes classifier, and Logistic Regression. On the Break His 400X Dataset, the system was tested. The system's accuracy and precision are used to evaluate its performance. To anticipate the outcomes in terms of probability, activation functions such as ReLu have been utilized. The work looked at a variety of machine learning processes for detecting cancer of the breast. A comparison of SVM, CNN, Logistic regression, KNN, Random Forest, and Naïve Bayes was conducted. CNN has been found to beat previous approaches in precision, accuracy, and data set size.

In Hamsagayathri and Sampath [29], the Priority-based decision tree classifier technique is implemented for the Wisconsin Breast cancer dataset in this research effort. This research examines the various decision tree classifier techniques for its original, prognostic, and diagnostic datasets using WEKA software. The Kappa statistic, Accuracy, Precision, Specificity, Recall, Sensitivity, RMSE, Entropy, TP Rate, F-Measure, FP Rate, and ROC are used to assess the classifiers' performance. Giving to simulation findings, the REP Tree classifier categorizes data with an accuracy of 93.63% and a minimum of 0.1628 RMSE. In addition, the RE P-Tree algorithm takes less time to develop the model, with 0.959 PRC and 0.929 ROC values. It is affirmed that the REP Tree technique is has a better performance compared to other algorithms for the SEER dataset by comparing sorting results.

Ponnuraja et al. [30] the goal is to examine the prediction results of a decision tree algorithm that uses age categorization to categorize breast cancer patients (both male and female). The work anticipated that in the age group 42–52 years, the mortality rate of female breast cancer patients was 95.1% using our approach, together with additional risk variables. Male and female predictors and risk factors are achieved in the same way. The decision tree method yields a path with the 96.4% survival rate (highest) and the 96.4% death rate (highest). (95.1%). Logistic regression is used to cross-validate the outcome. Male and female patients of breast cancer in the age categories (42) and (42–52) are classified as greatly risky. The method proposed aids doctors in identifying high-risk groups and planning patient care accordingly.

In Nurhayati, et al. [31], PSO was employed as a feature selection to enhance the performance of SVM, Logistic Regression, Naïve Bayes, KNN, and Decision Tree. In addition, the classification technique was employed as a classifier to determine the suitability size. PSO's performance is also compared to that of a newly developed method, the Genetic Algorithm. PSO is shown to increase the performance of many classification algorithms using medical data from the UCI Breast Cancer Dataset. PSO, on the other hand, is unable to outperform the Genetic Algorithm in terms of feature selection.

Kapil and Rana [32] recommended an updated decision tree methodology as a decision tree augmented by weight and applied it on WBCD and another dataset of breast cancer obtained from the UCI repository. They found that they ranked each function using the Chi-square test and maintained the appropriate features for this classification assignment. Their suggested methodology achieved approximately 99% precision for the WBCD dataset, although it obtained approximately 85–90% precision for the breast cancer dataset.

The Naïve Bayes, J48 Decision Tree, and RBF techniques were used on the WBCD dataset by Chaurasia et al. [33]. WEKA version 3.6.9 was used as an analysis tool. They reached an NB accuracy of 97.36%, 93.41% J48 Decision Tree, and an accuracy of 93.41% for RBF, correspondingly.

Hasan et al. [24] devised a statistical model that focuses on the symbolic regression of multi-gene genetic programming in the prediction of cancer of the breast. The ten-fold method is intended to discourage overfitting. It shows a quantitative analysis as well. The stop criteria were established for the model; however, the generation level was not higher than zero. The model has obtained a precision of 99.28% with a precision rate of 99.26%.

Yue et al. [34] In the application of forecasting cancer of the breast on the WBCD benchmark dataset, detailed analyses of K-NNs, SVM, Decision Tree, and ANNs techniques were primarily illustrated. According to the scientists, the more reliable result was provided by the deep belief networks (DBNs) method of ANN construction (DBNs-ANNs). 99.68% accuracy was obtained by this architecture, while the SVM approach and a two-step prediction model achieved 99.10% classification precision for the SVM process. They also analyzed the technique ensemble in which the voting technique was used to incorporate SVM, Naïve Bayes, and J48. 97.13% precision was obtained by the ensemble process.

Aruna et al. [35] used the decision trees, naïve Bayes, and SVM to characterize a dataset of Wisconsin breast cancer and achieved the highest result with an accuracy score of 96.99% using the SVM.

Vard et al. [36] analyzed a rigorous technique for forecasting eight types of cancer, such as ovarian cancer, cancer of the breast, and prostate cancer, First, they used PSO in their study to normalize datasets and methods of computational feature extraction to distinguish attributes on a structured dataset. For classifications, they then applied a multilayer perceptron neural network, SVM, and decision tree.

Wang et al. [37] researched the best way to find cancer of the breast predictions with data mining techniques on multiple files. SVM, ANN, Bayes nave classifier, and AdaBoost Tree were used. The problem of reducing the function's space was addressed, so Principal Component Analysis (PCA) was used to diminish it. In the assessment section of the model results, they used two databases: the Wisconsin Diagnostic and Breast Cancer Database. They gave a thorough models analysis and test failures.

Kourou et al. [38] studied the breakdown of the risk categories for cancer patients into two forms, little and high. SVM, Bayesian networks (BNs), ANN, and decision tree (DT), approaches were applied to develop a model for cancer dangers or patient results.

Azar et al. [39] suggested using Decision Tree variants to build a method to predict breast cancer. The modes used in this approach are the Decision Tree Forest (DTF) and Boosted Decision Tree (BDT), and Single Decision Tree (SDT). After that, the conclusion is occupied by practicing and reviewing the data collection. The accuracy obtained by BDT and SDT is 98.83% 97.07%, respectively, during the training phase, suggesting that BDT performs better. In the testing phase, the decision tree forest was 97.51% reliable, while SDT was 95.75% correct. The dataset was generated using a ten-fold cross-validation method.

Banu and Subramanian [40] have highlighted Naïve Bayes breast cancer prediction approaches and compared analyses for Bayes, the Bayes Belief Network (BBN), and the Tree Augmented Naïve Bayes Bayes Buildings (TAN). They utilized SAS-EM to implement the models (Statistical Analytical Applications Business Miner). The same WBCD dataset is used in their study. Their results have shown that with the help of gradient, Bbn, BAN, and TAN have achieved a precision of 91.7%, 91.7%, and 94.11% correspondingly. Consequently, the analysis reveals that Tree Augmented Naïve Bayes (TAN), among Naïve Bayes methods, is the best classifier for this dataset.

Amit and Chinmay [41], worked on smart ant colony optimization wireless personal communications, for Task Offloading in Fog Computing. Inactivity is the main issue in cloud computing applications. Fog computing is a technique for resolving the issues mentioned above in cloud computing. In time-sensitive real-time IoT-sensor applications, fog computing meets the low-latency requirement of QoS. As a result, various fog nodes compute the tasks of IoT-sensor applications. A meta-heuristic scheduler called Smart Ant Colony Optimization (SACO) task offloading procedure is proposed in this paper to offload IoT-sensor application tasks in a fog environment. The results were compared and the technique reduces task offloading period by 13%, 7%, 6%, then 4%.

Sachin et al., [42] provided an image steganography approach that uses a variety of algorithms to secure the secret data using a Binary bit-plane decomposition

(BBPD)-based picture encryption procedure. Following that, an adaptive embedding procedure based on the Salp Swarm Optimization Algorithm (SSOA) is developed to maximize payload capacity. The SSOA method is used to efficiently confined the edge and smooth blocks. The quality of the stego images is then improved using a Fuzzy Neural Network with a backpropagation knowledge technique. The stego pictures are then communicated to the destination using an IoT protocol that is highly secure.

Arindam et al., [43], worked on an advanced key conversation protocol that has been proposed using whale optimization-based neural synchronization. Intruders can easily tamper with crucial information by snuffling, hoaxing, phishing, or using a Man-In-The-Middle (MITM) attack during the exchange of sensitive statistics. The information must be sent securely with a high level of encoding while maintaining validation, secrecy, and veracity. As a result of these mentioned objectives, researchers are compelled to design a neural network-based, quick, and secure security procedure. For brain synchronization, a specific neural network topology termed the Double Layer Tree Parity Machine (DLTPM) is suggested. Two DLTPMs use the same input but have distinct weight vectors, then update the weights employing neural learning directions through trading output. It leads to perfect management in several steps, and the weights of the two DLTMs turn out to be identical. The secret key is made up of these identical weights. However, there is very little study in the field of optimizing neural weight vectors for quicker neural synchronization utilizing a nature-inspired technique. A whale optimization-based DLTPM is proposed in this article. This suggested DLTPM model employs a whale algorithm optimized weight vector for faster synchronization, secured, and faster. A series of parametric tests were performed on the proposed technique. The results were compared to some more recent methods. The proposed technique's results have proven that it is effective and has a strong potential.

Chinmay [44], worked on the Tele-wound network, by developing an effective filtering strategy for chronic wound pre-processing images. The goal of this study is to use enhanced image processing algorithms and suitable filtering to correctly assess the healing status of chronic wounds. Filtering techniques that are efficient help to minimize the noise in wound photos. Different settings are compared to illustrate the simulation results. Peak signal to noise ratio (PSNR), signal to noise ratio, mean square error (MSE) and mean absolute error is all performance measures. The outcome demonstrates adaptability. In terms of strong PSNR and lowered MSE between the unique and filtered image, median filtering outperforms. The PSO process is proposed in this paper for segmenting wound areas using a suitable color space selection. For chronic wound segmentation, the PSO procedure in the DB channel achieved 99% accuracy. The proposed Linear discriminant analysis classifier has an overall tissue prediction accuracy of 98%. The goal is to create a telemedicine background for wound analysis by enhancing the alliance among health specialists, patients, and telemedical managers from rural and city zones who are involved in providing upkeep to resolution the overdue treatment.

The summary of this study has shown that the results obtained using machine learning algorithms have suggested required novel improvements, hence this study proposes an enhanced PSO-decision tree model.

4.3 Methods and Materials

4.3.1 Dataset Description

The dataset was collected from the UCI machine-learning library. This dataset includes 699 cases, each of which is either benign or malignant. Four hundred and fifty-eight instances which are equivalent to (65.50%) of these cases are benign, while two hundred and forty-one instances which are equivalent to (34.50%) are malignant. The dataset's class is divided into 2 and 4 cases, where 4 corresponding to the malignant case and 2 corresponding to the benign case. The attributes are mentioned in Table 4.1 as part of the dataset.

Table 4.1 Attributes of the dataset

S/N	Attributes	Description	Domain
1	Class	An indication of a tumor kind	2 (benign) 4 (malignant)
2	Clump thickness	Multilayers of cancerous cells are common, but mono-layers of benign cells are common.	1–10
3	Uniformity of cell size	Cancer cells come in a variety of sizes and shapes.	1–10
4	Uniformity of cell shape	Cancer cells come in a variety of sizes and shapes.	1–10
5	Marginal adhesion	Normal cells tend to conjoin, whereas malignant cells do not.	1–10
6	Single epithelial cell size	Enlarged epithelial cells could be cancerous cells.	1–10
7	Bare nuclei	The nuclei of benign tumors are frequently not bound by the rest of the cell.	1–10
8	Bland chromatin	In benign cells, the nucleus quality	1–10
9	Normal nuclei	In normal cells, the nucleus is a tiny structure that is hardly visible.	1–10
10	Mitoses	Cell division is the process by which cells divide.	1–10

4.3.2 Training and Testing Phase

75% of the dataset was used for training our model to extract features from the dataset while 25% was used for testing to know how appropriate the model behaves for prognosis.

4.3.3 Feature Selection

In machine learning, classification is an important activity that seeks to arrange each entry in the data grouped into diverse classes founded on the data represented by its characteristics. It is hard to decide which characteristics are useful without prior knowledge. Therefore, several functions, including important, irrelevant, and redundant features, are typically added to the data collection. On the other hand, irrelevant and redundant characteristics are unsuitable for classification and can also degrade classification efficiency due to the vast search space identified as “the curse of dimensionality” [45]. This problem can be solved using feature filtering, which selects only the most important features for classification. Variable selection, also known as function selection, decreases functions, time reductions, the accuracy of classification by removing or reducing unnecessary and redundant characteristics [46, 47].

Feature selection is the procedure of choosing significant characteristics for the classification task. The outcomes of the feature selection are utilized to advance the classification’s performance. By eliminating some uninformative data, feature selection can help accelerate the learning process [33]. The feature selection procedure is performed during the preprocessing stage before the classification procedure. Thus, feature selection reduces the number of feature subsets and lowers training expenses.

Feature selection, attribute selection, or variable subset selection are terms used in machine learning and statistics to describe the procedure of choosing a subset of specific features (variables, predictors) for utilization in model building. The PSO algorithm is used to pick features in this analysis.

4.3.4 PSO Feature Selection

Following the data loading in a CSV file, a feature selection approach was used, a particle swarm optimization technique mentioned in the literature study. A set of features with a lower number than the original feature has been formed due to this selection. Features that have been removed are those that are no longer relevant [48].

4.3.5 Particle Swarm Optimization

Kennedy and Eberhart suggested the Particle Swarm Optimization procedure in 1995 as a result of their research into bird predation activity. The procedure is easy to use, and the rules are straightforward. Each particle has a fitness value derived by the fitness function, and each particle's position is a potential solution. Position, fitness and velocity, value are the three attributes of each particle. It's a good algorithm for dealing with feature selection issues because:

1. easy encoding of a feature
2. global search facility
3. reasonable computationally
4. fewer parameters, and more straightforward implementation.

For the reasons mentioned above, the PSO is used to choose features. The principal space is the search space in which PSO was used to discover and pick a subset of principal components or core features. The particles in PSO represent candidate solutions in the quest space and form a population, also known as a swarm.

Pseudocode for PSO

1. Initialize population sample
2. Evaluate fitness
3. Compare each fitness particle assessment to the existing P-best particles
4. Compare the assessment of fitness with the general best prior population to get G-best
5. Update steps (4) and (2)
6. If the ending condition has not been satisfied, go to step 2
7. End

4.3.6 Decision Tree

The decision tree is primarily used in sequential decision problems to identify, forecast, and promote decision-making. In some depth, this approach involves three kinds of decision trees [49]. The first is an algorithm based on a series of knowledge nodes for a recommended course of action; the second is classification and regression trees, and the third is survival trees [50]. There are two elements to the decision tree algorithm: tests (rules) and nodes. The primary idea behind this technique is to create a flow chart with a root node at the top. Until you reach a leaf node, all remaining (non-leaf) nodes denote a test of a sole or several qualities (final result). Because of their strength as classification tools, in data mining use, decision tree algorithms are frequently utilized [51]. Some of the most critical explanations why decision trees are utilized in classification and data mining are listed: Decision trees are one of the most user-friendly algorithms in data mining since they create intelligible rules. They establish linkages between dataset attributes clearly and understandably. The importance of essential qualities is indicated through decision trees, which is an important aspect of building rules between attributes. Each one's level, when comparing with other categorization techniques, such as scientific equations, decision trees require less computing. Decision trees are authoritative classification techniques that are becoming increasingly popular considering advancing information systems and data mining. As the name says, this approach recursively separates observations to improve prediction accuracy; branches are used to form a tree. The root, internal, and leaf nodes make up the structure of a decision tree. Unknown data records are classified using the tree structure. For decision tree induction, several algorithms have been suggested.

A decision tree is a graphical model that depicts choices and their future consequences. Three types of nodes consist of decision trees [52].

1. Node of decision: sometimes represented by squares displaying choices that can be made. Both distinct choices available at a node are displayed by lines originating from a rectangle.
2. Node of chance: Often represented by circles displaying the effects of chance. Chance effects are incidents that may arise but are beyond the decision-capacity makers to control.
3. Terminal node: sometimes represented by triangles or lines with no additional decision nodes or nodes of chance. Terminal nodes represent the effects of the decision-making process.

4.3.6.1 How Does the Decision Tree Work?

The decision to divide a forest into strategic divisions has a significant impact on its accuracy. The judgment parameters for classification and regression trees are different. Decision arbors utilize several techniques to assess if a node could split into at least two or more sub-nodes. The development of sub-nodes enhances homogeneity. In other words, we may infer that the pureness of the node improves concerning the target variable. The decision tree separates the nodes into every variable and then selects the split, resulting in a homogenous majority of the sub-nodes.

4.3.6.2 Proposed System

Figure 4.1 shows the proposed system flow. Firstly, we load the raw data, then apply feature selection using the PSO algorithm, and then apply the decision tree classifier to the reduced dataset, select and training, and testing the dataset and then the result is obtained.

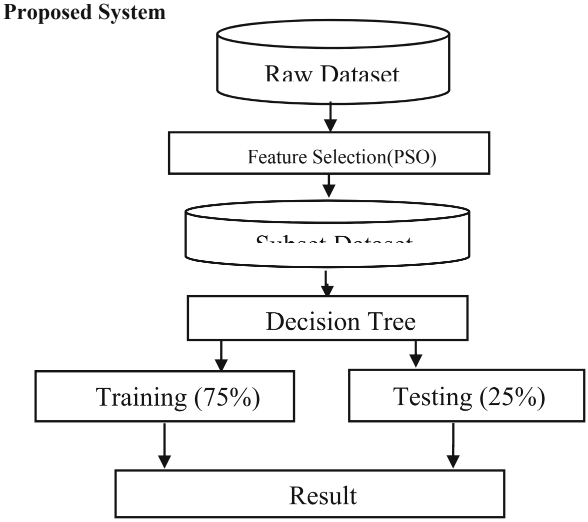


Fig. 4.1 The system flow diagram adopted for this study

4.3.7 Performance Evaluation

The assessment of performance is an integral fragment of the machine learning procedure. The three main subtasks of evaluation are examined: measuring performance, resampling data, and determining the statistical significance of the results. Performance evaluation is of great significance because it shows how well the model is behaving and shows its effectiveness and efficiency. There are various performance methods in machine learning, but this research made use of the following performance metrics, namely: Precision, Accuracy, Sensitivity, Specificity, Recall, F-score, False acceptance rate, Error rate, False rejection rate. The following metrics were selected because they are the most reliable techniques when it comes to working with the clinical dataset, such as the breast cancer dataset used for analyses (Table 4.2).

4.4 Results and Discussion

The observations gained from implementing the proposed method were explored in this section, with several interfaces showing the effects. In analyzing and comparing this analysis with previous studies, this section has already been included.

Table 4.2 Performance metrics with its significance (Role or meaning)

S/N	Performance metrics	Significance
1	Precision	This is a relevant measure-retrieved example.
2	Accuracy	The most basic scoring factor is ACCURACY. It works out the percentage of cases that are properly categorized.
3	Sensitivity	The sensitivity score, also known as the recall or true positive, indicates how likely a sample with breast cancer characteristics would result in a positive test result
4	Specificity	The specificity, also known as the true negative, refers to a classifier's ability to recognize negative outcomes.
5	Recall	Is a metric that measures the no of true positives forecast from the total no of positives in the dataset. It's also known as sensitivity.
6	F-score	It's a metric for assessing a model's precision and recall
7	Error rate	Which is the rate of times the forecast is incorrect
8	False acceptance rate	This happens when we admit a user that we should have refused in the first place.
9	False rejection rate	This happens when we refuse a user that should have been approved in the first place.

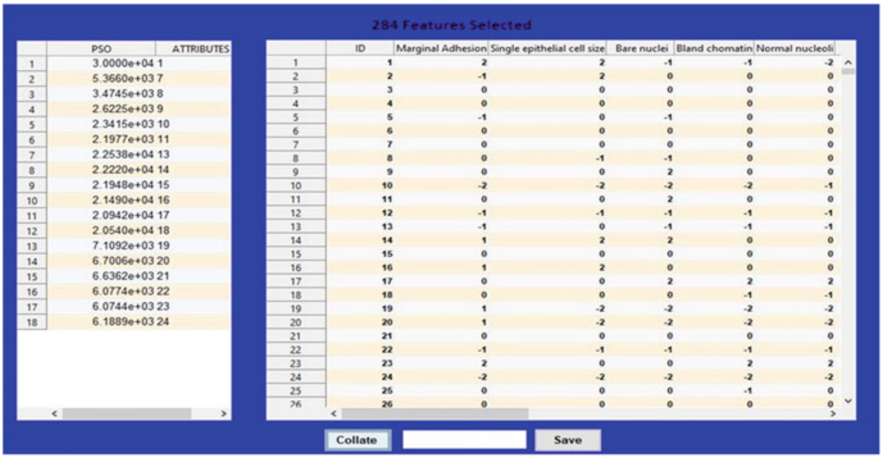


Fig. 4.2 Feature selection using PSO

4.4.1 *Results*

Figure 4.2 shows the loaded breast cancer data processing using the Particle Swarm Optimization function selection algorithm. In the feature selection mode, features are selected using the PSO. The 699 observations were reduced to 284 entities after applying PSO; Fig. 4.2 shows the selected features. The obtained result output saved was passed into the classifiers in further analysis.

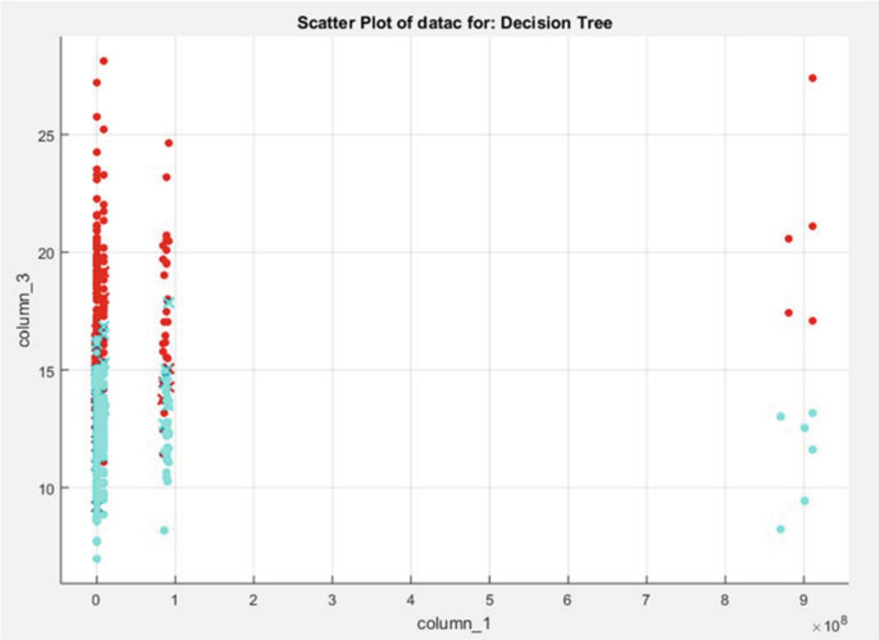


Fig. 4.3 Scattered plot for PSO and DT

Figure 4.3 depicts the preferred function and its distribution throughout the narrative. Instances are more evenly distributed across columns 0 and 1 and sparingly distributed between columns 8 and 9. There are no misfit instances between columns 8 and 9.

Figure 4.4 shows the receiver operating characteristic curve; this represents the DT classifier performance in the entire classification thresholds. Two parameters are plotted on this curve: And the true positive rate axis is higher than the false positive rate axis. The curve starts from zero (0) at the false-positive axis to one (1) at the same axis.

Figure 4.5 shows the confusion matrix result for the classified components extracted using PSO and DT techniques. The True positive yields 184, false-negative yields 18 likewise false-positive yields 26, and true negative yields 341 TP = 184 FP = 26 TN = 341 FN = 18. The nine following performance metrics were used: Detailed formula and workings are shown below:

In this work, PSO and DT were used to predict the presence of cancer of the breast in a woman using online clinical data. As seen in Table 4.3, the result was 92.26% accuracy. This thesis will aid clinicians in their decision-making process by analyzing the data examination using machine learning perspectives. However, there are still several issues with the data available, and sufficient genetic information is needed to help predict and identify chronic diseases. In addition, the predictive correctness of models is critical for hospitals and networks of infected patients.

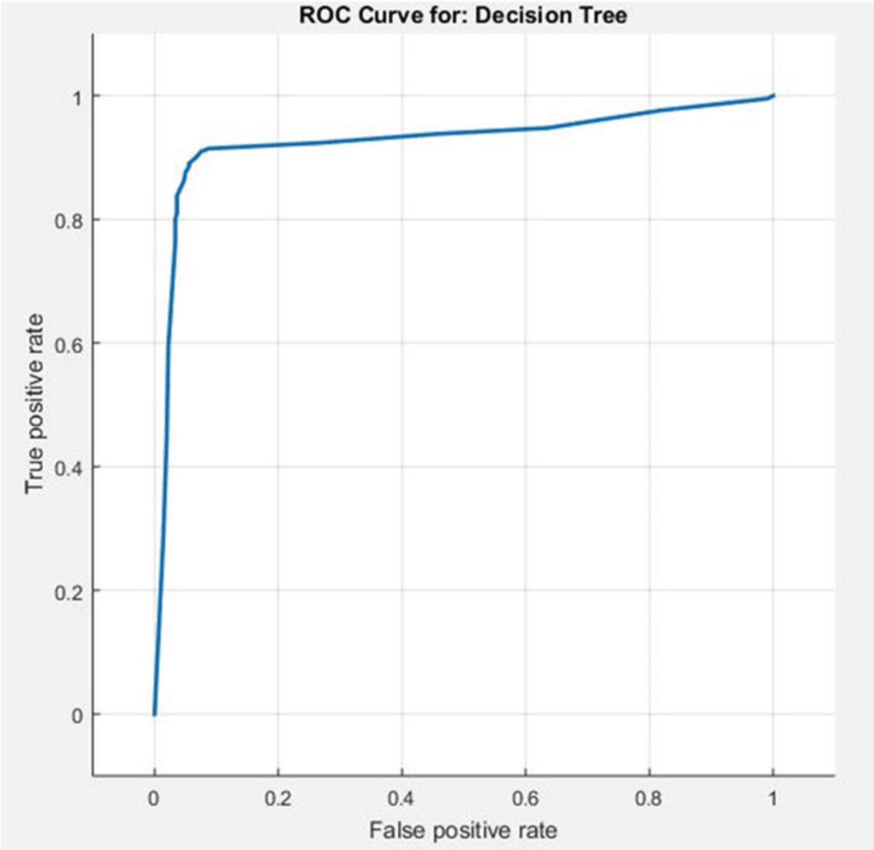


Fig. 4.4 ROC curve for DT

The proposed system performed better to detect breast cancer ailment with an accuracy of 92.26% compared with previous research. For instance, Musa et al., 2020 had an accuracy of 87.3% using only a DT as the classifier, Silva et al., 2019 made use of four classifiers, namely: NB, SVM, GRNN, and J48, for prediction and had an accuracy of 91%, Lavanya et al., 2011 used DT algorithm and got an accuracy of 71.32%. Furthermore, Mohammed et al. 2020 made use of three algorithms as well, which are J48, NB & SMO and had 75.52% accuracy, and lastly, Pritom et al., 2016 employed the NB, C4.5, and SVM for prediction and had an accuracy of 75.75%, As shown in Table 4.4, the proposed system used two algorithms which are PSO and DT, and outperformed those researchers that used even more than one classifier.

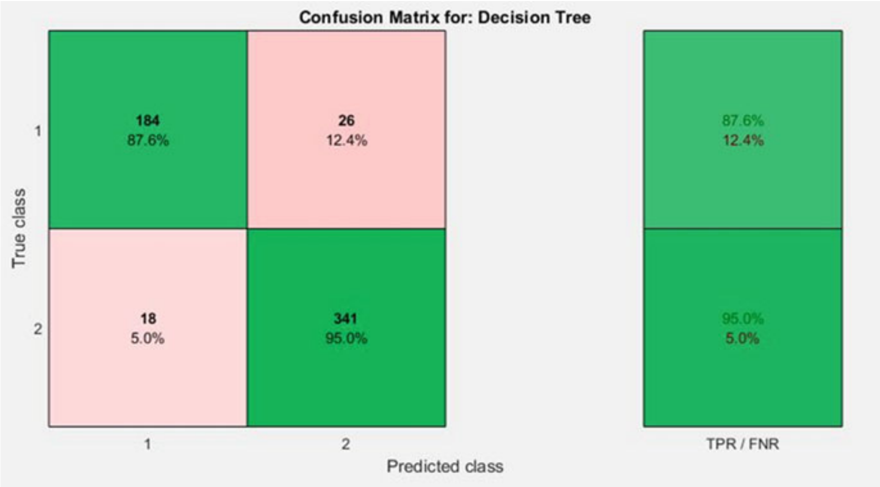


Fig. 4.5 Confusion matrix for DT

Table 4.3 Investigational results

S/N	Performance measures	Values
1	Accuracy	92.26%
2	Sensitivity	91.08%
3	Specificity	92.91%
4	Precision	87.06%
5	F-score	89.32%
6	Recall	91.08%
7	Error rate	0.217
8	False acceptance rate	0.0724
9	False rejection rate	0.08910

Table 4.4 Comparative analysis

Authors & Year	ML method used	Accuracy
Musa & Aliyu [20]	DT	87.3%
Silva et al. [13]	NB, SVM, GRNN and J48	91%
Lavanya & Rani [53]	DT	71.32%
Mohammed et al. [54]	J48, NB & SMO	75.52%
Pritom et al. [48]	NB, C4.5, SVM	75.75%
Proposed system	PSO + DT	92.26%

4.5 Conclusion

Machine learning techniques have been extensively used in several studies, especially for medical applications. In this study, machine learning algorithms using the PSO feature selection algorithm and Decision tree machine learning classifier were applied for breast cancer detection from the UCI repository. The PSO has been of great significance as a feature selecting tool for generating more effective results according to exclusive literature review. The study achieved 92.26% accuracy and was related to the state-of-the-art. However, this research proves to be efficient and can be beneficial for decision-making. In the future, this study suggests a hybridized approach with PSO to enhance the classification performance further in terms of evaluation metrics such as accuracy among others, and compare the performance with classifiers such as SVM and KNN.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Park, S. H., & Han, K. (2018). Methodologic guide for evaluating clinical performance and effect of artificial intelligence technology for medical diagnosis and prediction. *Radiological Society of North America, 286*(3), 800–809.
2. Darrab, S., & Ergenc, B. (2017). Vertical pattern mining algorithm for multiple support thresholds. In: International Conference on Knowledge-Based and Intelligent Information and Engineering (KES). *Procedia Computer Science, 112*, 417–426. Google Scholar.
3. Darrab, S., & Ergenc, B. (2016). Frequent pattern mining under multiple support thresholds, the International Conference on Applied Computer Science (ACS). *Wseas Transactions on Computer Research, 4*, 1–10. Google Scholar.
4. Mori, M., Akashi-Tanaka, S., Suzuki, S., Daniels, M. I., Watanabe, C., Hirose, M., & Nakamura, S. (2016). Diagnostic accuracy of contrast-enhanced spectral mammography in comparison to conventional full-field digital mammography in a population of women with dense breasts. *Breast Cancer, 24*(1), 104–110. Springer.
5. World Health Organization. (2014). *WHO position paper on mammography screening*. World Health Organization.
6. Breast Cancer: Statistics, Approved by the Cancer.Net Editorial Board, 04/2017. [Online]. Retrieved August 26, 2018, from http://www.cancer.net/cancer-types/breast-cancer/statistics.
7. Pantel, P. (1998). *Breast cancer diagnosis and prognosis*. University of Manitoba.
8. You, H., & Rumbe, G. (2010). Comparative study of classification techniques on breast cancer FNA biopsy data. *International Journal of Artificial Intelligence and Interactive Multimedia, 1*(3), 6–13.
9. Kamel, S. R., Yaghoub Zadeh, R., & Kheirabadi, M. (2019). Improving the performance of the support-vector machine by selecting the best features by gray wolf algorithm to increase the accuracy of diagnosis of breast cancer. *Journal of Big Data, 6*, 90. https://doi.org/10.1186/s40537-019-0247-7
10. Chinmay, C., & Arij, N. A. (2021). Intelligent internet of things and advanced machine learning techniques for COVID-19. *EAI Endorsed Transactions on Pervasive Health and Technology, 1-14*. https://doi.org/10.4108/eai.28-1-2021.168505

11. Kononenko, I. (2001). Machine learning for medical diagnosis: History, state of the art and perspective. *Artificial Intelligence in Medicine, 23*(1), 89–109.
12. Sakri, S. B., Rashid, N. B. A., & Zain, Z. M. (2018). Particle swarm optimization feature selection for breast cancer recurrence prediction. *IEEE Access, 6*, 29637–29647.
13. Silva, J., Lezama, O. B. P., Varela, N., & Borrero, L. A. (2019). Integration of data mining classification techniques and ensemble learning for predicting the type of breast cancer recurrence. In R. Miani, L. Camargos, B. Zarpelão, E. Rosas, & R. Pasquini (Eds.), *GPC 2019, LNCS* (Vol. 11484, pp. 18–30). Springer. https://doi.org/10.1007/978-3-030-19223-5_2
14. Borges, L. (2015). *Analysis of the Wisconsin breast cancer dataset and machine learning for breast cancer detection*. Conference: Workshop de Visão Computacional.
15. Ahmed, M. T., Imtiaz, M. N., & Karmakar, A. (2020). Analysis of Wisconsin breast cancer original dataset using data mining and machine learning algorithms for breast cancer prediction. *Journal of Science, Technology and Environment Informatics, 09*(02), 665–672.
16. Asri, H., Mousannif, H., Al Moatassime, H., & Noel, T. (2016). Using machine learning algorithms for breast Cancer risk prediction and diagnosis. *Procedia Computer Science, 83*, 1064–1069. https://doi.org/10.1016/j.procs.2016.04.224
17. Kumar, V., Mishra, B. K., Mazzara, M., Thanh, D. N., & Verma, A. (2020). Prediction of malignant and benign breast cancer: A data mining approach in healthcare applications. *Advances in Data Science and Management, 2020*, 435–442. https://doi.org/10.1007/978-981-15-0978-0_43
18. Ojha, U., & Goel, S. (2017). A study on prediction of breast cancer recurrence using data mining techniques. In *7th International Conference on Cloud Computing, Data Science & Engineering – Confluence* (pp. 527–530). IEEE.
19. Srikanth, K., Zahoor, S., Huq, U., & Kumar, A. P. S. (2019). Analysis, implementation, and comparison of machine learning algorithms on breast Cancer dataset using WEKA tool. *International Journal of Recent Technology and Engineering (IJRTE), 7*(6S).
20. Musa, A. A., & Aliyu, U. M. (2020). Application of machine learning techniques in predicting of breast Cancer metastases using decision tree algorithm, in Sokoto northwestern Nigeria. *Journal of Data Mining in Genomics & Proteomics, 11*, 220. https://doi.org/10.35248/2153-0602.20.11.220
21. Ganggayah, M. D., Taib, N. A., Har, Y. C., et al. (2019). Predicting factors for survival of breast cancer patients using machine learning techniques. *BMC Medical Informatics and Decision Making, 19*, 48. https://doi.org/10.1186/s12911-019-0801-4
22. Higa, A. (2018). Diagnosis of breast Cancer using decision tree and artificial neural network algorithms. *International Journal of Computer Applications Technology and Research, 7*(1), 23–27.
23. Bellaachia, A., & Guven, E. (2010). *Predicting breast cancer survivability using data mining techniques*. Department of Computer Science, The George Washington University.
24. Hasan, M. K., Islam, M. M., & Hashem, M. M. A. (2016). Mathematical model development to detect breast cancer using multi-gene genetic programming. In *Proceedings of 5th International Conference on Informatics, Electronics, and Vision (ICIEV)* (Vol. 2016, pp. 574–579). Khulna University of Engineering & Technology.
25. Sumbaly, R., Vishnusri, N., & Jeyalatha, S. (2014). Diagnosis of breast cancer using decision tree data mining technique. *International Journal of Computer Applications, 98*(10), 16–24.
26. Saputra, R. H., & Prasetyo, B. (2020). Improve the Accuracy of C4.5 Algorithm Using Particle Swarm Optimization (PSO) feature selection and bagging technique in breast cancer diagnosis. *Journal of Soft Computing Exploration, 1*, 1.
27. Park, E. Y., Yi, M., Kim, H. S., & Kim, H. (2021). A decision tree model for breast reconstruction of women with breast cancer: A mixed method approach. *International Journal of Environmental Research and Public Health, 18*(7), 3579. https://doi.org/10.3390/ijerph18073579

28. Bhise, S., Gadekar, S., Gaur, A. S., Bepari, S., & Deepmala Kale, D. S. A. (2021). Breast cancer detection using machine learning techniques. *International Journal of Engineering Research & Technology (IJERT), 10*, 7.
29. Hamsagayathri, P., & Sampath, P. (2017). Decision tree classifiers for classification of breast cancer. *International Journal of Current Pharmaceutical Research, 9*(2), 31. https://doi.org/10.22159/ijcpr.2017v9i1.17377
30. Ponnuraja, C., Lakshmanan, B. C., Srinivasan, V., & Prasanth, B. K. (2017). Decision tree classification and model evaluation for breast cancer survivability: A data mining approach. *Biomedical and Pharmacology Journal, 10*(1), 281–289. https://doi.org/10.13005/bpj/1107
31. Nurhayati, Agustian, F., & Lubis, M. D. I. (2020). Particle swarm optimization feature selection for breast cancer prediction. In *2020 8th International Conference on Cyber and IT Service Management (CITSM)* (pp. 1–6). IEEE. https://doi.org/10.1109/CITSM50537.2020.9268865
32. GPC. (2019). Pervasive, and cloud computing. In *Lecture notes in computer science* (Vol. 11484). Springer. https://doi.org/10.1007/978-3-030-19223-5_2
33. Chaurasia, V., Pal, S., & Tiwari, B. (2018). Prediction of benign and malignant breast cancer using data mining techniques. *Journal of Algorithms & Computational Technology, 12*(2), 119–126.
34. Yue, W., et al. (2018). Machine learning with applications in breast cancer diagnosis and prognosis. *Designs, 2*(2), 13.
35. Aruna, S., Rajagopalan, S., & Nandakishore, L. (2011). Knowledge-based analysis of various statistical tools in detecting breast cancer. *Journal of Computer Science and Information Technology, 2*, 37–45.
36. Vard, A., Firouzabadi, F., Sehhati, M., & Mohebian, M. (2018). An optimized framework for cancer prediction using immune signature. *Journal of Medical Signals and Sensors, 8*, 161. https://doi.org/10.4103/jmss.JMSS_2_18
37. Wang, H., & Yoon, W.S. (2015). Breast cancer prediction using data mining method. In *Proceedings of the 2015 Industrial and Systems Engineering Research Conference*. Nashville, TN, USA. 30 May–2 June 2015. [Google Scholar].
38. Kourou, K., Exarchos, T. P., Exarchos, K. P., Karamouzis, M. V., & Fotiadis, D. I. (2015). Machine learning applications in cancer prognosis and prediction. *Computational and Structural Biotechnology Journal, 13*, 8–17. https://doi.org/10.1016/j.csbj.2014.11.005
39. Azar, A. T., & El-Metwally, S. M. (2012). Decision tree classifiers for automated medical diagnosis. *Neural Computing and Applications, 23*(7–8), 2387–2403.
40. Banu, A. B., & Subramanian, P. T. (2018). Comparison of Bayes classifiers for breast cancer classification. *Asian Pacific Journal of Cancer Prevention (APJCP), 19*(10), 2917–2920.
41. Amit, K., & Chinmay, C. (2021). Task offloading in fog computing using smart ant colony optimization. In *Wireless personal communications* (pp. 1–22). Springer. https://doi.org/10.1007/s11277-021-08714-7
42. Sachin, D., Chinmay, C., Jaroslav, F., Rashmi, G., Arun, K. R., & Subhendu, K. P. (2021). SSII: Secured and high-quality steganography using intelligent hybrid optimization algorithms for IoT. *IEEE Access, 9*, 1–16. https://doi.org/10.1109/ACCESS.2021.3089357
43. Arindam, S., Mohammad, Z. A., Moirangthem, M. S., Abdulfattah, N., Chinmay, C., & Subhendu, K. P. (2021). Artificial neural synchronization using nature inspired whale optimization. *IEEE Access, 9*, 16435–16447. https://doi.org/10.1109/ACCESS.2021.3052884. ISSN: 2169-3536.
44. Chinmay, C. (2017. ISSN: 0929-6212). Chronic wound image analysis by particle swarm optimization technique for tele-wound network. *Springer: International Journal of Wireless Personal Communications, 96*(3), 3655–3671. https://doi.org/10.1007/s11277-017-4281-5
45. Gheyas, I. A., & Smith, L. S. (2010). Feature subset selection in large dimensionality domains. *Pattern Recognition, 43*(1), 5–13. https://doi.org/10.1016/j.patcog.2009.06.009
46. Unler, A., & Murat, A. (2010). A discrete particle swarm optimization method for feature selection in binary classification problems. *European Journal of Operational Research, 206*(3), 528–539. https://doi.org/10.1016/j.ejor.2010.02.032

47. Muhammad, S., Javeria, A., Nadia, G., Seifedine, K., & Chinmay, C. (2021). Quantum machine learning architecture for COVID-19 classification based on synthetic data generation using conditional adversarial neural network (CGAN). *Cognitive Computation*, 1–12, doi: https://doi.org/10.1007/s12559-021-09926-6.
48. Pritom, A. I., Munshi, M. A. R., Sabab, S. A., & Shihab, S. (2016). Predicting breast cancer recurrence using effective classification and feature selection technique. In *19th International Conference on Computer and Information Technology (ICCIT)* (pp. 310–314). IEEE.
49. Hastie, T., Tibshirani, R., & Friedman, J. (2001). *The elements of statistical learning*. Springer.
50. Dey, N. (2019). *Classification techniques for medical image analysis and computer-aided diagnosis*. Academic Press.
51. Shrivastava, S., Sant, A., & Aharwa, R. (2013). An overview on data mining approach on breast Cancer data. *International Journal of Advanced Computer Research, 3*(4), 2249–7277.
52. Berry, M. J., & Linoff, G. S. (2008). Mastering data mining: The art and science of customer relationship management. *Industrial Management & Data Systems, 100*(5), 245–246.
53. Lavanya, D., & Rani, K. (2011). Performance evaluation of decision tree classifiers on medical datasets. *International Journal of Computer Applications, 26*(4), 1–4. https://doi.org/10.5120/3095-4247
54. Mohammed, S. A., Darrab, S., Noaman, S. A., & Saake, G. (2020). Analysis of breast cancer detection using different machine learning techniques. In Y. Tan, Y. Shi, & M. Tuba (Eds.), *Data mining and big data. DMBD 2020* (Communications in computer and information science) (Vol. 1234). Springer. https://doi.org/10.1007/978-981-15-7205-0_10

Part II
AI in Healthcare

Chapter 5
Accountable, Responsible, Transparent Artificial Intelligence in Ambient Intelligence Systems for Healthcare

Ioannis Vourganas, Hani Attar, and Anna Lito Michala

Abstract The future due to various socioeconomic reasons will demand an increased need for the extension of rehabilitation in home environments. However, due to the rapid development of the Ambient Intelligent (AmI) systems, various solutions through different approaches could solve problems which have concerned the health industry. However, AmI approaches due to complexity and multidisciplinarity should utilize the right tools in order to become a successful solution in the health sector. AmI consists of two main components. The hardware part which utilizes various sensors (wearable, ambient, contactless). This is combined with an AI part, which utilizes advanced Machine Learning algorithms. Successful AmI systems should follow various criteria. This chapter aims to review the required criteria for the integration of AmI into home-based health and care. A case study is reviewed, which combines and complies with several identified criteria. The system was tested with human subjects it was non-intrusive nor wearable, with a patient centric approach. The system demonstrated encouraging results with high accuracy. Moreover, Accountable, Reliable and Transparent AI was applied successfully to proact individualization and increase the level of trust. Although the AmI systems are promising, research is premature. More systematic research is needed for integration to the healthcare domain.

Keywords Ambient Intelligence · Accountable AI · Responsible AI · Transparent AI · Medical AmI · Home-based rehabilitation · Elder monitoring · Home rehabilitation

I. Vourganas (✉)
School of Design and Informatics, Abertay University, Dundee, UK
e-mail: i.vourganas@abertay.ac.uk

H. Attar
Faculty of Engineering, Department of Energy Engineering, Zarqua University, Zarqa, Jordan
e-mail: hattar@zu.edu.jo

A. L. Michala
School of Computing Science, University of Glasgow, Glasgow, UK
e-mail: annalito.michala@glasgow.ac.uk

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_5

5.1 Introduction to Ambient Intelligence

Nowadays, there is undoubtedly a rapid development of technology for rehabilitation and monitoring purposes. Advancements in intelligent healthcare systems bridge data collection with artificial intelligence and decision support systems. The number of new patients as well as the number of elder people who exploit the technological advancements is growing day by day. The main problem arises when various technologies either for monitoring or/and rehabilitation do not take under consideration the personality of the user. Each patient is different, and when the approach towards the use of any technology is "one solution to fit all patients" this might affect the rehabilitation progress of the patient [1].

Moreover, for monitoring purposes as well as for rehabilitation some of the users are not quite keen to use any technology which utilizes intrusive means [2]. Intrusive means are defined as the means which can affect or bridge the privacy of the user in any way, such as cameras.

Based on Ref. [1] there are two main categories of technologies for rehabilitation. The first is the one which is being used in the clinical environment and the second is being used for home rehabilitation and/or monitoring. The clinical approaches due to the involved cost which are neither offered or being approachable to all patients. On some occasions clinical approaches are being offered to the patient but for limited time and then the patient continues the rest of his therapy in his own environment [3, 4].

Various technologies for rehabilitation and monitoring could be categorized based on different criteria such as their way of approaching the rehabilitation and of course the technological aspects that they utilize. Particularly, the Ref. [1] identifies three main aspects which have been used for comparison of rehabilitation technologies. The first one is the level of motivation (Fig. 5.1). In other words, how motivated a user/patient feels in order to continue with his rehabilitation daily program. This is quite important especially for self-rehabilitation purposes. For

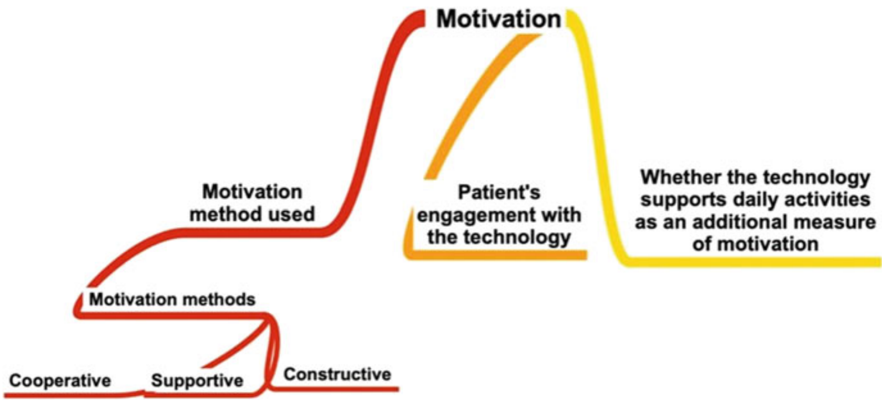


Fig. 5.1 Criteria for AmI to support motivation enhancement in medical applications

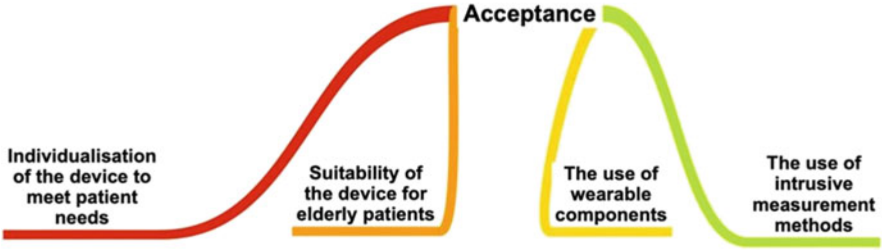


Fig. 5.2 Acceptance criteria for AmI in the field of medical applications

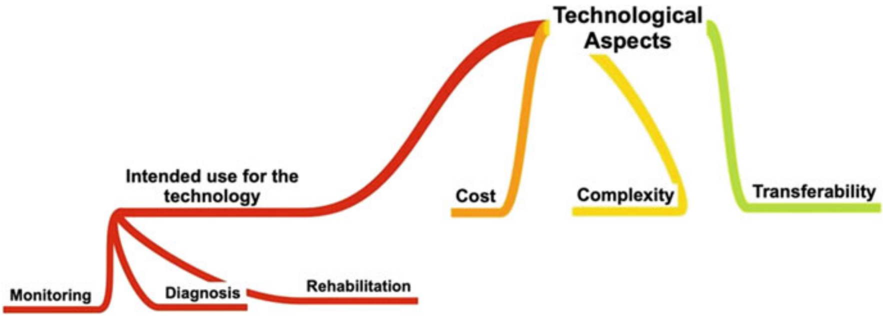


Fig. 5.3 Technological aspects affecting acceptance and motivation enhancement in medical applications and AmI

example, for stroke patients some of the systems for self-rehabilitation will be abandoned after 90 days of use [5]. Hence, long term therapy goals will be difficult to accomplish. The second aspect is acceptance of technology (Fig. 5.2). For example, for elder patients, latest technological advancements such as video games, or exoskeleton apparatus, might not be suitable [6]. Finally, the third aspect is the technological aspects (Fig. 5.3), for example indented use for the technology (monitoring, rehabilitation, diagnosis), cost and complexity.

At the moment in the market as well as for research purposes there are various systems for monitoring which contribute to diagnosis for critical illnesses such as dementia. For example, smart meters can identify patterns based on power consumption, they are able to understand user habits and through pattern analysis identify the beginning of a health condition [7]. However, although smart meters do not utilize any intrusive means most of the commercial systems do, which render them inappropriate for wide use due to privacy concerns [8].

The rest of the chapter is organized as follows. The remaining of this section will define the concepts discussed. In Sect. 5.2 applications of AmI in healthcare will be presented as well as a relevant case study, in Sect. 5.3 various challenges and opportunities of implementing AmI in various environments will be analyzed in depth. Section 5.4 will discuss the importance of Accountable, Reliable and Transparent Artificial Intelligence for AmI applications. In Sect. 5.5 advancements of

ART in AmI will be presented. The chapter will be concluded in Sect. 5.6. Following this discussion the main contributions of this chapter are:

- Reviewing the criteria and requirements for the successful implementation of AmI in healthcare
- Discussing of open challenges and opportunities in AmI for healthcare in respect to ART AI requirements.
- Demonstrating that ART AmI meets or even exceed the performance of state of the art systems that do not satisfy the ART design requirements.

5.1.1 What Is AmI?

Ambient Intelligence (AmI) is party of the Intelligent healthcare systems and expands in various healthcare applications, from remote surgeries to monitoring of elder patients in their home environment. In order to answer the question and maybe try to describe what Ambient Intelligence (AmI) is, a simple example would be useful for the reader. Imagine various sensors installed in a room (Fig. 5.4) and on user/patient which will be monitoring daily activities or rehabilitation progress. Then high-volume data from the sensors will be transferred using a communication protocol, (Zigbee, BLE, WiFi). Then all the data from the various sensors will be collected on a database. Further advanced statistical analysis, Artificial Intelligence (AI) or applied Machine Learning (ML) will be utilized in order to understand or monitor the behavior or progress of the users. Then all the processed information is sent to a Human Machine Interface (HMI) where all the results could be communicated to the user in a proper and well understood manner.

Hence, AmI provides a highly intelligent and highly interactive integrated environment. These are systems that are: embedded to the user's environment, intelligent to understand the surrounding environment of the user, tailored to the user's needs, able to be adapted, and able to anticipate a variety of user behaviors [1]. Figure 5.5 summarizes the ideal characteristics of such a system.

5.1.2 Why Is AmI Important?

AmI is quite important because it can bridge the gaps of various technological approaches. Although, for example it is difficult to offer a complete rehabilitation program, because it is integrated to the user's environment AmI can provide significant help by monitoring and transferring real time data [9] for example the progress of daily activities. Based on Ref. [1] the self-efficacy of the patients is increased when they are able to accomplish small daily tasks. For example, open the door, or close the window. This in turn increases the self-confidence which increases the motivation and the level of engagement with their rehabilitation process.

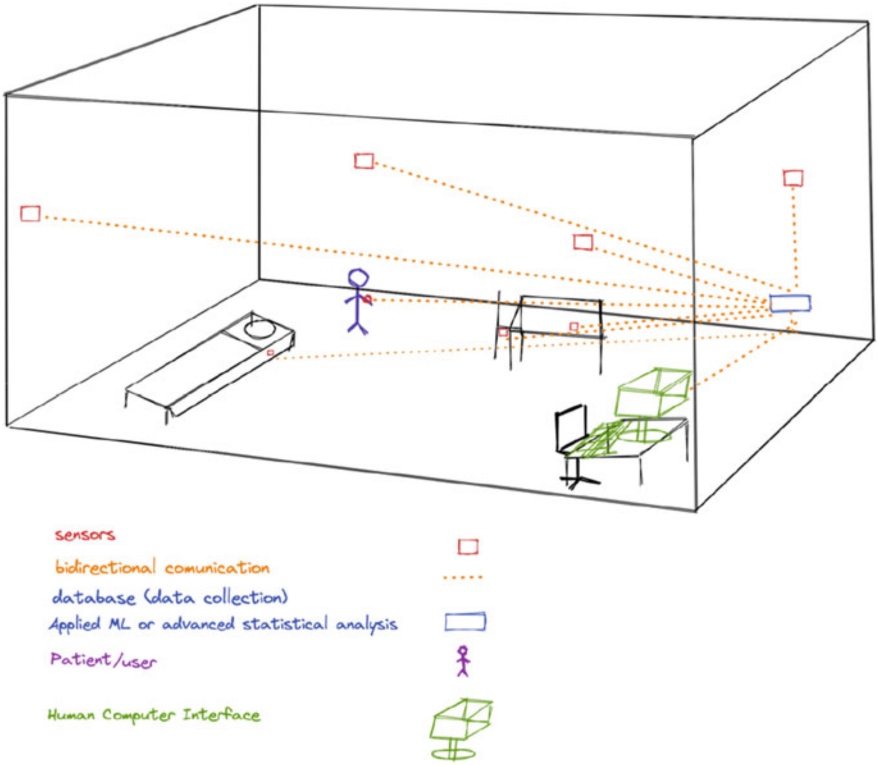
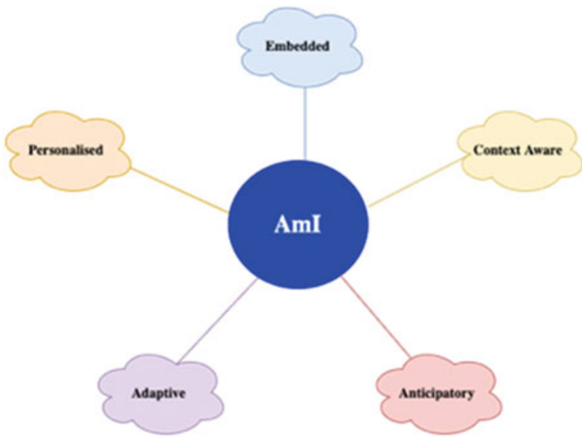


Fig. 5.4 An example AmI installation in the home environment including wearable sensors for patient monitoring

Fig. 5.5 Characteristics of the AmI ideal system



Moreover, through the utilization of ambient sensors, AmI can be widely used for monitoring purposes without employing intrusive or wearable means. Through a simple HMI, AmI systems are able to notify the users as well as the specialists regarding their progress. AmI for self-rehabilitation and in a home setting can help significantly through the massive data collection of the user's environment. Using this data, after advanced analysis and applied machine learning, AmI is able to learn the user's patterns and either help with a diagnosis of a comorbidity or probably help with the detection of an illness onset in early stages or provide a more tailored rehabilitation experience to the user by promoting the individualization of rehabilitation. AmI can work independently or complementary with other monitoring or rehabilitation systems [10, 11].

However, AmI systems are quite premature and further research is needed in order to identify their full capacity on monitoring and rehabilitation [12]. What is currently missing is a system which can maintain and combine high level of motivation and engagement by helping the individual through rehabilitation exercises to accomplish daily tasks. This system should not be either intrusive or wearable and it must be able to individualize given that the personality of people in need differs from one another. This system should be able to provide feedback in a simple and understandable manner, transferable along various illnesses and should be able to detect early stages of a comorbidity. Usually, the cost for several systems is associated proportionally with high level of complexity, thus more expensive systems tend to be more complex. Hence, the cost should be kept low in order to become approachable to more people in need [1].

5.2 Applications of AmI in Healthcare

AmI has been used in several environments in healthcare and on various applications. Although most of the results are quite promising due to the complexity and multidisciplinarity of AmI further research might be necessary on critical applications. Further evaluation of its usefulness as well as additional testing is needed. With the term critical it is meant applications of AmI in healthcare which is used in critical environments such as hospital's Intensive Care Units (ICU's) and during surgical procedures. Moreover, AmI is being used on home environment on non-critical health applications such as monitoring and rehabilitation [13].

In Refs. [14–16]researchers have highlighted the need of AmI in order to improve the hospital spaces allocation for patients as well as the improvement of the overall business operation. Hospitals should be able to provide a holistic approach to the patients' treatment, and high quality of services and thus should be highly organized. Hence, AmI could play a crucial role in order to improve the quality of healthcare delivery and clinician efficiency, in a variety of hospital settings.

Particularly, ICUs are specially designed departments in clinics and hospitals. There is a high percentage of patients with critical illness or after surgical complications that end up in the ICU. Lately the health system of a lot of countries was tested during the COVID-19 pandemic; a viral infection which affects mostly the lungs and leads to severe pneumonia. The number of people ending up in ICU was increased exponentially. However, the use of ICU is accompanied with a significant high cost [17, 18].

Although most of the times ICU is quite necessary for the patient's survival and recovery, most of the times the recovered patients discharged from ICUs set up with a post-intensive care syndrome which is accompanied by various cognitive and physical problems such as pneumonia and atelectasis, cardiovascular complications, gastrointestinal complications, musculosketal complications, neurological disorders, endocrine system complications, integumentary system, and finally psychological disorders [19]. Patients' mobility in ICUs is being measured by trained observers. However, due to various factors such as human error and bias, these measurements are inaccurate and insufficient. Ambient intelligence could help on early patient mobilization, with contactless sensors, for example by monitoring pre-ambulation maneuvers (side to side turning, bed exercises etc.) [19] or with Non-invasive mobility sensors (NIMS) in order to measure accurately the moves of patient on an ICU bed in 24 h time frames [20]. Furthermore, researchers in Ref. [21] have combined applied machine learning particularly a Convolutional Neural Network (CNN) with depth sensors in order to classify mobility activities into four categories. The technological advancements of AmI can help to a reduction of ICU-acquired weakness by 40%.

Another significant issue in hospital environments is the control of hospital acquired infections. The numbers of patients worldwide which contracts a nosocomial infection ascends to 100 million per annum [22]. The main cause for nosocomial infections is the bad hygiene. One example is the limited frequency of handwashing activities. Although measuring these kind of activities remains challenging, researchers in Refs. [23, 24] have proposed an AmI approach by installing depth sensors above wall-mounted dispensers which could more precisely track handwashing activities. Then a Deep Neural Network (DNN) algorithm was trained for measuring compliance over 351 handwashing sessions in one hour time frame. The DNN algorithm accuracy percentage was 75%, which was 12% higher in comparison with an observer and 57% higher in comparison with a proximity algorithm.

Although the surgical route for some of the patients is necessary step for their treatment, there is a patient percentage of 14% worldwide who experience a negative outcome [25]. One of various reasons for example is the level of skills that the surgeon has acquired from previous surgical procedures whereas they were supervised and evaluated by peers or senior surgeons. Although feedback from peers and or senior members is always welcome, the percentage of undesirable outcomes could be reduced by 50% if the less skilled or less experienced surgeon would have obtained a faster and more proactive feedback [26]. Researchers in order to address this issue have utilized ambient cameras in Refs. [12, 27], in order to monitor a prostatectomy videos. Then a Convolution Neural Network (CNN) was trained to follow the direction of the needle driver path. For comparison, the golden standard was the peer-evaluation method, and the system as a whole was able to classify 12 surgeons based on their skills level with a percentage of accuracy of 92%.

Another undesirable outcome which is encountered during surgical procedures is the counting. Counting is the process, which is followed by trained staff during the surgery, it includes the counting of various objects which are being used for the surgery and the main scope of it, is to avoid any of the objects being forgotten within the patient [28]. Although various ways for counting are in use, such as the use of barcodes on laparotomy sponges [29], they have proved quite insufficient due to the lack of their transferability on other objects for example on needles and instruments. Researchers in order to address this issue in Ref. [30] have utilized AmI by installing ambient cameras for object counting.

An important task on hospital administration is the time spent over medical documentation. Currently physicians are expected to keep and update medical documentation for every patient visit which increases the workload. One approach from the hospitals to relieve the physician's documentation burden is the hiring of medical scribes. However, due to the cost involved, this is not always the preferred solution [31]. In Refs. [32, 33] a Deep Neural Network was trained on a high volume of outpatient audio of discussions between doctors and patients. Then a learning algorithm was applied on the discussions that ambient glass mounted microphones had recorded, with overall accuracy 80%, which was 4% greater than medical scribes.

However, the hospital environment is not the only target for AmI applications in health and care. AmI is quite promising due to its multisciplinarity and its complexity which makes it easily transferable to various environments such as the home environment [1]. This is particularly important in this age but more so in the future. Due to scientific developments in the last 100 years, the age limit of the population has been increased significantly. As a result, the life expectancy has increased. On the one hand living longer is quite desirable while on the other ageing of the population creates several needs for elderly to leave independently. Particularly, the number of people aged 65 and older in the world will rise from 700 million to 1.5 billion [34]. Hence, the upcoming years there would be an increased need for chronic illness management and rehabilitation, dietary and pharmaceutical planning as well as an increased need for completing daily tasks such as bathing, toileting etc. Due to cost complexity and the increased amount of elder population most of these activities would need to take place unattended in a home environment rather than a clinical environment [12, 10, 1]. Measuring the level of daily activities is quite challenging and quite important given that a falling risk can be easily detect it as well as an early diagnosis of an illness such as dementia [12].

There are various tests and self -evaluation tests to help evaluate the ability of an individual to carry out daily tasks. For example, daily activities can be evaluated through Falls Efficacy Scale and Balance Confidence Scale [35, 36]. However, due to the way that the individual fills the questionnaire it can introduce bias or an overestimation/underestimation of their abilities to carry out the daily tasks [37]. Researchers in order to address this issue have suggested on various studies the utilisation of a variety of sensors such as accelerometers, tri-axial accelerometers, smart watches and mobile phone applications, electrocardiogram sensors, heart rate sensors and more [10, 38]. However, wearable sensors appear not to be elderly-friendly for two reasons. First of all, the elder population is not so familiar with the new technology in comparison with young people [1]. Secondly, the wearable devices cannot evaluate if an elder had used additional help in order to complete a daily task [39]. However, evaluation of daily tasks could be achieved with contactless sensors.

5.2.1 *State-of-the-Art: A Case Study*

Evidently AmI is promising for a variety of applications in the health and care domain. To better understand the potential of AmI as well as the ability to successfully support the domain specific needs, this subsection will discuss a state-of the-art AmI case study.

In Ref. [10] researchers have deployed an AmI system which consists of a couple of contactless sensors. The sensors used were pyroelectric (PIR) sensors. Due to the low cost of the sensors they had to be modified in order to serve the scope of the project. The sensors were mounted in a cascade which was manufactured for this purpose. The tests were caried in a lab environment with human subjects and not in an apartment or a home environment. In order to evaluate the ability of human subjects to carry out daily activities and due to the fact that there were no previous data of daily activities evaluation for comparison, two certified tests of the United Kingdom's National Health System (NHS) were used. The two tests which were used for comparison were Timed Up and Go (TUG) and Five Time Sit to Stand Test (FTSTS). The rationale of using these two tests was due to their simplicity, accuracy, suitability, and their ability to combine more than 2 daily activities. Moreover, both of the tests can be used in a home environment without specialist supervision. Although for critically ill patients, supervision by a family member or carer might be necessary. Furthermore, patients or elderly people face several difficulties to stand, walk and turn. Hence, these tests have sufficiently used in order to evaluate patients or elderly on how successfully they are able to accomplish each task based on the time of completion.

The TUG test is fairly simple (Fig. 5.6), the patient is being sited on an armless chair with their hands crossed over the chest. On the word GO, patients should stand up without using their hands. Then they would need to cover a three meters distance and make a180-degree turn. Then they would need to walk back, towards the chair and sit down again without using their hands as an additional support.

Similarly for the FTSTS (Fig. 5.7) test the patient is being sited on an armless chair. On the word Go, the patient needs to stand up and sit down five times without using any additional support; their hands for example.

The AmI system was tested on both occasions. The time of each experiment was recorded using a video camera as a golden standard and a stopwatch. The stopwatch by itself could not be used for evaluation in the experiment due to bias and human

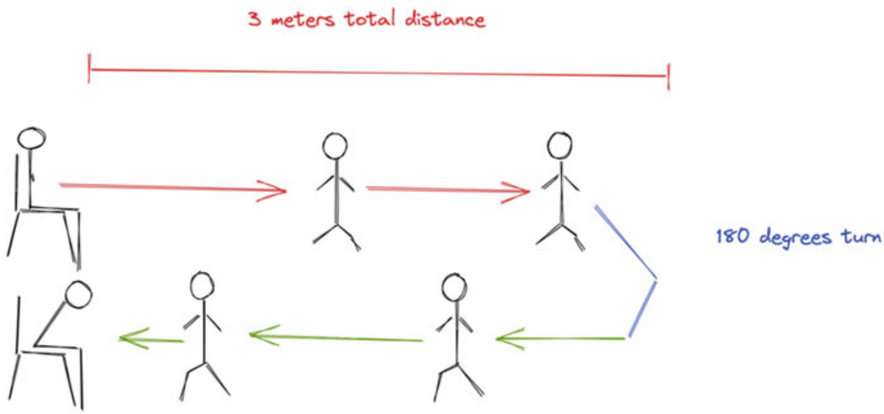
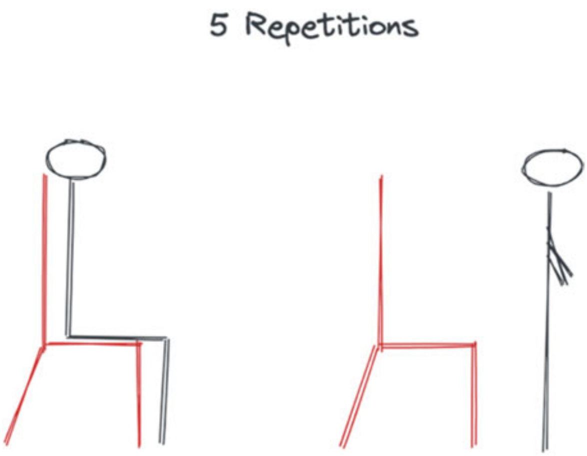


Fig. 5.6 The TUG test as defined by the NHS

Fig. 5.7 The FTSTS test as defined by the NHS



error. Although the nature and the topology of the experiment was different, the system was not altered, and a good level of transferability was demonstrated.

For the TUG test the first part of the edge computing system which includes the first sensor was placed near the chair of the participant, the height ⍰1 and ⍰2 of the placement as well as the exact distance $d1$ and $d2$ from the participant was calculated based on the participant's body metrics. The second sensor was placed at the 3 m distance as seen in Fig. 5.8, where the participant was about to make the U turn. Again, the placement of the sensor was calculated based on their body metrics. Hence, the height and the distance of system's placement was tailored to the characteristics of the patient, providing a more individualized experience. The data was transmitted to a collection station using the WIFI network.

For FTSTS the sensors were placed again based on the participant's body metrics. The first sensor was placed behind the head of the participants and the second sensor

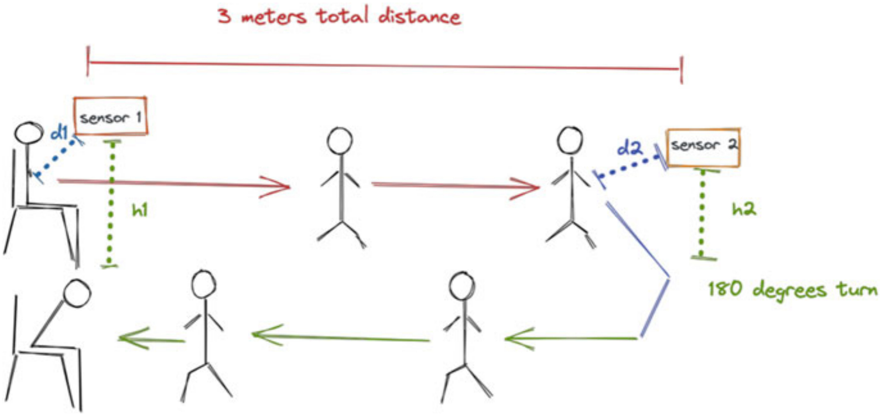


Fig. 5.8 Sensor placement for the AmI sensing case study for the TUG test

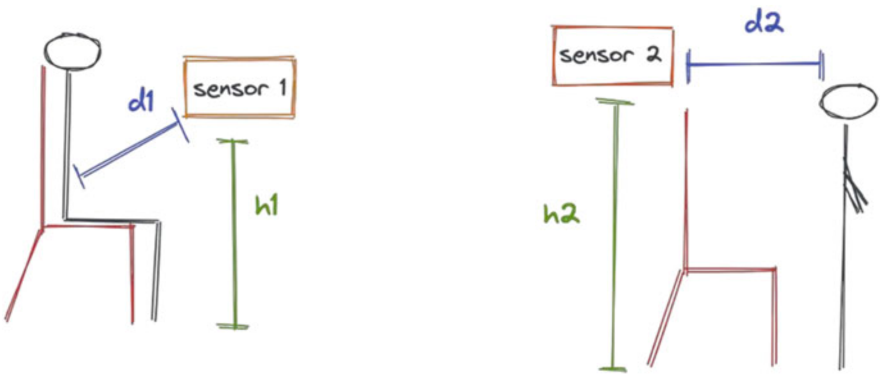


Fig. 5.9 Sensor placement for the AmI sensing case study for the FTSTS test

was placed near the chair of the participant (Fig. 5.9). The data was wirelessly collected.

The experiments were recorded and compared with the golden standard which was the video recording. To evaluate the performance several statistical analysis measures were used. The Bland-Altman analysis evaluated agreement between the two measurements. Additionally, Lin's concordance correlation coefficient, and interclass correlation coefficient were calculated to assess the agreement with the golden standard and the reliability of the measurements. Finally, an outlier analysis and a regression analysis reported p-values to assess statistical significance. Table 5.1 demonstrates the p-values for each test and monitored difficulty. The system demonstrated the ability of successfully capturing various main difficulties that most elderly and patients find challenging with their daily activities such as difficulty to stand, walk and turn. The system was able to capture the time accurately enough in comparison with the stopwatch and the video.

Table 5.1 Comparison of AmI system to the recorded video golden-standard; results of the regression analysis reported in p-Values for each difficulty

Set	p-Value
TUG Walk	2.16×10^{-41}
TUG Turn	5.6×10^{-41}
TUG Stand	3.4×10^{-41}
TUG Fast	0.097
TUG Normal	4.67×10^{-15}
FTSTS Difficulty	1.81×10^{-20}
FTSTS Fast	1.93×10^{-11}

Fast denotes execution of the experiment in accelerated pace while Normal denotes casual walking in the patient's own pace without difficulty

Hence, a low-cost system was designed, manufactured and deployed, which utilizes contactless non-intrusive ambient sensors. Sensors are integrated in the user's environment and can detect sufficiently various difficulties by measuring time of tests completion. Given, that the time of completion is being measured accurately, through applied machine learning, and advanced data processing, an individualized approach can be offered to the user. The percentage of likelihood for potential falling as well as early sign of an illness could be sufficiently detected in the home environment using this state-of-the-art AmI technology.

5.3 Challenges and Opportunities

AmI can improve the healthcare overall in various environments. On clinical environment by improving surgical operations, helping with various administrative tasks, monitoring patients in ICU, handling efficiently patients with cognitive problems. Due to a variety of issues, such as cost and ageing of the population, two important aspects such as rehabilitation and monitoring of patients will be transferred to the home environment in the coming years. AmI is quite promising for helping patients with their rehabilitation as well as with monitoring and early illness identification [1].

However, AmI due to its *multidisciplinarity and complexity* introduces various challenges. One of the main challenges for AmI, is the complex behavior identification in scenes with high level of complexity [12, 40]. This introduces the need for the application of more advanced techniques such as eye tracking, accurate estimation of body posture, object recognition and early identification. As an example, in relation to the case study that was aforementioned [10], all the testing process had taken place in the lab environment. However, in a home environment there might be other tenants or residents who can occlude the sensor's useful view. Sometimes there are objects or furniture in the home setting which can obstruct sensors. In order for this problem to be addressed there is an extensive need for new advanced machine learning algorithms, or more sophisticated design approach for ambient sensors [11].

Another challenge is the handling and learning from *high volume data* (Big Data). Following from the assumption that each house or hospital will utilize some sort of an AmI system, the volume of data will increase in the near future [41]. As a consequence, the need for development of advanced machine learning algorithms will increase. New introduced algorithms should be able to handle big data and model rare events [12]. Moreover, due to the large amount of data there is always a storage issue, probably the cloud could be a potential solution although due to several issues involved such as cost which is related to the storage capacity, computational capacity and network bandwidth can become an expensive option [42]. Most importantly the cloud has *privacy and security implications* especially for medical data [43–45]. For large-scale-activities the training of ML models will require significant amount of time as well as power, linking to sustainability challenges [11]. Further, in many medical applications networking infrastructure pauses challenges for big data live streaming and processing [46]. Network Coding (NC) is a technique that aims to reduce the transmission power and improve network performance, which is regarded as important work in this domain [47].

There is a benefit from continuous monitoring and data collection through AmI. On several occasions a patient should be monitored 24/7. This will give the opportunity to the AmI system to learn the patient and raise flags on some events of rare behavior. The system through monitoring of rare events will be able to identify and recognize patterns related to an illness for example. This could potentially lead to early prognosis of an illness for some patients [11]. An example could be related to the aforementioned case study [10]. Through *continuous monitoring* of the participant, the system was able to study and learn the subject through the data that was collected. Then the new set of data could be compared against the old collected dataset as well as against the NHS datasets with various completion times for a variety of illnesses [11]. If a participant who was walking normally suddenly had developed a difficulty to turn then the system was able to raise a flag of a potential health issue. The system will continue measuring the completion time of the participant and recognize if this was an one time event or if there is continuity. Then if there is a continuity of the event and based on the pattern it can raise a potential flag with a prediction or early prognosis of the onset of a new condition.

However, due to continuous monitoring of the user's environment, AmI can raise some *privacy and security issues* [48]. Data continuously collected could reveal unintentionally a possible health condition to third parties [49]. Ambient cameras, for a large amount of people, are characterized as intrusive means due to bridge of privacy [1]. Moreover, in the home environment they could cause possible security issues, for example a camera which is monitoring a patient could easily reveal the home condition, number of occupants, if there is someone in the property etc. [50]. On the hospital setting for example AmI could be utilized in order to identify if a room is occupied. However, if the room for example is occupied, the ID of the occupants could be identified. Moreover, there could be potential issues of patient data sharing between for example healthcare providers and third parties (e.g. insurer) [12].

AmI utilizes machine learning. Hence, the predictions accuracy of the system relies on *good quality and unbiased datasets* [11]. However, there might be occasions where the datasets are not totally unbiased in the healthcare domain [51]. Thus, the error in the prediction will be significantly large for minorities affected by those implicit or explicit biases. Moreover other ethical considerations are related to the use of AI and open challenges exist around the trust, accountability, and responsibility of AI [11].

5.4 Importance of Accountability, Reliability and Transparency (ART)of AI in AmI

The rapid development of technology the last decade has increased the computational capacity limit. Hence, researchers are increasing becoming more able to test and apply algorithms on various applications with a high level of complexity such as Neural Networks. Due to the high level of performance and accuracy of predictions Neural Networks have been used widely for healthcare applications, from cancer detection through image processing to monitoring of patients in ICU's. However, although Neural Networks are quite promising, their operation is characterized as a black box, due to the lack of explainability associated with their predictions. Hence, a Neural Network can predict accurately a tumor. However, the model itself is difficult to be trusted by specialists due to lack of transparency and explainability on its decision. The rationale and reasoning on how a Neural Network took a particular decision on high complexity models is unknown [52]. Hence, applied machine learning algorithms in healthcare sector should be responsible (Fig. 5.10) and they should follow certain rules in order to be trusted by health and care professionals [53]. Lately the EU has published a legal frame regarding the use of AI on critical applications [13]. In order to understand what responsible AI stands for, various factors such as ethics, accountability, transparency, regulation and control, socioeconomic impact, design and responsibility should be introduced and analyzed. ART AI in healthcare is of paramount importance. Patients could experience disastrous or irreversible effects due to a wrong decision of the system.

5.4.1 Ethics and Accountability

AI is being used lately on several fields and on various applications. Healthcare, the justice system, the power industry, the car industry are some of many industries where AI provides its services. Although AI could contribute on the development of various applications which serve various industries, ethics is one important factor which needs to be taken under consideration during the design phase. Hence, during the design process, designers would need to be able to understand the reasoning

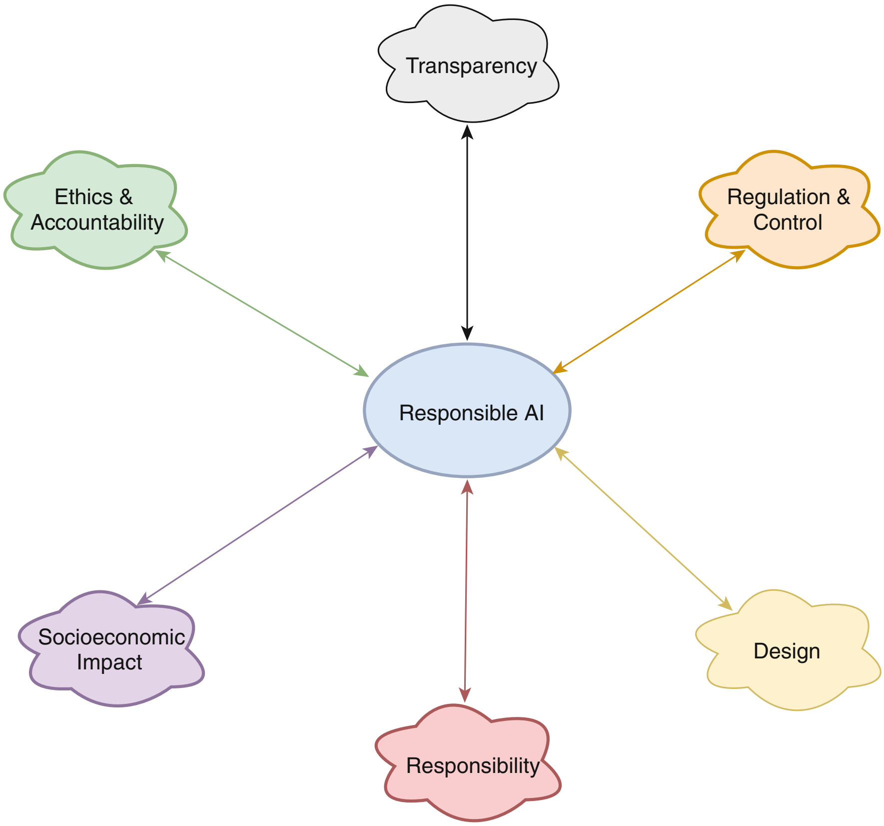


Fig. 5.10 The research areas and challenges comprising responsible AI

behind the existence of an application which utilizes AI. This process should ascertain that the AI system as a whole does not bridge or violating the human moral code. This links to the need of eliminating bias in a dataset which decreases discrimination and in turn minimize the error of the prediction and increases the level of ethics. One example is the location-based algorithms. For example, they could link various police incidents with geographic locations and the history of crime rate [54]. The algorithm then is able to predict the percentage of likelihood of crime recurrence. Hence, if the data input to the algorithm appear to have high level of bias, then this could result on biased arrests in a particular area with history of high crime rates [55]. Thus, AI systems should be monitoring for unintended and unethical consequences, this will allow to the designer to interpret and evaluate or re-evaluate the model's decision. This increases model's accountability and interpretability and aligns it with the moral code of the user. This partially links with the black box problem which can be found on several algorithms [56, 57].

5.4.2 Transparency

Decision justification is an important factor which needs to be taken under consideration for an AI model. It is quite important for the designer as well as for the user to be able to understand the rationale behind the prediction or decision of the model. Explainability behind of model's decision should be on an adequate level, this will lead to a better evaluation of the outcome/prediction. Often models which are characterised by their high level of simplicity tend to be more explainable but this could decrease the accuracy of the model. Usually, designers in order to address this issue are able to combine models with high level of simplicity and advanced models with higher level of complexity, then through post-hoc analysis techniques and modification of input, the transparency of the model could be significantly improved [57, 58].

5.4.3 Regulation and Control

AI is being used widely nowadays and its percentage of involvement into people's daily life will be gradually increased. Hence, the interaction between human beings and machines will be a daily phenomenon in the forthcoming years. A percentage of the rapid technological advancements were allowed to happen through the use of AI. Responsibility and accountability of the models' decisions should be taken under consideration very seriously. One example could be the use of the driverless cars, who would be accountable for a fatality that might happen due to a car accident/incident. Another example could refer to use of military robots, who is responsible or accountable for an accidental death of a soldier. Regulatory bodies could define a legal frame, like for example the approach that was introduced by the EU recently. A legal frame could help on handling undesired outcomes of a system, define guidelines for actions taken by the system itself and assign liabilities and responsibilities to whoever is accountable for the model, for example the designer. The EU legal frame categorises AI applications based on the risk that they can introduce to acceptable, high, and low risk. There is specific guidance for the design of high risks AI systems, where it has been clearly defined that the design of those systems must be transparent and interpretable [57, 59].

5.4.4 Socioeconomic Impact

Although this problem is not of computing or engineering nature, it affects the society and hence should be analysed further. Due to the integration of AI in people's lives, one main issue that could be potentially raised, is the acceptability of AI from the society especially for autonomous systems which can introduce bias and discrimination occasionally. Thus, further research should be conducted along with continuous monitoring of the system's decision combined with a person centred approach based on specific applications, in order to eliminate bias or discriminative behaviors. Furthermore, the integration of AI in the workplace could be another potential issue that needs further investigation. For example, the reaction of employees after the realization that their skills are not necessary anymore, or the reaction of employers after the realization that the cost of a competitive equipment which implements AI is significantly higher [57, 60].

5.4.5 Design

There is an increased need for the involvement of multidisciplinary teams because AI integration in people lives introduces problems and challenges which are multidimensional and consider various aspects such as ethical and economical. Multidisciplinarity in the design process will be able to reduce further the unintentional bias, through the combination and share of knowledge and expertise of various domains [57].

5.4.6 Responsibility

AI has been integrated and introduced lately on various crucial sectors such as defence and healthcare. However, applications which could be harmful to humanity should be classified based on level of sensitivity and hence further research would be required for this kind of applications in order to prevent undesired outcomes. Moreover, the questions which could possibly arise is who is the person responsible on the case of an unpredicted outcome which could lead to an unwanted event, could be the end user or the designer for example. Moreover, due to thin margins among the definitions of ART AI, responsibility differs from accountability which refers to decisions justification of AI systems [57, 61].

5.4.7 ART and AmI

In terms of explainability and interpretability of the AI model it was found [62] specifically for Neural Networks that although they perform well with high accuracy in various health applications most of the times there is significant blackboxness. Thus, they are quite difficult to interpret or to either justify or explain their decisions. Although, some steps have been taken towards the explainability of the Blackbox model, the studies are still premature in this direction, especially if the Neural Network is of high complexity (multiple layers) [62]. Hence, the use of Neural

Networks on some healthcare applications could impose a level of uncertainty as well as a high level of insecurity which could make the model sometimes untrustworthy to the specialists and to the users. Particularly for the end users the model decision should be presented in such way, in which should be well understood and should be characterized by its simplicity like simple texts or sentences, a shape that most of the users would be able to interpret and understand. For example, various rehabilitation systems provide feedback to the patients which is of high complexity, as a result the patient finds it difficult to quantify and understand their progress and this leads to lack of motivation for further rehabilitation as well as to low level of engagement. On the other hand Ambient intelligence systems are capable to address this issue through dialogic explanations of systems behavior and through continuous observation of the needs of the user [1, 10, 11].

5.5 Advancements in ART AmI

As discussed in the previous sections, in the future, due to economical as well as social reasons, activities such as monitoring, and rehabilitation will be transferred into home environment. For example, the number of patients early discharged is approximately 50.000[63]. All these patients will continue with their rehabilitation in their home environment. This happens due to cost reduction per person and due to the complexity of the rehabilitation process. Due to different personalities for a large amount of people the rehabilitation is a much easier task when they are surrounded by family. However, most of the times additional attention is needed on the rehabilitation equipment. The rehabilitation equipment on most occasions provides a one size fits all solution. However, various studies show [1] that a more individualized approach has a positive impact on rehabilitation outcome. Hence, there is an increased need for ambient systems that will be able to provide an individualized experience to the user and they will increase the patient's motivation to engage with their rehabilitation program. Moreover, the AI approach of the AmI system should be complied with ethical principles with an increased level of accountability, responsibility and transparency in order to increase the user acceptance. This section will examine a case study of an advanced system combining AmI and ART AI principles to provide individualized health and care support at home. The following case study describes how the AI approach was selected and integrated to the system that was tested and presented in Sect. 5.2.

In order to design the right AI approach for the system presented in Sect. 5.2 [11] and due to the complexity of the rehabilitation process a multidisciplinary team was selected with various backgrounds such as biomedical engineering, electronic and electrical engineering and computing science. During the design process special attention and consideration were given on the datasets. Unbalanced datasets could introduce high level of bias due to a class misrepresentation. Moreover, in terms of explainability of the AI the approached focused mainly on the level of patients engangement based on feedback provided by the system. In terms of interpretability, various algorithms were reviewed and tested in order to select the most performant and interpretable.

Due to the wide use of home-based monitoring and rehabilitation systems from several individuals who belong on a wide age range there is an increased need of unbiased AI, given that all individuals should enjoy the same level of fairness and support. Moreover, the engagement of the system usage is direct proportional with the level of interpretability and explainability, while complexity of the system is inversely proportional with motivation level. Hence, the proposed AmI system should be interpretable, explainable and of low complexity.

Concepts of ART AI were evaluated in order to construct the proposed system in compliance with them. Considerations in the design of responsible AI are divided into three categories [11, 59]: Ethics by design (technical and algorithmic), ethics in design (regulatory and engineering), and ethics for design (code of conduct and standards). For the case study an analysis of these parameters was performed focusing on Neural Networks and Random Forests. For systems which utilize AI and are focused in home monitoring and rehabilitation, an important aspect is the computational capacity. Neural Networks require significant capacity and time to train. Moreover, Neural Networks in comparison with other algorithms could increase the carbon footprint due to higher power consumption during the training process. On the other hand in comparison with Neural Networks, Random forests could be an effective option for healthcare applications although in order to maintain a good level of interpretability and explainability they should be of low complexity [11].

Another algorithmic approach that can have positive ART AI impact at the design stage of healthcare is the ensemble learning. Ensemble learning is the combination of decisions of weak learners (combination of heuristic algorithms with heterogenous MLmodels) in order to minimize various factors which could increase the level of error in the prediction such as noise, variance and bias and reduce computational capacity [64]. Boosted trees is an option which supports ART with an increase the level of explainability and support the bias-variance trade off [65]. However, boosted trees are of high complexity and a simplification process is required in order to communicate information efficiently with high level of accountability, interpretability and transparency [66].

Along the same lines, stacking could be another option; stacking is an ensemble machine learning method which uses a single model to learn the most efficient way of combining different predictions from several heterogeneous machine learning models on the same dataset. For example, a combination of K-Nearest Neighbours (KNN) with Xtreme Gradient Boosting (XG-Boost) which can overcome issues like robustness, interpretability and overfitting. XG-Boost appears to have a high level of accuracy while at the same time can keep the computation capacity low and provide a sufficient level of transparency. This makes XG-Boost an ideal algorithm for an individualized approach [67].

The proposed system which is being examined in this case study utilises a method which combines, low level computational footprint boosting and a hybrid stacking ensemble learning method in order to promote an individualized ARTAI approach

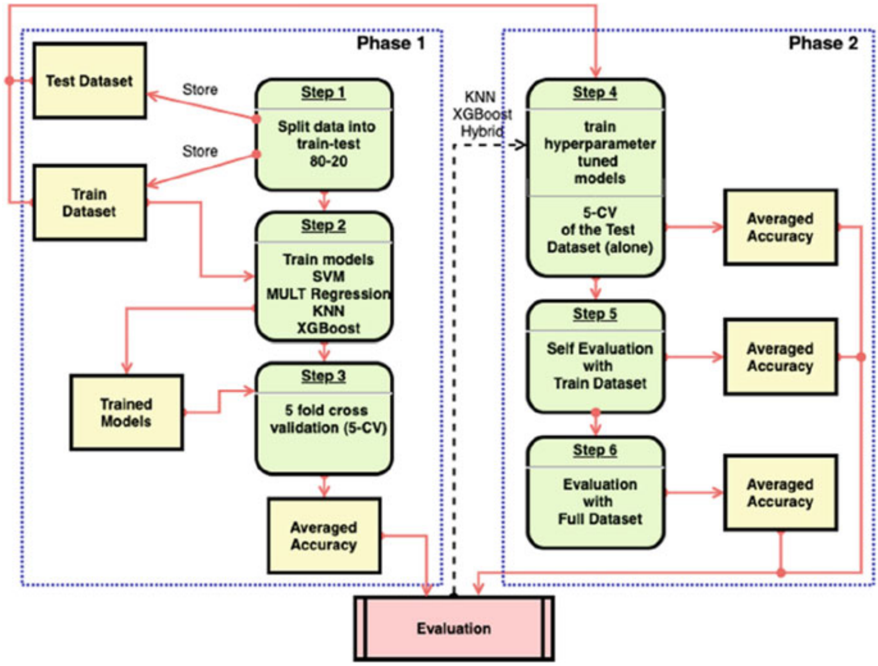


Fig. 5.11 AI model development methodology to ensure ART AI principles adherence

meeting the criteria which were identified in Ref. [1]. Figure 5.11 summarizes the design time considerations and methodology to enable better alignment with the ART principles.

The first phase improves the bias reduction of the dataset as well as the evaluation of several models from low to high complexity. This process allowed for a well design input dataset that ensures fairness and ethical training of the model. At the same time the evaluation process ensures the compliance with the ART principles through the selection of a boosted random forest model method and a knearest neighbors method both of which have high explainability and transparency potential. Finally, the ensemble approach improves the performance of the model while simplifying the overall model design and provides the desired individualization of the AmI system.

Beyond the design and compliance to the ART principles the proposed model advances the state of the art in automated difficulty identification as well as comorbidity detection through an AmI non intrusive approach. In a comparative analysis to other intrusive automated TUG and FTSTS tests the model demonstrated an improvement in accuracy performance as presented in Table 5.2.

Table 5.2 Comparative analysis of the case study against automated TUG and FTSTS methods using intrusive means and various AI algorithms with variable adherence to ART principles

Test	Method	Accuracy (%)
FTSTS	Decision trees [68]	92
	k-Nearest Neighbors [68]	91
	Neural Networks [69]	94.68
	Case Study [11]	100
TUG	Neural Networks [70]	85
	Case Study [11]	100

5.6 Conclusion and Future Work

This chapter presented the concept of ambient intelligence and elaborated on the vast breadth of applications of AmI in the medical domain. Applications in the hospital were discussed in terms of ICUs and surgical theatres. Given the fact that, there is an increased dispatch of patients to their home environment for various socio-economic reasons, as a result, it is expected that AmI could provide a significant benefit for patient monitoring in the home environment. The example of rehabilitation monitoring was discussed through a case study. The case study demonstrated the clinical relevance, efficiency, and validity of AmI that was developed with the limitations of the acceptance criteria for AmI in medical applications.

Further the chapter examined the use of AI to provide individualized AmI health and care support. Under this concept the challenges and opportunities introduced by ethical and ART considerations were reviewed and design time considerations established. Then a case study demonstrated that systems designed according to the ART principles can: (1) not only match but also (2) exceed the performance of less explainable or less transparent methods such as Neural Networks (NNs).

Further research is required to improve AmI systems and for their implementation in a variety of healthcare applications. This involves researching less intrusive methods but also methods that support the ART design requirements across the full stack from the sensor to the intelligence layer. Particularly research is required to improve the ART component of algorithms such as NNs.

References

1. Vourganas, I., Stankovic, V., Stankovic, L., & Kerr, A. (2019). Factors that contribute to the use of stroke self-rehabilitation technologies: A review. *JMIR Biomedical Engineering, 4*, e13732. https://doi.org/10.2196/13732
2. Patel, S., Park, H., Bonato, P., Chan, L., & Rodgers, M. (2012). A review of wearable sensors and systems with application in rehabilitation. *Journal of NeuroEngineering and Rehabilitation, 9*, 21. https://doi.org/10.1186/1743-0003-9-21
3. (2017). *State of the Nation: stroke statistics*.
4. (2018). *State of the Nation: stroke statistics*.

5. Szeto, A. (2005). 5 Rehabilitation engineering and assistive technology. In J. D. Enderle, S. M. Blanchard, & J. D. Bronzino (Eds.), *Introduction to biomedical engineering* (2nd ed., pp. 211–254). Academic Press.
6. Debes, C., Merentitis, A., Sukhanov, S., Niessen, M., Frangiadakis, N., & Bauer, A. (2016). Monitoring activities of daily living in smart homes: understanding human behavior. *IEEE Signal Processing Magazine, 33*, 81–94. https://doi.org/10.1109/MSP.2015.2503881
7. Fell, M., Kennard, H., Huebner, G., Nicolson, M., Elam, S., & Shipworth, D. (2017). *Energising health: A review of the health and care applications of smart meter data*. UCL Energy Institute.
8. Wang, Y., Chen, Q., Hong, T., & Kang, C. (2018). Review of smart meter data analytics: applications, methodologies, and challenges. *IEEE Transactions on Smart Grid, 10*(3), 3125–3148. https://doi.org/10.1109/TSG.2018.2818167
9. Alwateer, M., Almars, A. M., Areed, K. N., Elhosseini, M. A., Haikal, A. Y., & Badawy, M. (2021). Ambient healthcare approach with hybrid whale optimization algorithm and Naïve Bayes classifier. *Sensors, 21*, 4579. https://doi.org/10.3390/s21134579
10. Vourganas, I., Stankovic, V., Stankovic, L., & Michala, A. L. (2020). Evaluation of home-based rehabilitation sensing systems with respect to standardised clinical tests. *Sensors, 20*, 26.
11. Vourganas, I., Stankovic, V., & Stankovic, L. (2021). Individualised responsible artificial intelligence for home-based rehabilitation. *Sensors, 21*, 2. https://doi.org/10.3390/s21010002
12. Haque, A., Milstein, A., & Fei-Fei, L. (2020). Illuminating the dark spaces of healthcare with ambient intelligence. *Nature, 585*, 193–202. https://doi.org/10.1038/s41586-020-2669-y
13. *A European approach to Artificial intelligence | Shaping Europe's digital future*. Retrieved July 23, 2021, from https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence.
14. Adams, J. G., & Walls, R. M. (2020). Supporting the health care workforce during the COVID-19 global epidemic. *JAMA, 323*, 1439. https://doi.org/10.1001/jama.2020.3972
15. Patel, R. S., Bachu, R., Adikey, A., Malik, M., & Shah, M. (2018). Factors related to physician burnout and its consequences: A review. *Behavioral Science, 8*, 98. https://doi.org/10.3390/bs8110098
16. Lyon, M., Sturgis, L., Lendermon, D., Kuchinski, A. M., Mueller, T., Loeffler, P., Xu, H., & Gibson, R. (2015). Rural ED transfers due to lack of radiology services. *The American Journal of Emergency Medicine, 33*, 1630–1634. https://doi.org/10.1016/j.ajem.2015.07.050
17. Halpern, N. A., Goldman, D. A., Tan, K. S., & Pastores, S. M. (2016). Trends in critical care beds and use among population groups and Medicare and Medicaid beneficiaries in the United States: 2000–2010. *Critical Care Medicine, 44*, 1490–1499. https://doi.org/10.1097/CCM.0000000000001722
18. Halpern, N. A., & Pastores, S. M. (2010). Critical care medicine in the United States 2000–2005: An analysis of bed numbers, occupancy rates, payer mix, and costs. *Critical Care Medicine, 38*, 65–71. https://doi.org/10.1097/CCM.0b013e3181b090d0
19. Zhang, L., Hu, W., Cai, Z., Liu, J., Wu, J., Deng, Y., Yu, K., Chen, X., Zhu, L., Ma, J., & Qin, Y. (2019). Early mobilization of critically ill patients in the intensive care unit: A systematic review and meta-analysis. *PLoS One, 14*, e0223185. https://doi.org/10.1371/journal.pone.0223185
20. Reiter, A., Ma, A., Rawat, N., Shrock, C., & Saria, S. (2016). Process monitoring in the intensive care unit: Assessing patient mobility through activity analysis with a non-invasive mobility sensor. In S. Ourselin, L. Joskowicz, M. R. Sabuncu, G. Unal, & W. Wells (Eds.), *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2016* (pp. 482–490). Springer International Publishing.
21. Yeung, S., Rinaldo, F., Jopling, J., Liu, B., Mehra, R., Downing, N. L., Guo, M., Bianconi, G. M., Alahi, A., Lee, J., Campbell, B., Deru, K., Beninati, W., Fei-Fei, L., & Milstein, A. (2019). A computer vision system for deep learning-based detection of patient mobilization activities in the ICU. *Npj Digital Medicine, 2*, 1–5. https://doi.org/10.1038/s41746-019-0087-z

22. World Health Organization. (2011). *Report on the burden of endemic health care associated infection worldwide*. World Health Organization.
23. Haque, A., Guo, M., Alahi, A., Yeung, S., Luo, Z., Rege, A., Jopling, J., Downing, L., Beninati, W., Singh, A., Platchek, T., Milstein, A., & Fei-Fei, L. (2018). *Towards vision-based smart hospitals: A system for tracking and monitoring hand hygiene compliance*. ArXiv170800163 Cs.
24. Singh, A., Haque, A., Alahi, A., Yeung, S., Guo, M., Glassman, J. R., Beninati, W., Platchek, T., Fei-Fei, L., & Milstein, A. (2020). Automatic detection of hand hygiene using computer vision technology. *Journal of the American Medical Informatics Association, 27*, 1316–1320. https://doi.org/10.1093/jamia/ocaa115
25. Anderson, O., Davis, R., Hanna, G. B., & Vincent, C. A. (2013). Surgical adverse events: a systematic review. *American Journal of Surgery, 206*, 253–262. https://doi.org/10.1016/j.amjsurg.2012.11.009
26. Bonrath, E. M., Dedy, N. J., Gordon, L. E., & Grantcharov, T. P. (2015). Comprehensive surgical coaching enhances surgical skill in the operating room: A randomized controlled trial. *Annals of Surgery, 262*, 205–212. https://doi.org/10.1097/SLA.0000000000001214
27. Law, H., Ghani, K., & Deng, J. (2017). Surgeon technical skill assessment using computer vision based analysis. In F. Doshi-Velez, J. Fackler, D. Kale, R. Ranganath, B. Wallace, & J. Wiens (Eds.), *Proceedings of the 2nd Machine Learning for Healthcare Conference* (pp. 88–99). PMLR.
28. Greenberg, C. C., Regenbogen, S. E., Lipsitz, S. R., Diaz-Flores, R., & Gawande, A. A. (2008). The frequency and significance of discrepancies in the surgical count. *Annals of Surgery, 248*(2), 337–341. Retrieved July 23, 2021, from https://pubmed.ncbi.nlm.nih.gov/18650646/
29. Cima, R. R., Kollengode, A., Clark, J., Pool, S., Weisbrod, C., Amstutz, G. J., & Deschamps, C. (2011). Using a data-matrix-coded sponge counting system across a surgical practice: impact after 18 months. *Joint Commission Journal on Quality and Patient Safety, 37*, 51–58. https://doi.org/10.1016/s15537250(11)37007-9
30. Kadkhodamohammadi, A., Gangi, A., de Mathelin, M., & Padoy, N. (2017). *A multi-view RGB-D approach for human pose estimation in operating rooms*. ArXiv170107372 Cs.
31. Rich, N. (2017). The impact of working as a medical scribe. *The American Journal of Emergency Medicine, 35*, 517. https://doi.org/10.1016/j.ajem.2016.12.020
32. Chiu, C. C., Tripathi, A., Chou, K., Co, C., Jaitly, N., Jaunzeikare, D., Kannan, A., Nguyen, P., Sak, H., Sankar, A., Tansuwan, J., Wan, N., Wu, Y., & Zhang, X. (2018). *Speech recognition for medical conversations*. ArXiv171107274 Cs Eess Stat
33. Pranaat, R., Mohan, V., O'Reilly, M., Hirsh, M., McGrath, K., Scholl, G., Woodcock, D., & Gold, J. A. (2017). Use of simulation based on an electronic health records environment to evaluate the structure and accuracy of notes generated by medical scribes: Proof-of-concept study. *JMIR Medical Informatics, 5*, e30. https://doi.org/10.2196/medinform.7883
34. Division UP. (2019). *World population ageing*. UN.
35. Soh, S. L.-H., Lane, J., Xu, T., Gleeson, N., & Tan, C. W. (2021). Falls efficacy instruments for community-dwelling older adults: a COSMIN-based systematic review. *BMC Geriatrics, 21*, 21. https://doi.org/10.1186/s12877-020-01960-7
36. Park, E.-Y., Lee, Y.-J., & Choi, Y.-I. (2018). The sensitivity and specificity of the falls efficacy scale and the activities-specific balance confidence scale for hemiplegic stroke patients. *Journal of Physical Therapy Science, 30*, 741–743. https://doi.org/10.1589/jpts.28.741
37. Carlsson, G., Haak, M., Nygren, C., & Iwarsson, S. (2012). Self-reported versus professionally assessed functional limitations in community-dwelling very old individuals. *International Journal of Rehabilitation Research. Internationale Zeitschrift für Rehabilitationsforschung. Revue Internationale de Recherches de Réadaptation, 35*, 299–304. https://doi.org/10.1097/MRR.0b013e3283544d07
38. Wang, Z., Yang, Z., & Dong, T. (2017). A review of wearable technologies for elderly care that can accurately track indoor position, recognize physical activities and monitor vital signs in real time. *Sensors, 17*, E341. https://doi.org/10.3390/s17020341

39. Katz, S. (1983). Assessing self-maintenance: Activities of daily living, mobility, and instrumental activities of daily living. *Journal of the American Geriatrics Society, 31*, 721–727. https://doi.org/10.1111/j.1532-5415.1983.tb03391.x
40. Sadeghian, A., Alahi, A., & Savarese, S. (2017). *Tracking the untrackable: Learning to track multiple cues with long-term dependencies*. ArXiv170101909 Cs.
41. Halamka, J. D. (2014). Early experiences with big data at an academic medical center. *Health Affairs Project HOPE, 33*, 1132–1138. https://doi.org/10.1377/hlthaff.2014.0031
42. Verbraeken, J., Wolting, M., Katzy, J., Kloppenburg, J., Verbelen, T., & Rellermeyer, J. S. (2019). *A survey on distributed machine learning*. ArXiv191209789 Cs Stat.
43. Bader, J., & Michala, A. L. (2021). Searchable encryption with access control in industrial Internet of Things (IIoT). *Wireless Communications and Mobile Computing, 2021*, e5555362. https://doi.org/10.1155/2021/5555362
44. Kishor, A., Chakraborty, C., & Jeberson, W. (2021). A novel fog computing approach for minimization of latency in healthcare using machine learning. *International Journal of Interactive Multimedia and Artificial Intelligence, 1*, 6.
45. Chakraborty, C., Banerjee, A., Kolekar, M. H., Garg, L., & Chakraborty, B. (2021). *Internet of things for healthcare technologies*. Springer.
46. Attar, H. H., Solyman, A. A. A., Mohamed, A.-E. F., Khosravi, M. R., Menon, V. G., Bashir, A. K., & Tavallali, P. (2020). Efficient equalisers for OFDM and DFrFT-OCDM multicarrier systems in mobile E-health video broadcasting with machine learning perspectives. *Physical Communication, 42*, 101173. https://doi.org/10.1016/j.phycom.2020.101173
47. Attar, H., Khosravi, M., Igorovich, S., Georgievna, K., & Alhihi, M. (2021). E-Health communication system with multiservice data traffic evaluation based on a G/G/1 analysis method. *Current Signal Transduction Therapy, 16*(2). https://doi.org/10.2174/1574362415666200224094706
48. Rockhold, F., Nisen, P., & Freeman, A. (2016). Data sharing at a crossroads. *The New England Journal of Medicine, 375*, 1115–1117. https://doi.org/10.1056/NEJMp1608086
49. Wiens, J., Saria, S., Sendak, M., Ghassemi, M., Liu, V. X., Doshi-Velez, F., Jung, K., Heller, K., Kale, D., Saeed, M., Ossorio, P. N., Thadaney-Israni, S., & Goldenberg, A. (2019). Do no harm: a roadmap for responsible machine learning for health care. *Nature Medicine, 25*, 1337–1340. https://doi.org/10.1038/s41591-019-0548-6
50. Emam, K. E., Jonker, E., Arbuckle, L., & Malin, B. (2011). A systematic review of reidentification attacks on health data. *PLoS One, 6*, e28071. https://doi.org/10.1371/journal.pone.0028071
51. Cahan, E. M., Hernandez-Boussard, T., Thadaney-Israni, S., & Rubin, D. L. (2019). Putting the data before the algorithm in big data addressing personalized healthcare. *npj Digital Medicine, 2*, 1–6. https://doi.org/10.1038/s41746-019-0157-2
52. Adadi, A., & Berrada, M. (2018). Peeking inside the black-box: A survey on Explainable Artificial Intelligence (XAI). *IEEE Access, 6*, 52138–52160.
53. Lahav, O., Mastronarde, N., & van der Schaar, M. (2018). *What is interpretable? Using machine learning to design interpretable decision-support systems*. ArXiv Prepr ArXiv181110799.
54. Langan, P. A. (1995). *The racial disparity in US drug arrests*. Bureau of Justice Statistics BJS US Department Justice of Justice Programs U S Am.
55. Morrison, W. D. (1897). The interpretation of criminal statistics. *Journal of the Royal Statistical Society, 60*, 1–32.
56. Yu, H., Shen, Z., Miao, C., Leung, C., Lesser, V. R., & Yang, Q. (2018). *Building ethics into artificial intelligence*. ArXiv181202953 Cs.
57. Taylor, S., Boniface, M., Pickering, B., Anderson, M., Danks, D., Følstad, A., Leese, M., Müller, V., Sorell, T., Winfield, A., & Woollard, F. (2018). Responsible AI – Key themes, concerns & recommendations for European research and innovation. Retrieved September 11, 2020, from https://eprints.soton.ac.uk/426307/

58. Larsson, S., & Heintz, F. (2020). Transparency in artificial intelligence. *Internet Policy Review, 9*(2), 1–16.
59. Iphofen, R., & Kritikos, M. (2019). Regulating artificial intelligence and robotics: Ethics by design in a digital society. *Contemporary Social Science, 16*, 1–15. https://doi.org/10.1080/21582041.2018.1563803
60. Abrardi, L., Cambini, C., & Rondi, L. (2019). *The economics of artificial intelligence: A survey*. Social Science Research Network.
61. Coeckelbergh, M. (2020). Artificial intelligence, responsibility attribution, and a relational justification of explainability. *Science and Engineering Ethics, 26*, 2051–2068. https://doi.org/10.1007/s11948-019-00146-8
62. Choudhary, A. (2019). *Decoding the black box: An important introduction to interpretable machine learning models in python*.
63. Admin. (2017). Briefing: Health and care of older people in England 2017. In: *healthierfuture*. Retrieved December 2, 2020, from https://www.healthierfuture.org.uk/publications/2017/february/briefing-health-and-care-older-people-england-2017.
64. Stojić, A., Stanić, N., Vuković, G., Stanišić, S., Perišić, M., Šoštarić, A., & Lazić, L. (2019). Explainable extreme gradient boosting tree-based prediction of toluene, ethylbenzene and xylene wet deposition. *Science of the Total Environment, 653*, 140–147.
65. Sharma, N., & Anju, J. A. (2019). Extreme gradient boosting with squared logistic loss function. In M. Tanveer & R. B. Pachori (Eds.), *Machine intelligence and signal analysis* (pp. 313–322). Springer.
66. Arrieta, A. B., Díaz-Rodríguez, N., Del Ser, J., Bennetot, A., Tabik, S., Barbado, A., García, S., Gil-López, S., Molina, D., Benjamins, R., et al. (2020). Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI. *Information Fusion, 58*, 82–115.
67. Kazienko, P., Lughofer, E., & Trawinski, B. (2015). Editorial on the special issue "Hybrid and ensemble techniques in soft computing: Recent advances and emerging trends.". *Soft Computing, 19*, 3353–3355. https://doi.org/10.1007/s00500-015-1916-x
68. Acorn, E., Dipsis, N., Pincus, T., & Stathis, K. (2015). Sit-to-stand movement recognition using kinect. In A. Gammerman, V. Vovk, & H. Papadopoulos (Eds.), *Statistical learning and data sciences* (pp. 179–192). Springer International Publishing.
69. Hellmers, S., Fudickar, S., Lau, S., Elgert, L., Diekmann, R., Bauer, J. M., & Hein, A. (2019). Measurement of the chair rise performance of older people based on force plates and IMUs. *Sensors, 19*, 1370. https://doi.org/10.3390/s19061370
70. Silva, J. (2017). *Comparing machine learning approaches for fall risk assessment*. SCITEPRESS.

Chapter 6
Intelligent Elderly People Fall Detection Based on Modified Deep Learning Deep Transfer Learning and IoT Using Thermal Imaging-Assisted Pervasive Surveillance

Khosro Rezaee, Mohammad R. Khosravi, and Mohammad Kazem Moghimi

Abstract Early detection of knee osteoarthritis and poor balance can decrease falls in the elderly. Thus, automatic fall detection is an essential system for assuring the safety and health of the elderly. However, the use of the Visible Imaging System (VIS) installed in homes can affect people's privacy. Compared to visible imaging, thermal imaging involves people's privacy less and allows various incidents to be identified based on machine vision. A novel two-step framework through thermal imaging videos is introduced in this paper, including tracking humans and deep learning-based for recognizing the fall incidents. In the first step, the Kalman filter is employed to distinguish people's positions. Then, the novel modified ShuffleNet is utilized to refine the obtained bounding boxes of people at risk of falling. The proposed approach is implemented using the Internet of Things (IoT) deployment. The publicly thermal fall dataset analyses reveal the superior outcomes achieved with an average of less than 7% error compared to the conventional fall detection models. Besides, the IoT platform helps to process the incidents data and more efficiently, real-time monitoring, manage energy usage, and healthcare management.

Keywords Fall detection · Thermal imaging · Classification procedure · Deep transfer learning · IoT system · Kalman filter · ShuffleNet structure

K. Rezaee (✉)
Department of Biomedical Engineering, Meybod University, Meybod, Iran
e-mail: Kh.rezaee@meybod.ac.ir

M. R. Khosravi
Department of Computer Engineering, Persian Gulf University, Bushehr, Iran
e-mail: M.khosravi@sutech.ac.ir

M. K. Moghimi
Department of Communication Engineering, University of Sistan and Baluchestan, Zahedan, Iran
e-mail: K.moghimies@pgs.usb.ac.ir

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_6

6.1 Introduction

Elders are a vulnerable population globally, which according to population statistics after 2000, it has estimated that they have formed about one-eighth of the world population and mainly include elders with ages higher and 65 years, which are 750 million people [1–3]. According to population statics published in 2010, prediction demonstrates that in 2035, one-third of the European population will consist of individuals with ages higher than 65 years [4, 5]. Statistics show that disease of lower joints has involved 20 million people in the US, which most of these persons are elders with ages higher than 60 years [6, 7].

Early detection of this pain and debase let doctors propose an appropriate way of healing and prevention. They could examine significant changes like protrusion of elders' joint bone using radiography and precise analysis. In those radiographs, narrowing joint space, gradual erosion, and inclination is possible [7]. Specialists of elder medicine consider symptoms like pain, weakness of muscles, and lack of movement balance as signs of disorders in abnormal walking [8]. Analysis of the walking model could help detect human movement patterns disorders and prevent side effects like falling in elders; for example, changes in walking could merge with primary signs of neural disorders related to various types of disease [9]. Thermography is a non-invasive imaging method that works based on absorbing infrared rays and hears the record based on heat emitted from the surface of objects. Infrared ray is a kind of low-frequency, and long bandwidth signal sourced from all objects is the source of heat, in a way that more is the object texture, the more intensity of emitted infrared ray sourced from that object [10, 11].

Although detection of fall events and automatic detection of unbalancing in elders' movements has been studied in many types of research [4–17], various challenges may affect performance if these methods [18, 19]. Approaches based on video surveillance have some problems. We could mention the complexity of processing section design, low accuracy in detection, and lack of an appropriate mechanism for predicting the possibility of the fall event [20, 21]. Most of the proposed methods are based on visual video and images taken from elders' movements in indoor environments and healthcare systems. The proposed techniques are faced with various challenges like people's privacy and problems related to individual movement analysis in videos like artifacts and noise [22, 23]. Compared with visual imaging, thermal imaging preserves individual privacy to some proper extend and lets predication of various events like falls before their occurrence, based on machine learning techniques [24–30]. An accurate healthcare system that can show efficient performance in fall events and preserve people's privacy is essential. Figure 6.1 shows an example of an older person walking based on a visible camera, whose privacy has been considerably affected.

Internet of things (IoT) network refers to a network of distributed components (i.e., including gateways and other things) whose connection between these components is based on internet protocol [31].

Fig. 6.1 This figure shows an example of an older person walking based on a visible camera

Usually, their first connection hop is connected to computation services on the internet using wireless links [32]. The IoT structures are used in various and wide sections of nowadays life. IoT has some applications in agriculture, urban traffic management, smart houses management, military applications, and applications related to health care. With the growth of IoT networks, its surrounding challenges have increased which preserving safety is the most important challenge if IoT networks. The best contribution of this network is the prevention of commutation complexion in the analysis of different events, which by designing machine learning methods and utilizing this platform, we could provide satisfactory healthcare systems to people [33]. IoT is the candidate for solving fall detection challenges [34, 35] and establishing communication channels [36]. Hence, the ability of IoT and process layers help to analyze the multiple conditions of events [37]. Accordingly, we could utilize the IoT layers to develop the fall detection system, which has a high capability of big data processing and data storing [38].

Accurate monitoring based on thermal imaging algorithms and machine learning has significantly reduced risks related to preserving privacy and provides satisfactory event detection. In this chapter, we have utilized a healthcare system for earlier detection of falls for elders in the IoT platform, which notifies accidents resulting in injuries using lower limb thermal image analysis. The proposed method in this study is a new two-stage framework that utilizes thermal imaging include tracking elders and deep learning to detect fall accidents. In the first step, we have used the Kalman filter to detect elders' positions. Then, we employ a modified Shuffle Net to refine bounding boxes for a section of elders at risk of fall. The proposed method operates by applying an IoT platform. Using the Kalman filter and ShuffleNet structure is because of the ability of these two methods to fast processing and improve the accuracy of fall detection in elders.

Although various studies denoted the desirable categorization veracity of Deep Learning (DL) to distinguish fall incidents, assessment using thermal imaging is yet to be performed to determine fall and non-fall accidents. The drawbacks of DL decrease its benefits while being utilized for various anticipating sequences. There resides a wide array of hurdles for scheming Deep Learning networks, such as the prerequisite of majority data collection, unreasonable price of instruction because of complicated data patterns, and shortcomings of standard theory in choosing pertinent DL.

Besides functionality, veracity for predicting incidents is required for assessing illustrations such as thermal frameworks. It is imperative to include legitimate and competent components to maintain higher veracity.

Hence, to detect fall-related exposure in seniors, creating an accurate archetype is a required sequence.

Transfer Learning (TL) is an approach within machine learning in which a method that is established and tutored for one assignment as an initiation mark is then re-utilized for another duty. Because it contains a previously-tutored framework as a beginning mark for a tertiary assignment, Transfer Learning is distinguishable from Classical forms of machine learning.

For this subject, the approach used in this chapter presents clues of a computed sequence that assesses several structures, from which a ShuffleNet Structure withdraws components. Furthermore, overfitting will be substantially reduced due to the consolidation of the ShuffleNet and tracking model and the precise extraction of components. Moreover, incorporating accurate monitoring based on thermal imaging and machine learning algorithms would significantly reduce privacy risks and enhance falls' influential detection.

The remainder of the chapter is structured as follows: The second section discusses similar work. In Sect. 6.3, the proposed method for detecting fall events based on infrared imaging was provided. Section 6.4 explains the dataset used in our studies, as well as the results and commentary. Section 6.5 presents the findings of the investigation as well as potential plans.

6.2 Related Work

Jin et al. [39] have utilized infrared thermography imaging to recognize the movement disorder in the lower libs of a person. Their proposed work discussed knee arthroses pain recognition in thermal images and used feature extraction and classification to classify thermal images. They have used a support vector machine (SVM) to analyze data in the classification stage and subsequently detect the existence or not the presence of knee pain. Their proposed method has obtained detection accuracy of 85.49%, specificity of 85.51%, and a sensitivity of 85.72%. First, they have used symmetry property to classify knee areas to extract their statistical feature separately. They will perform area classification after symmetrizing the left and right knees. Lasanen et al. [40] have discussed joint inflammatory screening and rheumatoid arthritis of children in their study. Also, some research has focused on evaluating infrared thermal imaging efficiency on detection and control of knee are a disease. Calin et al. [41] have used thermal imaging in osteoarthritis, rheumatoid arthritis, and problem-related to ligament and tendon. The best results have been announced for monitoring patients following knee arthroplasty, with the sensitivity and specificity being 90% and 89%, respectively. Etehadtavakol et al. [42] have evaluated thermography potential in pain detection and monitoring on treatment. Their study mentioned that one could notify the intensity of knee osteoarthritis using plater skin surface temperature by thermography.

Table 6.1 investigates the literature survey and similar frameworks in fall detection based on their algorithms, advantages, and limitations.

Table 6.1 This table shows the comparative literature survey

Approach	Proposed algorithm	Advantages	Limitations
Cao et al. [25]	LSTM model and ellipse fitting	The accuracy of behavior identification can efficiently protect elders' privacy based on thermal imaging	Overfitting problem. The work has no IoT platform. The computational complexity is high
Jin et al. [39]	SVM classifier	Recognizing the movement disorder in the lower limbs of a person	Overfitting problem. The work has no IoT platform.
Calin et al. [41]	Statistical analysis of infrared images	Diagnosis of osteoarthritis, rheumatoid arthritis and ligament problems in infrared images.	The work has no IoT platform. It does not have automatic detection capability.
Subedi et al. [43]	Thermal image processing and feature extraction models	Their model is pre-screening tool for detection of canine bone cancer	The work has no IoT platform. Their method is not generalizable.
Hsieh et al. [44]	Feedback optical flow convolutional neural network	Their model is capable of identifying action posture and recognizing action motion based IoT platform	Their method is not generalizable. The privacy of the elderly is not preserved.
Vaiyapuri et al. [45]	Optimal deep convolutional neural network (IMEFD-ODCNN)	They optimized deep CNN for smart homecare application	The computational complexity is high. The privacy of the elderly is not preserved.
Kong et al. [46]	Enhanced tracking and Denoising Alex-net	They improved the tracking procedure and classified non-fall and fall incidents.	The computational complexity is high. The privacy of the elderly is not preserved. The work has no IoT platform.
Khan et al. [47]	Spatio-temporal adversarial learning	Their method is a generalizable model to detect the unseen falls.	The computational complexity is high. The work has no IoT platform.
Nogas et al. [48]	Deep spatio-temporal convolutional autoencoders	Their model is a generalizable model for non-invasive fall detection	The computational complexity is high. The work has no IoT platform.

Subedi et al. [43] introduced a framework based on the segmentation of the region of interest (RoI) area of the thermal image, texture feature extraction, spectrum, and histogram, and classification by Gabor descriptor features to detect the rupture in leg ligament during movement. Snekhalatha et al. [49] employed a quick greedy snake method and gray level co-occurrence matrix (GLCM) feature extraction to automatically segment X-ray images. Furthermore, they employed the RGB segmentation way to segment knee thermal pictures automatically. Finally, in individuals with rheumatoid arthritis, they compared extracted features from the segmented area of the knee from X-ray images and thermal images. They found a statistically significant difference in entropy among all retrieved features: difference, variance, average, homogeneity, and energy, indicating a significant difference between rheumatoid arthritis patients and healthy people.

In a study by Cao et al. [25], a scheme has been proposed to detect the fall incident as a healthcare system to protect elder's privacy. They first utilized infrared motion videos to collecting elders' behaviors for protecting their privacy. They use ellipse fitting for humans' five behaviors: sitting, standing, bending, squatting, and falling. Finally, they established an LSTM model using various variables as input for classification and feature extraction.

Most researchers have used Kinetic cameras to analyze different bony points and have studied skeleton infrared images to detect human body movement [50–53]. Classification algorithm like *k*-Nearest Neighbor (*k*-NN) [51], SVM [52, 53], hidden Markov model (HMM) [54], neural network (NN) [55], convolutional neural network (CNN) [56, 57] and others is proposed to detect fall. Accuracy of fall detection in elders regarding different algorithms was varying between 85% and 95%. Since Kinect is built mainly for virtual games, facilities have high cost, large size, complex algorithm, high hardware configurations, and complex usage.

Recently, the DL approach has additionally been increasingly utilized to fall detection [44–46, 58–66]. DL approaches require transferring data to the main server over the network for processing due to the difficulty of deployment directly on embedded devices. Although this procedure may encounter a high amount of processing, in some situations, such as nursing or monitoring homes, it promotes combined managing of the movement of the elderly in the outdoor environment to assure appropriate rescue in the event of a fall. Nevertheless, some approaches [44–46, 58–66] still require a considerable quantity of data to distinguish a fall incident, which occupies much network bandwidth in an IoT operation.

Although cameras can present all the data about the elderly, they breach people's privacy for vision-based sensors [27, 67–72]. Some cameras, such as thermal imaging, can be utilized to protect privacy. Additionally, thermal imaging can be used in image capturing through the night and in dark areas.

6.3 Proposed Methodology

The suggested approach is shown in Fig. 6.2. Kalman filter is used for the measurement labeled the system state. The Kalman filter thereby measures the structure by examining the definitive outcomes against calculated values and then scales the discrepancy.

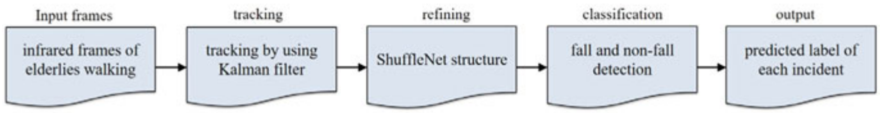


Fig. 6.2 The overall structure of the proposed method is to detect the non-fall and fall events

6.3.1 Tracking

The depicted equation below measures the Time t_i (Eq. 6.1) [73, 74]:

$$\widehat{E}(t_i) = G(t_i).\left[x(t_i) - M(t_i).\widehat{P}(t_i)\right] \tag{6.1}$$

In which, $G(t_i)$, $M(t_i)$, $x(t_i)$, and$\widehat{P}(t_i)$ are the Kalman gain, computing matrix, the system input, and predictive term, sequentially. Further, the $\widehat{P}(t_i)$ is described as Eq. (6.2):

$$\widehat{P}(t_i) = A(t_i).\widehat{E}(t_{i-1}) \tag{6.2}$$

The system matrix (i.e., the primary matrix is 2 × 2) is perpetual and is computed according to Eq. (6.3):

$$\begin{bmatrix} \widetilde{s}(x, y, t_i) \\ \widetilde{\dot{s}}(x, y, t_i) \end{bmatrix} = \begin{bmatrix} 1 & a_{1,2} \\ 0 & a_{2,2} \end{bmatrix} . \begin{bmatrix} \widehat{s}(x, y, t_i) \\ \widehat{\dot{s}}(x, y, t_i) \end{bmatrix} \tag{6.3}$$

where, $A(t_i)$ is distinctively expressed as the system matrix. Hence, the covariance matrix aids to develop the gain matrix. Within the proposed archetype, a specific frame is used as an input by utilizing the intensity rate of $s(x, y)$ at the time t_i. The measurement of the system state is thusly defined by using the $\widehat{s}(x, y, t_i)$, (i.e., intensity pixel of the background in point (x, y)). Moreover, the $\widehat{s}(x, y, t_i)$, the Eq. (6.1) can be rewritten as Eq. (6.3) by using estimation diversity:

$$\begin{bmatrix} \widehat{s}(x, y, t_i) \\ \widehat{\dot{s}}(x, y, t_i) \end{bmatrix} = \begin{bmatrix} \widetilde{s}(x, y, t_i) \\ s(x, y, t_i) \end{bmatrix} + G(x, y, t_i).\left(s(x, y, t_i) - M(x, y, t_i) \begin{bmatrix} \widehat{s}(x, y, t_i) \\ \widehat{\dot{s}}(x, y, t_i) \end{bmatrix} \right) \tag{6.4}$$

In which the background dynamics is denoted by using $a_{1,2} = a_{2,2} = 0.7$ and $H = [1\ 0]$. Additionally, the Kalman gains are defined as the matrix below (Eq. 6.5):

$$G(x, y, t_i) = \begin{bmatrix} g_1(x, y, t_i) \\ g_2(x, y, t_i) \end{bmatrix} \tag{6.5}$$

Inputs $g_1$and g_2 are expressed as:

$$g_1(x, y, t_i) = g_2(x, y, t_i) = \alpha.m_b(x, y, t_{i-1}) + \beta(1 - m_b(x, y, t_{i-1})) \tag{6.6}$$

It can be surmised that $m_b\ (x, y, t_{i-1})$ is a twofold plotting of pixels, which depicts whether a pixel with coordinates (x, y) in time t_{i-1} concords with the object's movement or the concentration of background pixels.

Equation (6.7) indicates this association in which the moving fragment or objective is defined as 1 and the background region is defined by zero value.

$$m_b(x, y, t_{i-1}) = \begin{cases} 1 & if\ P(x, y, t_{i-1}) \geq Th(x, y, t_{i-1}) \\ 0 & other \end{cases} \tag{6.7}$$

In Eq. (6.4), the gain factors would change if modes 0 or 1 appear and it is measured at the edge:

$$Th(x, y, t_i) = \left| \widehat{s}(x, y, t_i) - s(x, y, t_i) \right| \tag{6.8}$$

The above mentioned $Th(x, y, t_i)$ remains the same for x, y, and t_i values. If a moving item shall be within the background region, then a limitation should be placed according to the equation; however, on the contrary, it is deemed as the forefront area. Generally, if the variation between the computed grey-value in the background area and the supposed grey-value in mark (x, y) at given time t_{i-1} is determined to be above or similar to the $Th(x, y, t_i)$, then, the gain factor at given time t_i will be described as the α.

6.3.2 ShuffleNet

The extensive map channels included within the ShuffleNet framework are conducive to encrypting more information. Hence, the small architectures are considered more effective using the mentioned network. The uncertainty threshold is that lowered performance occurs in small frameworks using costly point-wise convolution (i.e., with a low count of channels). Like this, to produce the utmost correlation between input and output channels, it is suggested to collect information from different groups by group convolution. A ShuffleNet structure featuring point-wise group convolution (GConv) and channel shuffle was created and announced to minimize the complexity of the calculation process of 1 × 1 convolutions [75]. If the ShuffleNet is provided with a calculation allocation, then extensive feature maps can be utilized. This option will substantially augment the data processing volume for small networks that typically have insufficient channels. The insubstantial ShuffleNet framework is modified to repurpose the primary elderly movement detection initially introduced by the Kalman filter in the primary step. There are two segments within the redefined composition based upon a ShuffleNet with stride.

1. A 3 × 3 average pooling is appended to the circumventing route.
2. To maintain the reasonable cost of extending channel dimensions, the element-wise addition is substituted by concatenating the channel.

6.3.3 IoT Design

IoT framework comprises edge, cloud, and fog layers and provides processing, saving, organizing information, and managing the falling incidents of the elders. A three-step fall investigation structure and logical selection process are suggested. Hence, we will be able to perform estimations on every layer by utilizing instructions, energy management, the particular learning framework of every layer, and transfer techniques between tools and networks. For instance, a cellphone equipped with a FLIR ONE Thermal camera can detect falls by using both edge and fog as a tool. The suggested technique is also capable of being performed in actual time. This is facilitated by decreasing of resolution and dimension of frames and repurposing the frames to reduce the computational complexity. We intend to enhance the processing time by minimizing the data operating timeframe, enhancing accuracy regarding the constraints imposed on the overpopulation of elders in frames, and monitoring difficulties such as pixel occlusion or overlap between people and other non-human objects.

6.4 Experimental Results

The proposed structure is examined on the Thermal Fall revelation activity identification dataset. The dataset comprises motion images acquired by a FLIR ONE thermal recorder place on a smartphone equipped with Android OS in a room featured a sole viewpoint [24]. Out of 44 motion pictures, 35 videos of a fall incident are captured (36, 391 frames total, 828 fall frames). Only nine motion frames comprise ADL (22, 116 frames). The thermal images are set at 640 × 480 resolution. In Fig. 6.3, a few frames of ADL of the thermal images are showcased, which were gleaned from the captured motion frames set on 25 or 12 fps. The value for the primary learning rate (μ) in pre-train structures is appointed at 0.001.We employed fine-tuned procedure in TL structure. An approximate amount of 4–6 h is required to fine-tuning and prepare every convolutional ShuffleNet structural block. This matter is dependent on the precision of the training and test steps and the computation of errors.

Figure 6.3 has shown some examples of fall thermal images of an older person after applying them to preprocess. The data is separated into test and training data

Fig. 6.3 Several thermal frames of a person fall [24]

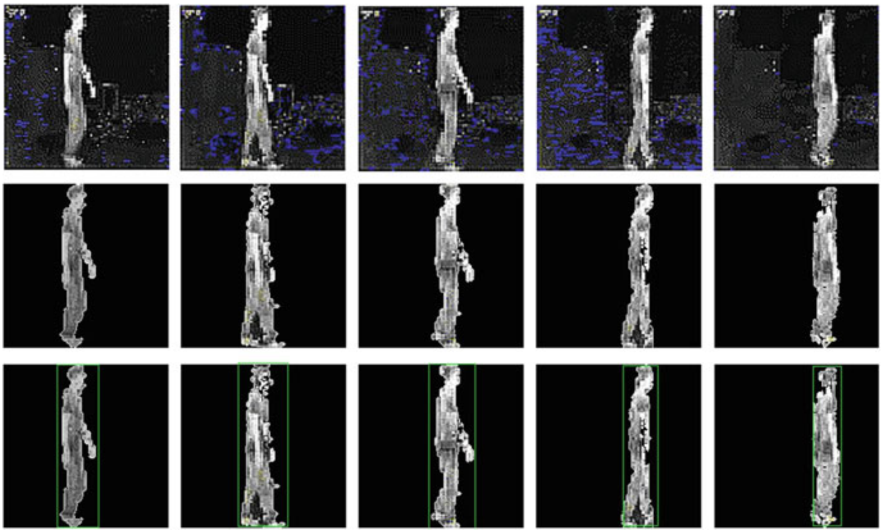


Fig. 6.4 The Kalman filter applies to infrared images (first row). The human bodies (second row) and tracking (third row) show the filter results

throughout the evaluation stage. We have proposed three fall stages which the proposed method evaluates and are processed in the IoT platform.

The three stages are different intensities of fall occurrence, which could help prediction of an upcoming accident. In first to third intensities, fall occurrence probability is low, medium, and high, respectively; these intensities are evaluated concerning elderly person body form changes. Most of the thermal frames of a person walking are labeled. The main advantage of labeling is the reduction and prevention of including frames without special and helpful information.

The error finding in the testing and training phase was indefinitely investigated to configure the optimal compatibility of every ShuffleNet model framework. If no sensible breakthrough in error finding and confirmation precision is not observed, the training procedure will be stopped.

As depicted in Fig. 6.4, we applied the Kalman filter into various motions frames to determine the dynamic placement of the elderly. The accuracies are evaluated in accordance with different structures to assess the efficiency of the fall detection model based on thermal or infrared frames.

As a result, the values of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) are determined for each time the method is performed in a 2 class problem. The first evaluations of tenrepetitions of similar methods are based on two classes, i. e, non-fall and events. Furthermore, second evaluations are conducted through three fall incidents, including high, medium, and low levels of intensities in fall events. Consequently, the results of the two states of classification have been represented in Tables 6.1 and 6.2, respectively. The maximum and minimum values of error measurements are depicted in Tables 6.2 and 6.3. The

Table 6.2 Evaluations of minimum and maximum values of calculated errors in two classes of fall detection

Tracking stage		Tracking+ ShuffleNet V1		Tracking+ ShuffleNet V2		Tracking+ ShuffleNet V3		Tracking+ Modified ShuffleNet		Tracking+ Modified ShuffleNet+ hand labeling	
Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑
0.17	0.20	0.06	0.14	0.07	0.13	0.05	0.09	0.03	0.04	0.01	0.03
0.16	0.22	0.06	0.14	0.07	0.13	0.06	0.10	0.02	0.05	0.02	0.03
0.17	0.24	0.07	0.15	0.06	0.13	0.06	0.09	0.03	0.07	0.005	0.03
0.16	0.19	0.06	0.15	0.05	0.14	0.06	0.08	0.03	0.06	0.02	0.04
0.22	0.24	0.10	0.15	0.09	0.11	0.08	0.09	0.03	0.05	0.015	0.03
0.16	0.18	0.09	0.13	0.07	0.12	0.09	0.08	0.02	0.05	0.015	0.02
0.16	0.22	0.07	0.16	0.08	0.10	0.06	0.10	0.04	0.07	0.015	0.02
0.19	0.24	0.06	0.15	0.06	0.10	0.05	0.11	0.04	0.06	0.01	0.04
0.20	0.24	0.06	0.12	0.08	0.12	0.09	0.09	0.04	0.07	0.01	0.05
0.18	0.21	0.08	0.14	0.07	0.11	0.07	0.11	0.05	0.07	0.01	0.03
0.177	0.218	0.072	0.143	0.071	0.119	0.067	0.086	0.033	0.059	0.013	0.032

Table 6.3 Evaluations of minimum and maximum values of calculated errors in three classes of fall detection

Tracking stage		Tracking+ ShuffleNet V1		Tracking+ ShuffleNet V2		Tracking+ ShuffleNet V3		Tracking+ Modified ShuffleNet		Tracking+ Modified ShuffleNet+ hand labeling	
Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑	Min↓	Max↑
0.19	0.22	0.11	0.15	0.08	0.17	0.09	0.14	0.06	0.11	0.04	0.08
0.20	0.23	0.10	0.17	0.10	0.18	0.10	0.15	0.06	0.09	0.04	0.08
0.16	0.24	0.12	0.19	0.11	0.17	0.10	0.12	0.05	0.10	0.05	0.07
0.15	0.18	0.11	0.17	0.12	0.16	0.08	0.13	0.06	0.10	0.04	0.08
0.19	0.24	0.13	0.17	0.11	0.17	0.07	0.15	0.07	0.11	0.03	0.09
0.17	0.20	0.11	0.17	0.13	0.16	0.10	0.14	0.08	0.10	0.04	0.10
0.20	0.22	0.09	0.19	0.10	0.15	0.12	0.17	0.06	0.12	0.05	0.08
0.17	0.24	0.10	0.18	0.09	0.16	0.11	0.15	0.04	0.09	0.05	0.07
0.18	0.25	0.11	0.17	0.10	0.17	0.10	0.14	0.06	0.09	0.04	0.07
0.17	0.23	0.12	0.20	0.08	0.16	0.08	0.14	0.08	0.10	0.03	0.07
0.179	0.225	0.108	0.176	0.101	0.156	0.095	0.143	0.062	0.101	0.041	0.069

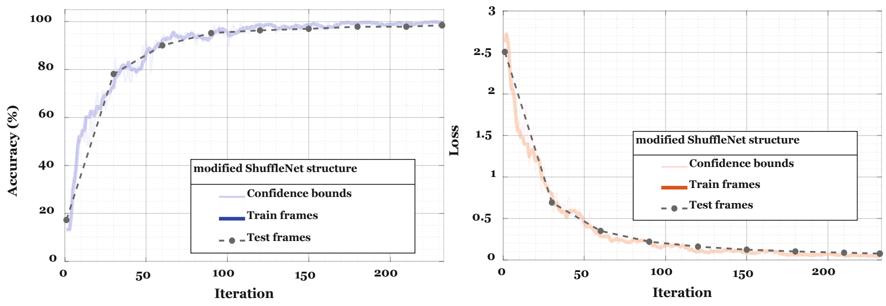


Fig. 6.5 The convergence speed of modified ShuffleNet based on train and test data

diagnosis accuracy of fall and non-fall incidents of various versions of ShuffleNet structures are outlined. These tables have compared different methods with the proposed method, including tracking, tracking with ShuffleNet V1, tracking with ShuffleNet V2, tracking with ShuffleNet V3, tracking with the modified form ShuffleNet V3, and tracking with the modified form ShuffleNet V3 with hand labeling the thermal frames.

As shown in Fig. 6.5, the convergence speed of modified ShuffleNet has shown in achieving optimal features considering the accuracy and loss function criteria. The train and test data have been analyzed, and the convergence has high speed based on limited epochs. There are difficulties in the Kalman filter because of an insignificant reduction in the total efficiency of identifying fall events. The accuracy of recognizing and tracking the elderly by this filter is relevant compared to other comparable systems in this field. Therefore, notwithstanding the overlap among the elderly's bodies, we can identify and track elders walking or nearing each other a short distance apart.

Nevertheless, the Kalman filter performs an optimal evaluation of the position of elders at each time movement. The Kalman filter further presents better results based on position assessments to prevent occlusion problems. The size of thermal images is decreased to 224 × 224 in relationship to the ShuffleNet input when the frames' resolution limits. The streamlined data labeling by an automatic method reduces computational complexity concerning modifying the analysis and sizes of video frames. Figure 6.6 depicts the performance of the proposedapproach in tracking and refining the results of tracking by modified ShuffleNet.The uncertainty problem has been solved to provide trust in outputs. The difference between the two test results in repeatable conditions was insignificant, and this point shown proportionally of results and their reliability.

We calculated variance and standard deviation 20 times for the first state of classification, and we obtained 2.45×10^{-4} and 0.0154, respectively. In the four-class state, these values were 2.99×10^{-4} and 0.0173, respectively. Additionally, we rejected the zero hypotheses (H_0). Subsequently, after calculation, we proved p-value (meaningful relationship of output classes with doctors' opinions about analysis of individual's movement in two-class and four-class model had values

Fig. 6.6 This figure shows the performance of the combined method in tracking and refining the results of tracking by modified ShuffleNet

Table 6.4 AUC values for thermal frame and anomaly level scores were used to compare the suggested method to similar strategies

Method	All frames	Tracked frames
Fusion-diff-ROI-3DCAE [23]	–	0.90–0.93
3DCAE-3DCNN [47]	0.95–0.96	0.88–0.90
Conv-LSTM AE [76]	0.76–0.83	0. 63–0.73
DSTCAE-C3D [48]	0.93–0.97	0.85–0.90
Kalman-modified ShuffleNet	0.95–0.98	0.94–0.98

lower than 0.028 and 0.045, respectively). Test results for all samples did not meet the acceptable range of H_0; thus, H_0 was not accepted ($\alpha = 0.05$ and thus $-Z_{\alpha-1}$ equals -1.65). The obtained values mean that the received confidence distance is more than 95%.

In similar studies utilizing fusion-Diff-ROI-3DCAE [23], 3DCAE-3DCNN [47], Conv-LSTM AE [76], and DSTCAE-C3D [48], the area under the curve (AUC) of ROC curve (i. e., receiver operating characteristic) was computes utilizing a criterion called frame-level anomaly score. Similar approaches do not present human tracking in the thermal video because the number of frames handled for testing and training varies. Hence, we test and train other models relating to the infrared frames on which the Kalman filter localizes an elderly human as a tracking technique. Table 6.4 reveals a comparison of the proposed model with previous systems using tracked thermal frames only, abbreviated as:

1. When only tracked thermal frames are used, the AUC values of similar approaches for fall detection decrease. Furthermore, the test and train sets in videos include similar empty thermal frames. Besides, minimal regeneration error on their thermal frames may result in high AUC values in older designs when testing data is used to examine the system.
2. The suggested techniques produce more reliable AUC of ROC than similar approaches. Also, a higher AUC was achieved against other models. The scheme concentrates on the region in the thermal frame where a human has movement.

Furthermore, to build a generalizable system, noise and improper information of frames in the scene could increase the network's complexity intended to achieve a suitable clarification. On the other hand, the proposed procedure indicates an automated approach that interprets thermal frames of fall and non-fall events. Furthermore, compared to hand-crafted feature extraction models, the deep learning strategies can learn optimal features without the need for additional feature extraction or feature engineering [77–79].The DTL model extracts rich features utilizing a modified ShuffleNet structure. Additionally, the ShuffleNet structure has been directed to a robust strategy due to conventional extracted features that significantly avoid overfitting problems in the walking analysis. It should be noted that the IoT components handle all activities and data flows. As a result, we presented a scenario in this chapter to demonstrate how to implement a fall detection system on IoT layers. We address ideas and difficulties as solutions in the end.

6.5 Conclusion

In this chapter, a practical model has been implemented for automated realizing fall and non-fall incidents as a monitoring system of elderly walking. Our model employs Kalman filter and deep modified ShffleNet learning to analyze the elderly activity based on thermal imaging. Infrared video frames of various kinds of action behaviors are employed as the test datasets to preserve individuals' privacy. Alternatively, infrared imaging and thermography techniques can capture valuable data of movement in older people. Therefore, a system can be established to obtain high accuracy on fall detection. It's worth noting that the thermal frames acquired are far lower in resolution than visible video footage. Both normal actions walking and falling incidents, had typical accurate categorization rates of around 95%. Several thermal and infrared frames were evaluated at the same time using various techniques. The experimental results show that the suggested algorithm for fall detection has a greater realization accuracy for different infrared video image datasets. It may effectively improve the accuracy of accidental falling diagnosis and present more aid as a health protection system. Hence, the mentioned design contributes a thoughtful scheme for fall detection of the elderly living alone while respecting their privacy.

Moreover, the IoT principles were employed in data analysis, which could be established as an emerging system that promotes processing and handling a fall analysis method in a real-time manner. The fall detection system is regarded as three steps, including prevention, prediction, and recognition parts. Moreover, The IoT has presented Fog, Edge, and Cloud cores as IoT layers to perform a fall event detection technology.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Rezaee, K., Haddadnia, J., & Delbari, A. (2015). Modeling abnormal walking of the elderly to predict risk of the falls using Kalman filter and motion estimation approach. *Computers & Electrical Engineering, 46*, 471–486.
2. Espinosa, R., Ponce, H., Gutiérrez, S., Martínez-Villaseñor, L., Brieva, J., & Moya-Albor, E. (2019). A vision-based approach for fall detection using multiple cameras and convolutional neural networks: A case study using the UP-fall detection dataset. *Computers in Biology and Medicine, 115*, 103520.
3. Rezaee, K., Haddadnia, J., & Delbari, A. (2013). Intelligent detection of the falls in the elderly using fuzzy inference system and video-based motion estimation method. In *2013 8th Iranian Conference on Machine Vision and Image Processing (MVIP)* (pp. 284–288).
4. Jokanović, B., & Amin, M. (2017). Fall detection using deep learning in range-Doppler radars. *IEEE Transactions on Aerospace and Electronic Systems, 54*(1), 180–189.
5. Rezaee, K., Haddadnia, J., Delbari, A., & Madanian, M. (2014). Predicting and monitoring of the elderly falls based on modeling of the motion patterns obtained from video sequences. *Iranian Journal of Ageing, 8*(4), 15–23.
6. Rezaee, K., Haddadnia, J., & Delbari, A. (2014). Elderly fall monitoring system based on Gaussian mixture models and anatomical changes in video sequences. *Journal of Machine Vision and Image Processing, 1*(2), 67–77.
7. Mobasheri, A., Rayman, M. P., Gualillo, O., Sellam, J., Van Der Kraan, P., & Fearon, U. (2017). The role of metabolism in the pathogenesis of osteoarthritis. *Nature Reviews Rheumatology, 13*(5), 302–311.
8. Ling, H., Wu, J., Li, P., & Shen, J. (2019). Attention-aware network with latent semantic analysis for clothing invariant gait recognition. *CMC-Computers Materials & Continua, 60*(3), 1041–1054.
9. Deleidi, M., Jäggle, M., & Rubino, G. (2015). Immune aging, dysmetabolism, and inflammation in neurological diseases. *Frontiers in Neuroscience, 9*, 172.
10. Zadeh, H. G., Kazerouni, I. A., Haddadnia, J., Rahmanian, M., Javidan, R., & Dezfuli, M. A. (2011). Distinguish breast cancer based on thermal features in infrared images. *Canadian Journal on Image Processing and Computer Vision, 2*(6), 54–58.
11. GhayoumiZadeh, H., Haddadnia, J., Hashemian, M., & Hassanpour, K. (2012). Diagnosis of breast cancer using a combination of genetic algorithm and artificial neural network in medical infrared thermal imaging. *Iranian Journal of Medical Physics, 9*(4), 265–274.

12. Ozcan, K., Velipasalar, S., & Varshney, P. K. (2016). Autonomous fall detection with wearable cameras by using relative entropy distance measure. *IEEE Transactions on Human-Machine Systems, 47*(1), 31–39.
13. Rezaee, K., & Haddadnia, J. (2014). Design of fall detection system: A dynamic pattern approach with fuzzy logic and motion estimation. *Information Systems & Telecommunication, 3*(7), 181.
14. Iazzi, A., Rziza, M., & Thami, R. O. H. (2021). Fall detection system-based posture-recognition for indoor environments. *Journal of Imaging, 7*(3), 42.
15. Khan, S. S., & Hoey, J. (2017). Review of fall detection techniques: A data availability perspective. *Medical Engineering & Physics, 39*, 12–22.
16. Malik, R., Rastogi, K., Tripathi, V., & Badal, T. (2019). An efficient vision based elderly care monitoring framework using fall detection. *Journal of Statistics and Management Systems, 22*(4), 603–611.
17. Iuga, C., Drăgan, P., & Bușoniu, L. (2018). Fall monitoring and detection for at-risk persons using a UAV. *IFAC-PapersOnLine, 51*(10), 199–204.
18. Mubashir, M., Shao, L., & Seed, L. (2013). A survey on fall detection: Principles and approaches. *Neurocomputing, 100*, 144–152.
19. Pannurat, N., Thiemjarus, S., & Nantajeewarawat, E. (2014). Automatic fall monitoring: A review. *Sensors, 14*(7), 12900–12936.
20. Hader, G. K., Ben Ismail, M. M., & Bchir, O. (2020). Automatic fall detection using region-based convolutional neural network. *International Journal of Injury Control and Safety Promotion, 27*(4), 546–557.
21. Igual, R., Medrano, C., & Plaza, I. (2013). Challenges, issues and trends in fall detection systems. *Biomedical Engineering Online, 12*(1), 1–24.
22. Yu, M., Yu, Y., Rhuma, A., Naqvi, S. M. R., Wang, L., & Chambers, J. A. (2013). An online one class support vector machine-based person-specific fall detection system for monitoring an elderly individual in a room environment. *IEEE Journal of Biomedical and Health Informatics, 17*(6), 1002–1014.
23. Mehta, V., Dhall, A., Pal, S., & Khan, S. S. (2021). Motion and region aware adversarial learning for fall detection with thermal imaging. In *2020 25th International Conference on Pattern Recognition (ICPR)* (pp. 6321–6328).
24. Vadivelu, S., Ganesan, S., Murthy, O. R., & Dhall, A. (2016, November). Thermal imaging based elderly fall detection. In *Asian conference on computer vision* (pp. 541–553). Springer.
25. Cao, X., & Zhang, H. (2021). Falling detection research based on elderly behavior infrared video image contours ellipse fitting. *International Journal of Pattern Recognition and Artificial Intelligence, 35*(2), 2154004.
26. Tzeng, H. W., Chen, M. Y., & Chen, J. Y. (2010). Design of fall detection system with floor pressure and infrared image. In *2010 International Conference on System Science and Engineering* (pp. 131–135).
27. Sokolova, M. V., et al. (2013). A fuzzy model for human fall detection in infrared video. *Journal of Intelligent & Fuzzy Systems, 24*(2), 215–228.
28. Tao, S., Kudo, M., & Nonaka, H. (2012). Privacy-preserved behavior analysis and fall detection by an infrared ceiling sensor network. *Sensors, 12*(12), 16920–16936.
29. Liu, Z., Yang, M., Yuan, Y., & Chan, K. Y. (2020). Fall detection and personnel tracking system using infrared array sensors. *IEEE Sensors Journal, 20*(16), 9558–9566.
30. Deep, S., Zheng, X., Karmakar, C., Yu, D., Hamey, L. G., & Jin, J. (2019). A survey on anomalous behavior detection for elderly care using dense-sensing networks. *IEEE Communications Surveys & Tutorials, 22*(1), 352–370.
31. Khosravi, M. R., & Samadi, S. (2019). Efficient payload communications for IoT-enabled ViSAR vehicles using discrete cosine transform-based quasi-sparse bit injection. *EURASIP Journal on Wireless Communications and Networking, 2019*(1), 1–10.

32. Abou-Nassar, E. M., Iliyasu, A. M., El-Kafrawy, P. M., Song, O. Y., Bashir, A. K., & Abd El-Latif, A. A. (2020). DITrust chain: Towards blockchain-based trust models for sustainable healthcare IoT systems. *IEEE Access, 8*, 111223–111238.
33. Jangra, P., & Gupta, M. (2018, August). A design of real-time multilayered smart healthcare monitoring framework using IoT. In *2018 International Conference on Intelligent and Advanced System (ICIAS)* (pp. 1–5).
34. Baker, S. B., Xiang, W., & Atkinson, I. (2017). Internet of things for smart healthcare: Technologies, challenges, and opportunities. *IEEE Access, 5*, 26521–26544.
35. Santos, J., Rodrigues, J. J., Silva, B. M., Casal, J., Saleem, K., & Denisov, V. (2016). An IoT-based mobile gateway for intelligent personal assistants on mobile health environments. *Journal of Network and Computer Applications, 71*, 194–204.
36. Mass, J., Chang, C., & Srirama, S. N. (2019). Edge process management: A case study on adaptive task scheduling in mobile IoT. *Internet of Things, 6*, 100051.
37. Kumar, G. (2021). Fuzzy based hybrid genetic algorithm for efficient cloud job scheduling. *Journal of Advanced Database Management & Systems, 8*(1), 6–16.
38. Attar, H. H., Solyman, A. A., Alrosan, A., Chakraborty, C., & Khosravi, M. R. (2021). Deterministic cooperative hybrid ring-mesh network coding for big data transmission over lossy channels in 5G networks. *EURASIP Journal on Wireless Communications and Networking, 2021*(1), 1–18.
39. Jin, C., Yang, Y., Xue, Z. J., Liu, K. M., & Liu, J. (2013). Automated analysis method for screening knee osteoarthritis using medical infrared thermography. *Journal of Medical and Biological Engineering, 33*(5), 471–477.
40. Lasanen, R., Piippo-Savolainen, E., Remes-Pakarinen, T., Kröger, L., Heikkilä, A., Julkunen, P., et al. (2015). Thermal imaging in screening of joint inflammation and rheumatoid arthritis in children. *Physiological Measurement, 36*(2), 273.
41. Calin, M. A., Mologhianu, G., Savastru, R., Calin, M. R., & Brailescu, C. M. (2015). A review of the effectiveness of thermal infrared imaging in the diagnosis and monitoring of knee diseases. *Infrared Physics & Technology, 69*, 19–25.
42. EtehadTavakol, M., Lucas, C., Sadri, S., & Ng, E. Y. K. (2010). Analysis of breast thermography using fractal dimension to establish possible difference between malignant and benign patterns. *Journal of Healthcare Engineering, 1*(1), 27–43.
43. Subedi, S., Umbaugh, S. E., Fu, J., Marino, D. J., Loughin, C. A., & Sackman, J. (2014, September). Thermographic image analysis as a pre-screening tool for the detection of canine bone cancer. In *Applications of Digital Image Processing XXXVII* (Vol. 9217, p. 92171D). International Society for Optics and Photonics.
44. Hsieh, Y. Z., & Jeng, Y. L. (2017). Development of home intelligent fall detection IoT system based on feedback optical flow convolutional neural network. *IEEE Access, 6*, 6048–6057.
45. Vaiyapuri, T., Lydia, E. L., Sikkandar, M. Y., Díaz, V. G., Pustokhina, I. V., & Pustokhin, D. A. (2021). Internet of things and Deep learning enabled elderly fall detection model for smart homecare. *IEEE Access, 9*, 113879–113888.
46. Kong, X., Chen, L., Wang, Z., Chen, Y., Meng, L., & Tomiyama, H. (2019). Robust self-adaptation fall-detection system based on camera height. *Sensors, 19*(17), 3768.
47. Khan, S. S., Nogas, J., & Mihailidis, A. (2021). Spatio-temporal adversarial learning for detecting unseen falls. *Pattern Analysis and Applications, 24*(1), 381–391.
48. Nogas, J., Khan, S. S., & Mihailidis, A. (2020). Deepfall: Non-invasive fall detection with deep spatio-temporal convolutional autoencoders. *Journal of Healthcare Informatics Research, 4*(1), 50–70.
49. Snekhalatha, U., & Sangamithirai, K. (2021). Computer aided diagnosis of obesity based on thermal imaging using various convolutional neural networks. *Biomedical Signal Processing and Control, 63*, 102233.
50. Xiong, X., Min, W., Zheng, W. S., Liao, P., Yang, H., & Wang, S. (2020). S3D-CNN: Skeleton-based 3D consecutive-low-pooling neural network for fall detection. *Applied Intelligence, 50*(10), 3521–3534.

51. Panahi, L., & Ghods, V. (2018). Human fall detection using machine vision techniques on RGB–D images. *Biomedical Signal Processing and Control, 44*, 146–153.
52. Berlin, S. J., & John, M. (2021). Vision based human fall detection with Siamese convolutional neural networks. *Journal of Ambient Intelligence and Humanized Computing, 2017*, 1–12.
53. Li, H., Li, C., & Ding, Y. (2021). Fall detection based on fused saliency maps. *Multimedia Tools and Applications, 80*(2), 1883–1900.
54. Ismail, M. M. B., & Bchir, O. (2017). Automatic fall detection using membership based histogram descriptors. *Journal of Computer Science and Technology, 32*(2), 356–367.
55. Alhimale, L., Zedan, H., & Al-Bayatti, A. (2014). The implementation of an intelligent and video-based fall detection system using a neural network. *Applied Soft Computing, 18*, 59–69.
56. Zhang, Z., Ma, X., Wu, H., & Li, Y. (2018). Fall detection in videos with trajectory-weighted deep-convolutional rank-pooling descriptor. *IEEE Access, 7*, 4135–4144.
57. Hagui, M., Mahjoub, M. A., & ElAyeb, F. (2019). A new framework for elderly fall detection using coupled hidden Markov models. *The International Arab Journal of Information Technology, 16*(4), 775–783.
58. Shen, L., Zhang, Q., Cao, G., & Xu, H. (2018, July). Fall detection system based on deep learning and image processing in cloud environment. In *Conference on Complex, Intelligent, and Software Intensive Systems* (pp. 590–598). Springer.
59. Pourazad, M. T., Shojaei-Hashemi, A., Nasiopoulos, P., Azimi, M., Mak, M., Grace, J., et al., (2020, January). A non-intrusive deep learning based fall detection scheme using video cameras. In *2020 International Conference on Information Networking (ICOIN)* (pp. 443–446).
60. Ezatzadeh, S., Keyvanpour, M. R., & Shojaedini, S. V. (2021). A human fall detection framework based on multi-camera fusion. *Journal of Experimental & Theoretical Artificial Intelligence*, 1–20.
61. Leite, G., Silva, G., & Pedrini, H. (2019, December). Fall detection in video sequences based on a three-stream convolutional neural network. In *2019 18th IEEE International Conference on Machine Learning and Applications (ICMLA)* (pp. 191–195).
62. Cameiro, S. A., da Silva, G. P., Leite, G. V., Moreno, R., Guimarães, S. J. F., & Pedrini, H. (2019, June). Multi-stream deep convolutional network using high-level features applied to fall detection in video sequences. In *2019 International Conference on Systems, Signals and Image Processing (IWSSIP)* (pp. 293–298).
63. Cai, X., Liu, X., An, M., & Han, G. (2021). Vision-based fall detection using dense block with multi-channel convolutional fusion strategy. *IEEE Access, 9*, 18318–18325.
64. Sengto, A., & Leauhatong, T. (2012, December). Human falling detection algorithm using back propagation neural network. In *The 5th 2012 Biomedical Engineering International Conference* (pp. 1–5). IEEE.
65. Lu, N., Wu, Y., Feng, L., & Song, J. (2018). Deep learning for fall detection: Three-dimensional CNN combined with LSTM on video kinematic data. *IEEE Journal of Biomedical and Health Informatics, 23*(1), 314–323.
66. Galvão, Y. M., Ferreira, J., Albuquerque, V. A., Barros, P., & Fernandes, B. J. (2021). A multimodal approach using deep learning for fall detection. *Expert Systems with Applications, 168*, 114226.
67. Rafferty, J., Synnott, J., Nugent, C., Morrison, G., & Tamburini, E. (2016). Fall detection through thermal vision sensing. In *Ubiquitous Computing and Ambient Intelligence* (pp. 84–90). Springer.
68. Zhong, C., Ng, W. W., Zhang, S., Nugent, C. D., Shewell, C., & Medina-Quero, J. (2020). Multi-occupancy fall detection using non-invasive thermal vision sensor. *IEEE Sensors Journal, 21*(4), 5377–5388.
69. Rafferty, J., Medina-Quero, J., Quinn, S., Saunders, C., Ekerete, I., Nugent, C., et al. (2019, May). Thermal vision based fall detection via logical and data driven processes. In *2019 IEEE International Conference on Big Data, Cloud Computing, Data Science & Engineering (BCD)* (pp. 35–40).

70. Bhandari, S., Babar, N., Gupta, P., Shah, N., & Pujari, S. (2017, October). A novel approach for fall detection in home environment. In *2017 IEEE 6th Global Conference on Consumer Electronics (GCCE)* (pp. 1–5).
71. Kido, S., Miyasaka, T., Tanaka, T., Shimizu, T., & Saga, T. (2009, January). Fall detection in toilet rooms using thermal imaging sensors. In *2009 IEEE/SICE International Symposium on System Integration (SII)* (pp. 83–88). IEEE.
72. Yu, L., Chen, H., He, H., Nie, H., Zhai, X., & Xiong, B. (2020, July). A fall detection system based on a thermopile imaging Array and a Back projection algorithm. In *2020 IEEE International Conference on Electro Information Technology (EIT)* (pp. 060–065). IEEE.
73. Chan, Y. T., Hu, A. G. C., & Plant, J. B. (1979). A Kalman filter based tracking scheme with input estimation. *IEEE Transactions on Aerospace and Electronic Systems, 2*, 237–244.
74. Kh, R., Ghezelbash, M. R., Haddadnia, J., & Delbari, A. (2012, December). An intelligent surveillance system for falling elderly detection based on video sequences. In *19th Iranian Conference of Biomedical Engineering (ICBME), Tehran, Iran* (pp. 20–21).
75. Zhang, X., Zhou, X., Lin, M., & Sun, J. (2018). Shufflenet: An extremely efficient convolutional neural network for mobile devices. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 6848–6856).
76. Nogas, J., Khan, S. S., & Mihailidis, A. (2018, July). Fall detection from thermal camera using convolutional LSTM autoencoder. In *Proceedings of the 2nd workshop on aging, rehabilitation and independent assisted living*, IJCAI Workshop.
77. Ravi, V., Narasimhan, H., Chakraborty, C., & Pham, T. D. (2021). Deep learning-based meta-classifier approach for COVID-19 classification using CT scan and chest X-ray images. *Multimedia Systems*, 1–15.
78. Rezaee, K., Badiei, A., & Meshgini, S. (2020, November). A hybrid deep transfer learning based approach for COVID-19 classification in chest X-ray images. In *2020 27th National and 5th International Iranian Conference on Biomedical Engineering (ICBME)* (pp. 234–241).
79. Rezaee, K., Rezakhani, S. M., Khosravi, M. R., & Moghimi, M. K. (2021). A survey on deep learning-based real-time crowd anomaly detection for secure distributed video surveillance. *Personal and Ubiquitous Computing*, 1–17.

Chapter 7
An Analytic Approach to Diagnose Heart Stroke Using Supervised Machine Learning Techniques

Anurima Majumdar, Sunipa Roy, and Chinmay Chakraborty

Abstract This chapter proposed how machine-learning algorithms can be used in developing intelligent health management systems (IHMS) specially for cardiovascular disease. With the increasing load of cardiovascular disease and events on the human race the proper diagnosis of the disease within time and prediction of the disease can save more lives. In this chapter the rudiments of machine learning algorithms are discussed. Six Supervised classification based techniques are analysed and compared to find the most suitable model to predict cardiovascular disease or chances of cardiovascular events for the provided dataframe. Six algorithms are used here. The Confusion matrix for each of the classifiers is evaluated. Comparative bar plot and AUC ROC plot is generated to measure the executions of the prototypes. It is observed that Support-Vector-Machine and K-Nearest-Neighbors achieved the highest accuracy (96.20%) which makes them most suitable for heart attack or myocardial infarction (MI) prediction for this given dataset.

Keywords Intelligent health management systems (IHMS) · Supervised machine learning · Naïve Bayes · Decision trees · Random forest · K-nearest neighbors · Logistic regression · Support vector machine · MI prediction · Confusion matrix · AUC-ROC plot

7.1 Introduction

The concept of heart disease or Cardio Vascular Disease (CVDs) can only affect people who are at their 40's or 50's is not valid anymore. In a recent study in 2019 by WHO, it was shown that heart attack is one of the prime-causes of death globally.

A. Majumdar (✉) · S. Roy
Department of Electronics and Communication Engineering, Guru Nanak Institute of Technology, Kolkata, West Bengal, India

C. Chakraborty
Birla Institute of Technology- Mesra, Ranchi, Jharkhand, India
e-mail: cchakrabarty@bitmesra.ac.in

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_7

Now a days even young adults in their early or mid-20s are also getting affected with the most common diseases like diabetes, high-blood pressure, hypertension, cardiac arrhythmias, and cardiovascular disease especially coronary heart disease (CHDs) which is the main reason behind strokes and sudden cardiac arrests (SDC). In some contemporary research by WHO (World Health Organization), appears that the main contributors behind the increasing rate of heart disease is the detrimental and improper lifestyle. In India from the prevalence of heart disease and stroke grew by 50% from 1990 to 2016. In past 25 years the mortality burden due to these disease over total deaths and disease has doubled in this country. In some recent studies [1, 2] it has been seen that during COVID-19 outbreak the risk of cardiovascular disease and events like stroke or heart attack increased. The main reason is suspected to be the fewer detection of cardiovascular events. The doctors on field were worried when a significant decrease was observed for cardiovascular events. "What happened to all those cardiovascular patients!!! Where are the heart attacks!! !" and it was suspected that due to the pandemic and the infectious nature of COVID-19, many people who are in potential danger of cardiovascular events are not seeking necessary medical treatment that they needed due to the fear of getting COVID-19 affected. It has been observed that deaths from Ischemic heart disease have increased significantly (almost 139% [2]) after the COVID-19 outbreak. Many people who got affected by COVID-19 got well but unfortunately ended up having a weak heart, hence increasing the chances of cardiovascular events. So in this current situation it can easily be predicted that the overall cardiovascular event burdens on the whole world are going to increase significantly in his coming years. It is observed that with proper lifestyle changes and adaptations of heart healthy habits not only decreases the risks of getting a heart disease in a healthy individual but also reduce the rate of morbidity due to ischemic events in patients. Also diagnosis of the disease in an early stage helps to reduce morbidity and increase the chance of a longer life span. Hence predicting and taking precautions are the best way to control this disease.

In this chapter a demonstration is given on how an intelligent health care system can be established by using supervised machine learning techniques. By Intelligent Health care system it means that an automated system which will keep the information regarding the vitals of the patient and the particular symptoms of the disease. That system will not only monitor the patient health but also can predict the chances of getting a certain disease in a healthy individual. Predicting and taking precaution accordingly can save many lives and sometimes can improve the life expectancy and the quality of living of the sufferer. First six different types of supervised Machine Learning models are compared and the finest with the best accuracy is investigated. A model based on the pre-eminent algorithm is implemented for monitoring and detection of the disease.

Major Contributions and Chapter Organisation:

- This chapter mainly focuses on the utilisation of modern analysis approaches such as Machine Learning to get a perfect picture of this medical emergency and how the medical facility can be improved so that it can be helpful for both, the patient and the doctors.

- In this research chapter we have identified the major parameters and performed predictive analysis and compared the results using five different machine learning algorithms i.e., Naïve Bayes(NB), Decision Trees(DT), Random Forest(RF), K-Nearest Neighbors (KNN), Logistic Regression (RL), Support Vector Machine (SVM). After performing the analysis, SVM Algorithm gave the best result.
- The main idea behind using the comparative model is to find out the best model that fits into the dataset, so that the doctors can have a better understanding of the problems regarding to a particular patient, making necessary analysis that is not only clear for the doctors but for the part of patients as well. This system can be implemented in the health sectors and can also be readily made available to the common man as an app so that they can get pre-notion about their problem, if suffering and get sure about the disease.
- The model for SVM and KNN achieved the highest performance for predicting MI with an accuracy of 96.20%.
- The chapter also provides an insight of the cardiovascular load on the society and need to detect it earlier
- The chapter demonstrates the role of supervised machine learning techniques for disease detection.

So, with this it will be easier to understand these algorithms but also their advantage of applications in Intelligent Health Care System Management (IHCSM).

The main objective and motivation of the chapter encompasses the very nature of cardiovascular disease, its fatality on human life, basics of Machine learning algorithms focusing supervised algorithms including case studies. The chapter aims to investigate whether machine-learning-algorithms can be up skilled to analyse and predict heart stroke and for that six interpretable machine learning algorithms i.e., Naïve Bayes(NB), Decision Trees(DT), Random Forest(RF), K-Nearest Neighbors (KNN), Logistic Regression (RL), Support Vector Machine (SVM) is used.

The first section of the chapter introduces the investigation work along with the objectives, motivations and contributions of the study; Section 7.2 reviews and discusses the literature survey. In the third section an overview of different machine learning algorithm is given. Section 7.4 investigates the generation of Machine learning Models for a given Dataset to predict heart attack and a comparative study followed by major deliverable, challenges and future scope. Conclusions are discussed in Sect. 7.5. In the last section all the references are mentioned.

7.2 Literature Survey

The paper [3] authors demonstrated the diagnosis procedure of "QDS" by using "microcosmic biological parameters". They have also established the fact that the malady in TCM can be detected in the microcosmic level. Authors in Ref. [4]

analysed the relation of “traditional Chinese medicine (TCM)” syndrome progression and cardiovascular disease in “patients with stable coronary heart disease (CHD)”. They have approached an investigation using compound networks to provide some valuable evidences for establishing a more effective intervention strategy with CM to stable CHD. In Ref. [5] authors seek to develop a “Smart Health Monitoring System” with machine learning. The arrangement can be able to define five parameters such as Electrocardiogram (ECG), Pressure, Temperature, Pulse rate, and Position identification by using wearable sensors. Also, a webpage will be used for live monitoring. The paper [6] exhibits a process to assort MI that integrates text mining tools and machine learning algorithms. They suggested the idea of mining patients’ features from the case sheets and the system is trained with the collected data. Data mining techniques in traditional medicine which was related to syndrome differentiation is used in Ref. [7]. In Ref. [8] authors proposed a method that will filter patients’ electrocardiograms (ECGs) and applies machine-learning classifiers to estimate seriousness. Also, in Ref. [9] authors proposed a pragmatic perspective to solve the issue of labeling multi-syndromes at once by using standardized exploration model. In the paper Ref. [10] authors approached methods of complex network and CHAID decision tree were applied to identify the TCM core syndromes of patients with CHD, and to establish TCM syndrome identification modes of CHD based on biological parameters. In Ref. [11] authors have proposed a new feature selection model that combines support vector machines with the glowworm swarm- optimization-algorithm based on the standard deviation of the features. Authors in Ref. [12] also found a solution for learning individual time series. In Ref. [13] authors provide assessment of the fundamental concepts and methods used for Machine Learning and its utilisation. The paper [14] represents an analysis to explore an automated-approach to EMR-based-pheno-typing-of stroke and its solutions. In Ref. [15] the research effort here presents a better insight to the integration of TCM and western medicine. The paper [16] describes anwee planned machine learning based identification system has been developed for the diagnosis of heart ailment. Also, in Ref. [17] authors have applied machine learning techniques to the problem of analyzing the functional outcome of ischemic stroke patients, post admission. The comparative study and role of machine learning strategies in analysis and prediction of disease are reported by authors [18–22]. Artificial intelligence is also applied for COVID-19 detection. Gaussian mixture model-universal background model (GMM-UBM) technique using the voice signal has been implemented to detect COVID 19 [23]. The AUC-ROC curves displayed the performance of the model in the range of 60–67%. Dash et al. reported one intelligent computing model to predict the SARS-CoV-2 pandemic outbreak [24]. The proposed prophet model is able to detect the variations in the growth pattern of disease which will be helpful to detect the risk factors and monitor the disease. A preprogrammed testing system for continuous chronic wound status monitoring [25]. Fuzzy c-means clustering for wound image segmentation, with the standard computational learning schemes: Linear Discriminant Analysis (LDA), Decision Tree (DT), Naïve Bayesian (NB) and Random Forest (RF) is proposed. 93.75% accuracy is reported. A review of the contribution of machine learning (ML) and IoT to square up to the epidemic is reported by Chakraborty et al. [26].

The case study (open source) reported by Abedi et al. [18]. In their work Author Abedi et al. (2021) used machine learning techniques to predict recurrence of stroke. Data from e-health records were used. Total of six-Machine-Learning algorithms were used to analyse namely-"Logistic-Regression,-Extreme Gradient Boosting, Gradient Boosting Machine, Random Forest, Support Vector Machine, Decision Tree". Total 2091 ischemic stroke were included for the study. The main objective was to see whether machine learning algorithms could be trained to predict such incidents.

The authors extracted data from GNSIS ("Geisinger Neuroscience Ischemic Stroke ("GNSIS")") dataset which was formed based on data and phenotypes developed by the research teams.

The data elements that were recorded and used for the research reported are (1) event date, (2) patient's age, (3) encounter type, (4) ICD ("International Classification of Diseases, Ninth/Tenth Revision") code and primary detection of the firstMI event, (5) if there is any recurrent-stroke, and (6) ICD code and initial diagnosis for the recurrence. Sex, Date of Birth, Date of Death, if there is any ancestral history of such event, last visit within the Geisinger system, comorbidities, and smoking status. Four characteristics selection strategies, five-prediction-windows, and two-sampling-strategies for developing 288 models are used to predict the recurrence in coming 5-years.

In the study the authors excluded patients who had repeated stroke within twenty four days of the first stroke. This 24 days window was considered to establish that the repeated stroke was unconstrained of the first event. The patients were divided into six groups. one-control group and five-case groups. The control group was with patients without any stroke recurrence during the 5-year follow-up. The rest comprised of patients who had a recurrence of the event between 24 days and "1, 2, 3, 4, and 5-years,"respectively.

During the data processing the individual case and control groups were divided into 80:20 ratio training and testing data. Total 53 features were used. Four sets of feature selection strategies were used "Set 1-all features; Set 2-all features except medication history; Set 3-features selected by at least two data-driven strategies; and Set 4-minimum set, obtained as the intersect of Set 2 and Set 3" [18].

Total 2091 adult patients come across the criteria for inclusion; 114 patients had a repeated stroke within 24 days from their first stroke event and were barred from the investigation. 51.6% were male patients. The average age was 68.1 years ("IQR (interquartile range) = 58–77"). 72% cases were of hypertension, 62% were of dyslipidemia and 29% were with diabetes. The rate of stroke reappearance was 11%, 16%, 18%, 20%, and 21% at 1, 2, 3, 4, and 5-year window, respectively.

Five data-driven approaches were used as described by the authors [18]:"(1) filter-based methods including Pearson correlation and univariate filtering; (2) embedded methods including RF and Lasso Regression; and (3) wrapper methods including the Boruta algorithm and recursive feature elimination". The methods of up sampling and down sampling were used to balance between minority class (recurrent stroke) and the dominant class. During up-sampling, “Synthetic Minority Over-sampling Technique (SMOTE)” were used and in the down-sampling, random selection of patients from the control group were done.

Six interpretable ML algorithms: “Logistic Regression(LR), Extreme Gradient Boosting (XGBoost), Gradient Boosting Machine(GBM), Random Forest(RF), Support Vector Machine(SVM), Decision Tree(DT)” and 4 feature or variable sets were used in this reported research [18]. This report was proposed to study the efficiency of machine learning algorithms in detecting chances of brain stroke recurrence with the help of the five above mentioned algorithms.

7.3 Machine Learning and It’s Algorithms

Machine learning is basically a family of algorithms which can adopt and improvise itself with the increment of input data amount. So it will automatically build a model depending on the basis of provided data with minimal human mediation. As the volume of data increase and varieties of data is growing, the demand of less complicated, cheaper and powerful computational process is also getting high.

Machine Learning Algorithms can be divided into three types (Fig. 7.1)

1. Supervised Machine Learning: Supervised Learning is when an input dataset with the accurate answer or desired output in it is provided to the model to train it. Here

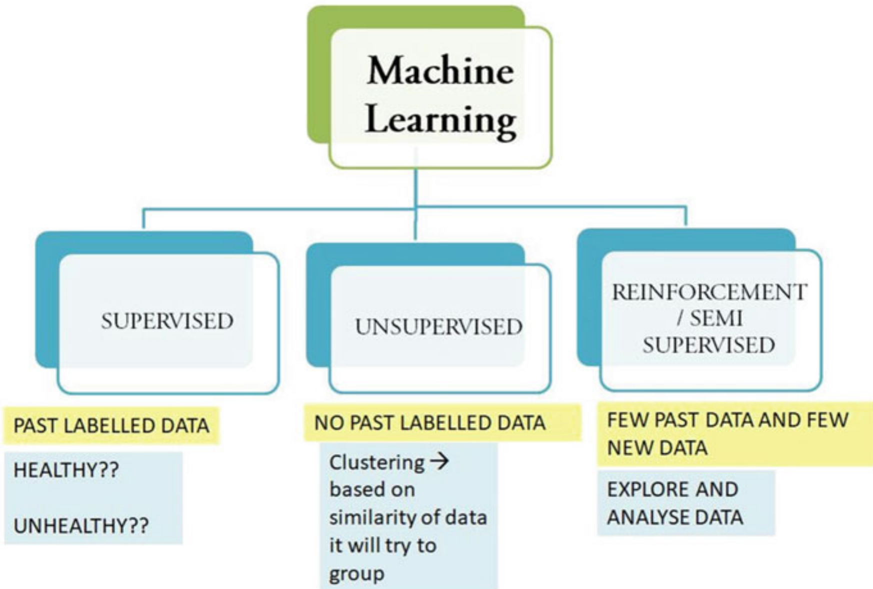


Fig. 7.1 The types of Machine Learning algorithm

the training dataset act as an instructor to the machine model. So some past labeled data is always given as input to the model.

2. Unsupervised Machine Learning: In Unsupervised machine learning techniques the models are trained with input dataset that does not contain any correct response in it. No past labeled data is always given as input to the model. Unsupervised machine learning problems can be arranged into Clustering (K-means clustering) and association(Apriori algorithm)
3. Reinforced or semi supervised Machine Learning: In Reinforced Machine Learning the model learn from it's own actions and experiences in an interactive environment by trial and error method. Here with the help of few past data and few new data the model itself has to explore and analyse data.

In this chapter we are about to discuss the supervised machine learning algorithms and we will find the most accurate of all for predicting the chances of getting heart attack by an individual under test.

When analyzing a big amount of data with supervised machine learning technique it can be divided into two parts:

7.3.1 Regression

In regression technique a pattern between a dependent and one independent variable is evaluated and based on that a prediction is made. Some very useful regression algorithms are Linear regression, logistical regression, Ridge regression, Lasso regression, SVM regression and polynomial regression. As regression helps in investigating the correlation between variables and depending on that can predict the continuous response variable so it can be very effective for score prediction or weather forecasting or risk assessment.

7.3.2 Classification

In classification algorithms some past labeled data is given as input to train the model. Then it uses one of the algorithms to put the test data in specific category. It identifies some specifications in the input data and try to label it or define it.

There are mainly six types of classifiers- Naïve Bayes(NB), Decision Trees(DT), Random Forest(RF), K-Nearest Neighbors (KNN), Logistic Regression (RL), Support Vector Machine (SVM).

Naïve-Bayes-Classifiers comprises of algorithms that are based on Bayes Theorem. Bayes theorem is very useful for large amount of data processing. In our dataset we can use Baye's theorem in following way

$$P(V|U) = \frac{P(U|V)P(V)}{P(U)} \tag{7.1}$$

Here V is the class-variable and U is a dependent-feature-vector.

So here we are trying to find the probability of event V depending on the probability of event. More simply probability of getting a heart attack depending on the probability of higher heart rate. Decision Tree (Fig. 7.2a) is another kind of Supervised Machine Learning where the particulars are continually chopped in accordance with a definite variable. The tree can be described by two structures, which are decision nodes and leaves. Decision nodes are used to create any resolution and do have manifold branches. Leaf nodes are the production of those conclusions and don't comprise any further branches. The nest Random Forest (Fig. 7.2b) classifier is a type of Supervised-Machine-Learning-Algorithm that optimizes the model accuracy without any much of hyper-tuning. The "forest" is built by combining a group of decision trees, in other words we can say that, random forest is the collection of many decision trees, where each decision tree gives out its own result and after collection of all those results similar to the concept of Bagging, the best one is given as output as the accuracy of the Random Forest Classifier. It is flexible to be used for both classification and regression chores. It's also easy to observe the related prominence it assigns to the input characteristics. K-Nearest-neighbor is one of the simplest algorithms established on supervised-machine learning-technique. Here the resemblance between a new data inserted in the dataset and other present data in the data set is considered to categorise the new data. It can be used both for classification and regression. K-NN does not make any kind of presumption on fundamental information. Suppose you have an image of a thing that looks similar to chair and table but you want to investigate whether it is a chair or a table (Fig. 7.2c). So K-NN algorithm can be implemented here to measure the similarity and depending on that it will give the predicted output. Another example of K-nearest Neighbour algorithm can be explained as (Fig. 7.2d) which is very much used in OTT platforms now a days to predict whether a person will like a particular type of product or not. Like whether a person who likes realistic suspenseful movie will like the new movie released in the same genre. Logistic--regression is a "supervised--learning--classification" algorithm. It predicts the prospects--of--a--target variable (Fig. 7.2e). The identity of dependent feature is dichotomous. It means that there would be only two-conceivable classes. It means that the dependent-variable-is-binary-in-nature-having data, coded as either 1- (means success/ yes) or 0- (means failure/no). A support-vector-machine which is also known as-SVM is a- supervised-machine-learning-model- that-uses the classification-algorithms-for two-group classification-problems. After providing an SVM-model with labeled-training-data-for each-category, they are then able to tag new input.

The aim of the support-vector-machine-algorithm is to discover a hyper-plane-in-an-N-dimensional space- (N — the number of features) that exclusively classifies the data-points. For separating the two-classes-of-data-points, there are many

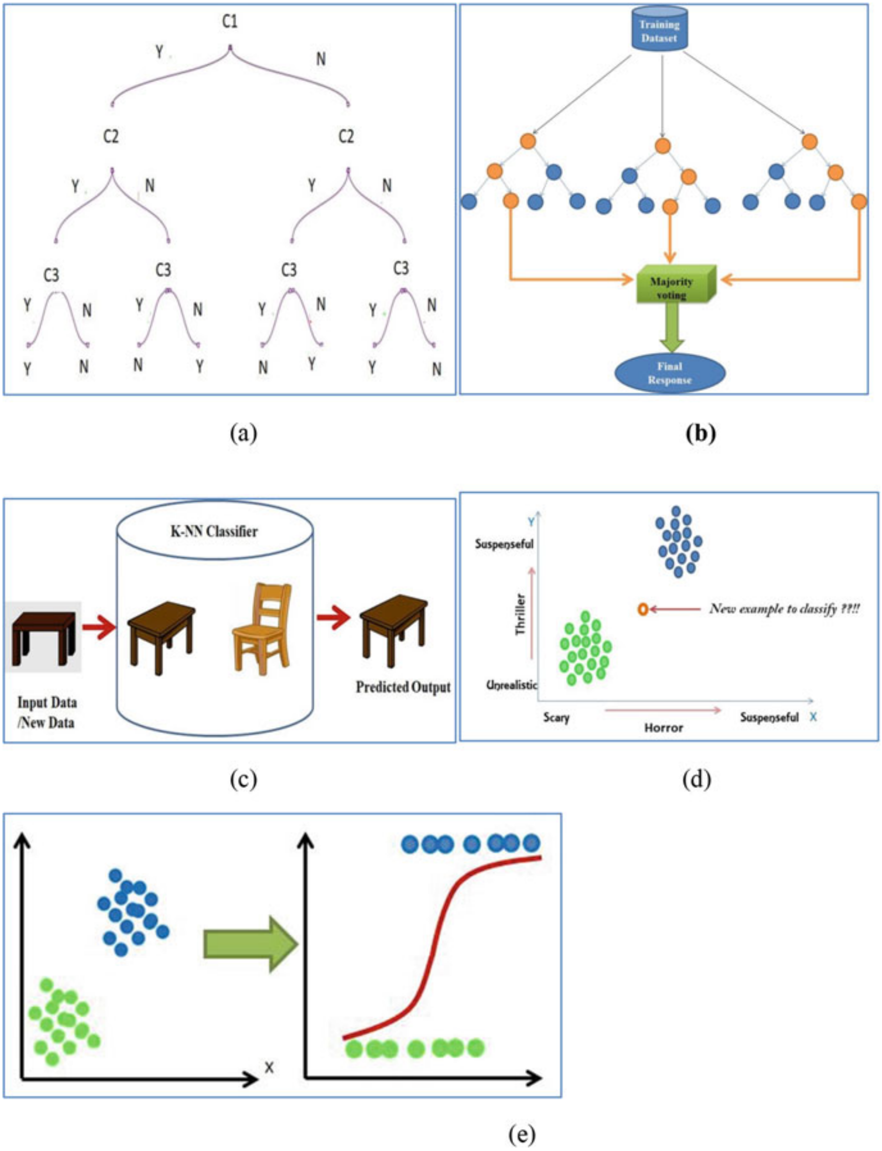


Fig. 7.2 Graphical Representation of (**a**) Decision Tree Classifier (**b**) Random Forest Classifier (**c**) K-NN classifier example 1 (**d**) K-NN classifier example 2 (**e**) Logistic Regression

possible hyperplanes to be chosen. SVM-can-be-of-two-types-Linear-SVM and Non-linear-SVM.

7.4 Generation of Machine Learning Models for a Given Dataset to Predict Heart Attack and a Comparative Analysis to Find which Algorithm Is most Accurate

As discussed earlier the family of Machine Learning is divided into mainly three types of algorithms namely Supervised-Learning, Unsupervised-Learning and Semi-Supervised or Reinforcement-Learning.

Supervised-learning is further divided into two types of cases when dealing with data – Classification and Regression. As we have already discussed about these divisions so we are not going to repeat them here. Here for this data processing we will only focus on six of the common classification algorithms namely Naïve Bayes (NB), Decision Trees (DT), Random Forest (RF), K-Nearest Neighbors (KNN), Logistic Regression (RL), Support Vector Machine (SVM).

As we have went through extensive literature survey and two case studies, In the next section have a step by step discussion how we can perform such comparative accuracy check for each of the algorithms.

7.5 Dataset Collection

Whenever collecting data to prepare a machine learning algorithm one need to investigate and obtain data that will be considered as input to the machine. This initialization is very crucial as the quality and the amount of data directly contributes to the accuracy or perfection of the model performance. One can create a datasheet and exported as .csv file. One can use the web scraping technique to collect information from the open sources available in the internet. The dataset used for the research work is obtained partially from kaggle.com, which is an open source for datasets and partially from affected volunteers. This database is initialized and analyzed to examine some major symptoms which may be an effective indicator that the person is prone to heart stroke or heart attack. The main contributing parameters as described below with their abbreviations used in the dataset will be considered for the analysis:

age: The age of the individual under test (IuT) when diagnosed (in case of effected individual) or the age of the healthy person under study.

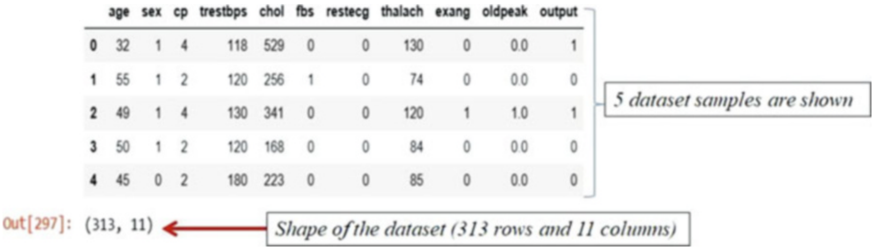
sex: Gender of the individual under test (1 = male, 0 = female)- Only male or female is considered for this research.

cp: -The-chest-pain (angina) experienced (Value 1: -typical angina, Value 2: -atypical angina, Value 3: -non-anginal pain, Value 4: -no symptom).

trestbps: blood-pressure- (mm-Hg) -of the-individual-under-test (IuT) at rest.

chol: Cholesterol-measurement in mg/dl of the individual under test (IuT).

fbs: Fasting-blood-sugar ("> 120-mg/dl, -1 = true; 0 = false") individual under test (IuT).



	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	output
0	32	1	4	118	529	0	0	130	0	0.0	1
1	55	1	2	120	256	1	0	74	0	0.0	0
2	49	1	4	130	341	0	0	120	1	1.0	1
3	50	1	2	120	168	0	0	84	0	0.0	0
4	45	0	2	180	223	0	0	85	0	0.0	0

Fig. 7.3 Response of the above code showing first 5 data samples from the dataset and also the shape of the whole dataset (snippet of the original code)

restecg: electrocardiographic measurement at rest ("0 =-normal, -1 =-having ST-T-wave abnormality*, 2 =-showing probable-or definite left ventricular-hypertrophy by Estes' criteria").

** ST-T wave abnormality: ST segment represents the gap between ventricular depolarization and repolarization. Normally ST-T segment abnormalities are observed due to myocardial ischaemia or infraction (i.e. Heart attack).*

thalach: Maximum-heart-rate reached by the individual under test (IuT).

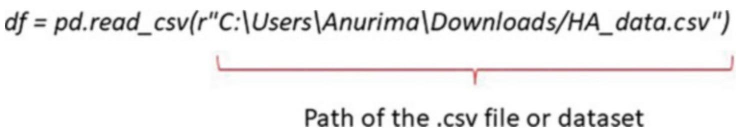
exang: Angina induced by Exercise ("1 =-yes; 0 = no").

oldpeak: exercise-induced-ST depression- comparative-to-rest ('ST'* relates-to positions on the-ECG plot.)

output: Heart-disease (0 = −no, 1- = yes).

The data is collected to train a model which can differentiate between people who are prone to heart attack and healthy individuals.

Dataset can be accessed by using:



Dataset can be viewed by using (Fig. 7.3):

```
df =-df.sample(frac = 1, random_state = 56).reset_index(drop = True)
display(df.head(5))
df.shape
```

The dataset used for this analysis contains 313 rows and 11 columns. Here data preprocessing may be utilized and the most accurate algorithm may be applied to get the most accurate results.

7.6 Data Pre-Processing

After-the-data is collected we need to organize it for building the model. Correlations between the different characteristics need to be observed and for that data visualization are needed. In Machine Learning variables are called features. So selection of characteristics is very important as this will directly influence the execution, analysis accuracy and outputs. In Statistics also quantitative illustrations and estimations of data is important which is allowed by data visualization to inspect a major set of tools for gaining a phenomenological learning and apprehension.

Next data balancing, this is a very crucial attribute specially when working with anomaly or theft detection. We need to balance the data so that the machine learning does not get biased towards a type of output or result and generalizing the knowledge does not fail. Let us take an example, suppose data analysis regarding electricity theft is being observed. Total observation is 500 and within that 2 theft is detected which is 0.4% of the total observation that makes this a rare event. Another example of Imbalanced data is rare disease detection modeling. In such cases if one writes a program without balancing the dataset then the result will give 100% accuracy for a person who does not have the rare disease but 0% accuracy for an effected person hence though the model accuracy seems high but practically it is a failure. So building a model with this kind of data input won't be very accurate to predict the recurrence of such event. Hence one needs to balance the data by getting a decent amount of information. Before balancing dataset must be divided into two parts-train data and test data, so that test data can be unbiased and the model evaluation is proper. Train data works as the teacher to the machine and through test data the accuracy of the machine learning algorithm that has been created can be measured. Normally training and testing data are divided into 80:20 ratios but that is not mandatory. One has the liberty to decide the training and testing data ratio for creating the model. sklearn's-*train_test_split*-function to split-the-training data-in two datasets; 80/20 split. This is important, so that over fitting does not occur.

Now to balance imbalanced data there are two techniques either of which can be followed – (1) Data Resampling Technique and (2) Ensemble Technique

Data Resampling can be of two types – Under sampling (Down sampling) and Oversample (Up sampling).

Now let us use the same example of the rare disease detection and prediction to understand Upsampling and downsampling. So in case of Down Sampling (Fig. 7.4a) one will collect the data for the minority class (rare disease) as it is or will randomly remove some of the majority-class data to-match-the number with the-minority-class. One should be careful while deleting data from the majority-class so that no important information gets deleted.

Now in case of over sampling or Up sampling (Fig. 7.4b) just the opposite synthetic data is generated from the observations in the minority class attributes. This repetition is continued until the minority class observations reach the number of majority class observations. Synthetic-Minority-Over-sampling-Technique

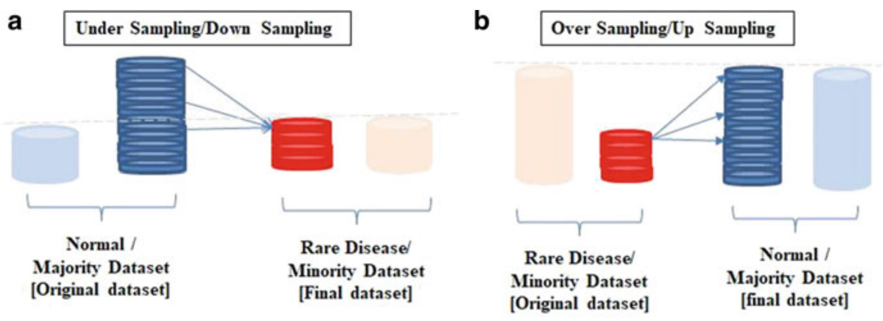


Fig. 7.4 Techniques to balance imbalanced data (**a**) Under sampling/Down Sampling (**b**) Over sampling/Up sampling

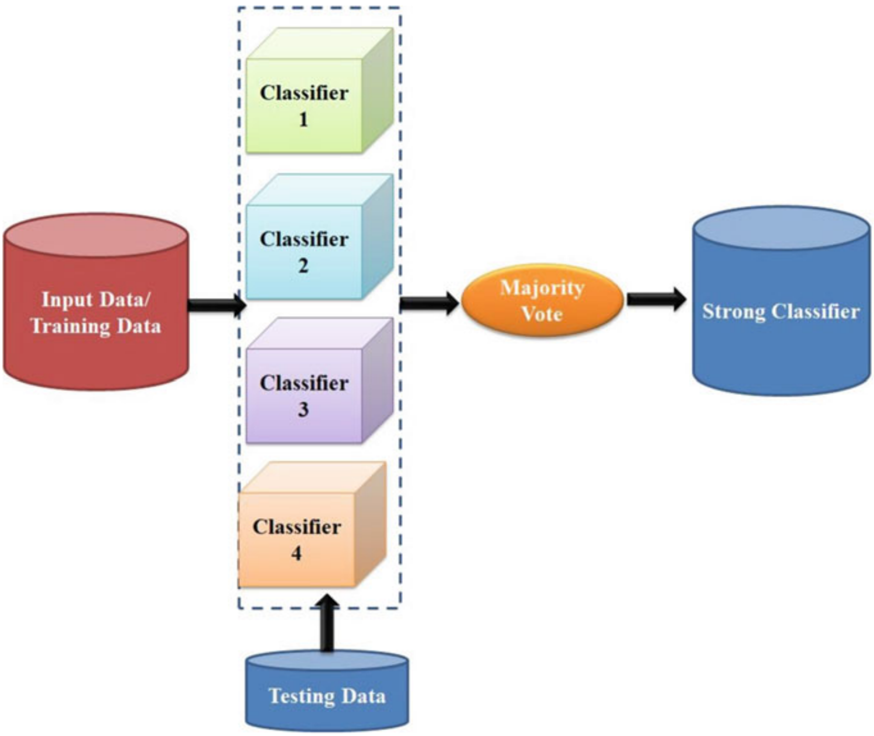


Fig. 7.5 Ensemble Technique to balance imbalanced data

(SMOTE) is widely used for this purpose where datapoint population in minority class is done by using k-nearest neighbor algorithm.

Ensemble Technique improves or produced one compound classifier by combining the response for a dataset from different classifiers (Fig. 7.5).

```
In [245]:  df.isnull().sum()

Out[245]:  age         0
           sex         0
           cp          0
           trestbps    0
           chol        0
           fbs         0
           restecg     0
           thalach     0
           exang       0
           oldpeak     0
           output      0
           dtype: int64
```

Fig. 7.6 Code response showing number of missing values for each feature (snippet of the original code)

So as we can see that processing the original data and making it suitable to be used for machine learning algorithm is a crucial part while generating a machine learning algorithm. Practically the real world data is not always in proper format. Sometimes due to failure to record data values can be missed. In that case one can simply delete the rows with missing values or imputation of the missing values can be done as a part of data preprocessing.

One can simply check whether there is missing values in the available dataset by using (Fig. 7.6)

```
df.isnull().sum()
```

df.describe().T – can be used to describe the dataset or to calculating some statistical data like min, mean and std. of the numerical values of the dataset or DataFrame (Fig. 7.7)

As we can see the dataset that has been used for analysis in this chapter does not contain any null or data or missing value (Fig. 7.8) as this dataset is dedicatedly created by the authors taking all the values from different open sources and volunteers. In case one is working with a dataset where null values or missing values are there handling that properly is very important to create a robust machine learning model.

When working with big amount of data then to analyse the dataset and to apprehend the different features identifying relationships or patterns and plotting them is a significant task for data visualization. Through data visualisation one can get a proper idea of the information meaning and patterns through graphical mapping

```
In [488]:  df.describe().T
Out[488]:
```

	count	mean	std	min	25%	50%	75%	max
age	313.0	48.130990	7.860080	28.0	43.0	49.0	54.0	69.0
sex	313.0	0.718850	0.450280	0.0	0.0	1.0	1.0	1.0
cp	313.0	2.894569	1.030809	0.0	2.0	3.0	4.0	4.0
trestbps	313.0	132.680511	17.467374	92.0	120.0	130.0	140.0	200.0
chol	313.0	248.223642	68.059795	85.0	207.0	240.0	279.0	603.0
fbs	313.0	0.111821	0.574808	0.0	0.0	0.0	0.0	9.0
restecg	313.0	0.252396	0.477241	0.0	0.0	0.0	0.0	2.0
thalach	313.0	103.316294	30.777827	54.0	78.0	89.0	125.0	187.0
exang	313.0	0.290735	0.454829	0.0	0.0	0.0	1.0	1.0
oldpeak	313.0	0.622045	0.917315	0.0	0.0	0.0	1.0	5.0
output	313.0	0.437700	0.496898	0.0	0.0	0.0	1.0	1.0

Fig. 7.7 Code response showing the statistical calculations of the numerical values of the dataset (snippet of the original code)

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	output
0	32	1	4	118	529	0	0	130	0	0.0	1
1	55	1	2	120	256	1	0	74	0	0.0	0
2	49	1	4	130	341	0	0	120	1	1.0	1
3	50	1	2	120	168	0	0	84	0	0.0	0
4	45	0	2	180	223	0	0	85	0	0.0	0

```
Out[297]: (313, 11)
```

Fig. 7.8 Dataset after data preprocessing is done (snippet of the original code)

or plotting. So it is basically the transformation of data into its visual context which will make it easier to comprehend for human brain.There are some visualisation techniques like:

Line-Plot
Bar-Chart
Treemaps-

Histogram-Plot
Box-and-Whisker Plot
Scatter-Plot

With a-awareness of these plots, one can easily get a qualitative-and illustrative understanding of maximum information that you come across from our given dataset.

7.6.1 Barplot (Figs. 7.9 and 7.10):

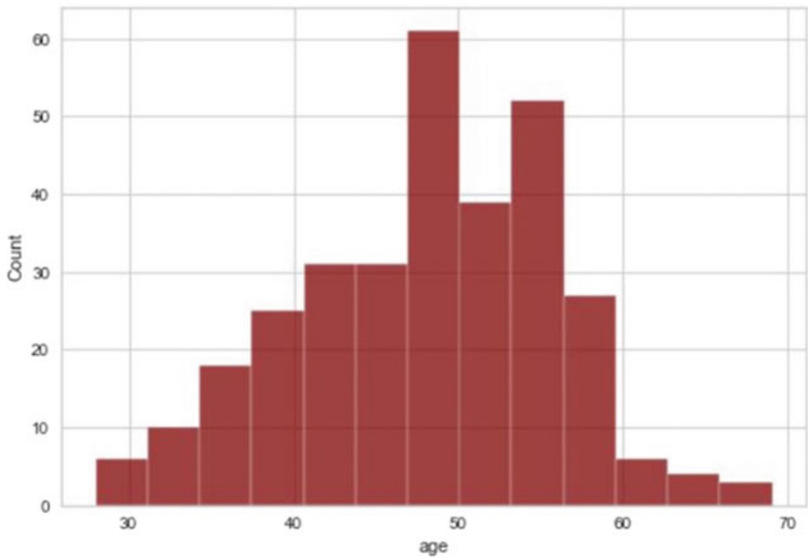
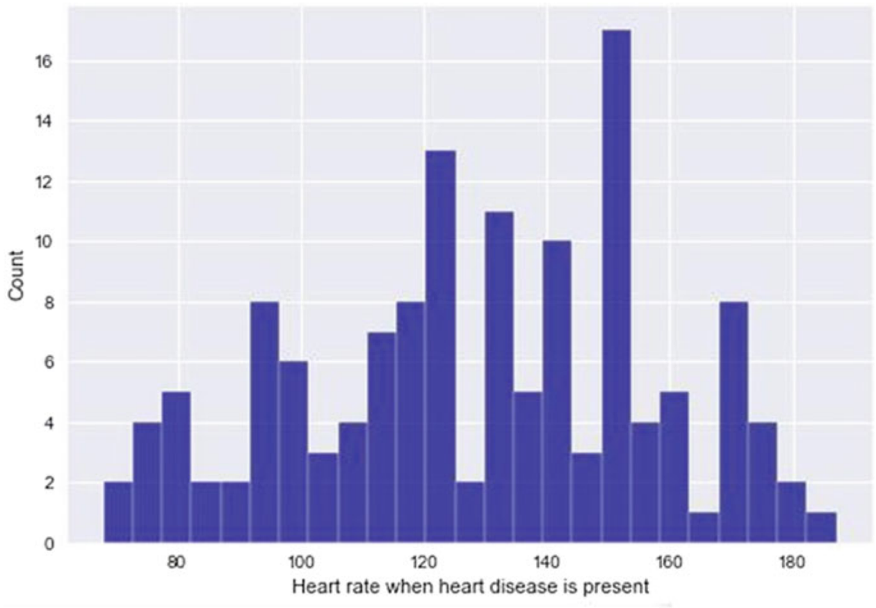
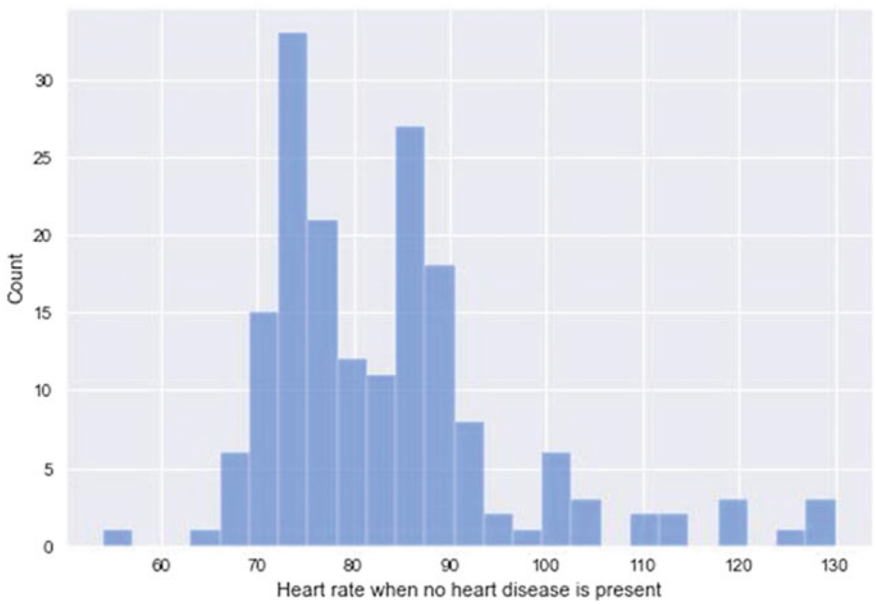


Fig. 7.9 MI affected people in different age group



(a)



(b)

Fig. 7.10 -Bar-plot-for the count of person with maximum heart rate when (**a**) heart disease is present and (**b**) when no heart disease

7.6.2 Heatmap

Another very useful visualisation tool to demonstrate the patterns between two variables is Heatmap. Heatmap is especially helpful when dealing with a large dataset. Just by looking at it carefully one can easily observe the change in colors or patterns for different features. Here we are using the heatmap from Seaborn library. Seaborn is a data visualisation library which we import along with other libraries at the beginning of the code writing. It will create a grid like pattern and simply here numeric will be replaced by colors. Suppose one need to find a maximum or a minimum value from a bigger dataset, using heatmap will be very useful in this case. While plotting the heatmap each of the two variables will be plotted on each of the axes. Through the color density of each box the correlations between two features is established visually. Normally denser the color correlation is higher.

From the below mentioned heatmap (Fig. 7.11) the correlation between each pair of features can easily be comprehended. The encircled mapping shows that the correlation between *output* (chances to get a heart attack) and *thalach* (heart rate) which is 0.8 (colour density higher or more towards red than other boxes) in a 0 to

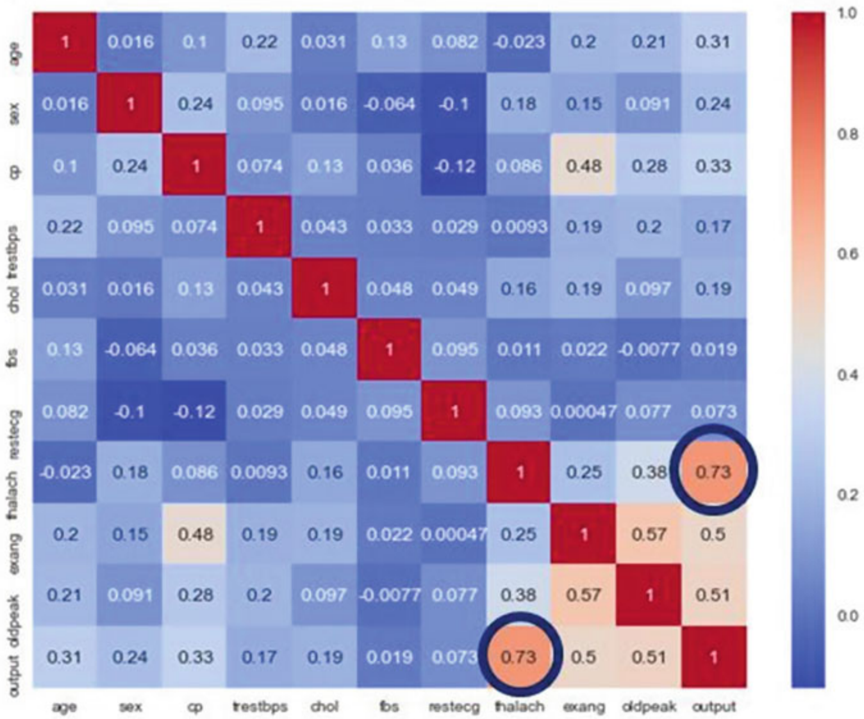


Fig. 7.11 Heatmap showing the correlation between the parameters

1 scale hence the chances of getting a heart attack is higher in people with high heart rate.

We can see that in the charts (Fig. 7.12) we have different types of columns, being categorical and numerical:

Categorical columns: sex, exang, cp, fbs, restecg.

Numeric columns: age, trestbps, chol, thalachh and oldpeak.

So from these plots the patterns or relationships can easily be evaluated. As an example from Fig. 7.12b it can be interpreted that men are more prone to heart attack than their female counterparts.

7.7 Comparative Analysis of the Model Responses

Now let us initiate modeling for the six algorithms. At the very beginning we will **"import"** the libraries from sklearn. Sklearn is free library software for machine-learning in Python. It is very useful and robust. Different techniques for machine learning along with statistical modeling including classification, clustering, regression etc. can be accessed through it. By using a code like following classifiers from sklearn library can be accessed. So for our convenience we would import all the necessary algorithms. In this example as we are using Naïve Bayes algorithm so GaussianNB is implemented as shown in the example.

E.g*: **from** sklearn.naive_bayes **import** GaussianNB.*

Like this all the algorithms are imported from the library to initiate the models.

Result Analysis:

Now let us discuss the performance of six different supervised machine learning algorithms on the dataset under test to predict and analyse the chances of heart attack.

A very important parameter to analyse any machine learning model is **Confusion Matrix** (Fig. 7.13).

Confusion Matrix is nothing but performance measurement of any machine learning algorithm. Its in a table format with four different arrangements of predicted value and real value. Both predicted and actual values are divided in two categories: True and False.

Now there can be four combinations.

True Positive – Tr_P: The predicted positive is true.

False Positive – Fa_P: error type I – Predicted Positive is not True.

True Negative –Tr_N: The predicted Negative is true.

False Negative – Fa_N: error type II – Predicted Negative is not True.

Calculations of Confusion Matrix:

Recall: Recall represents how many predictions were correct and can be computed as given in Eq. 7.2.

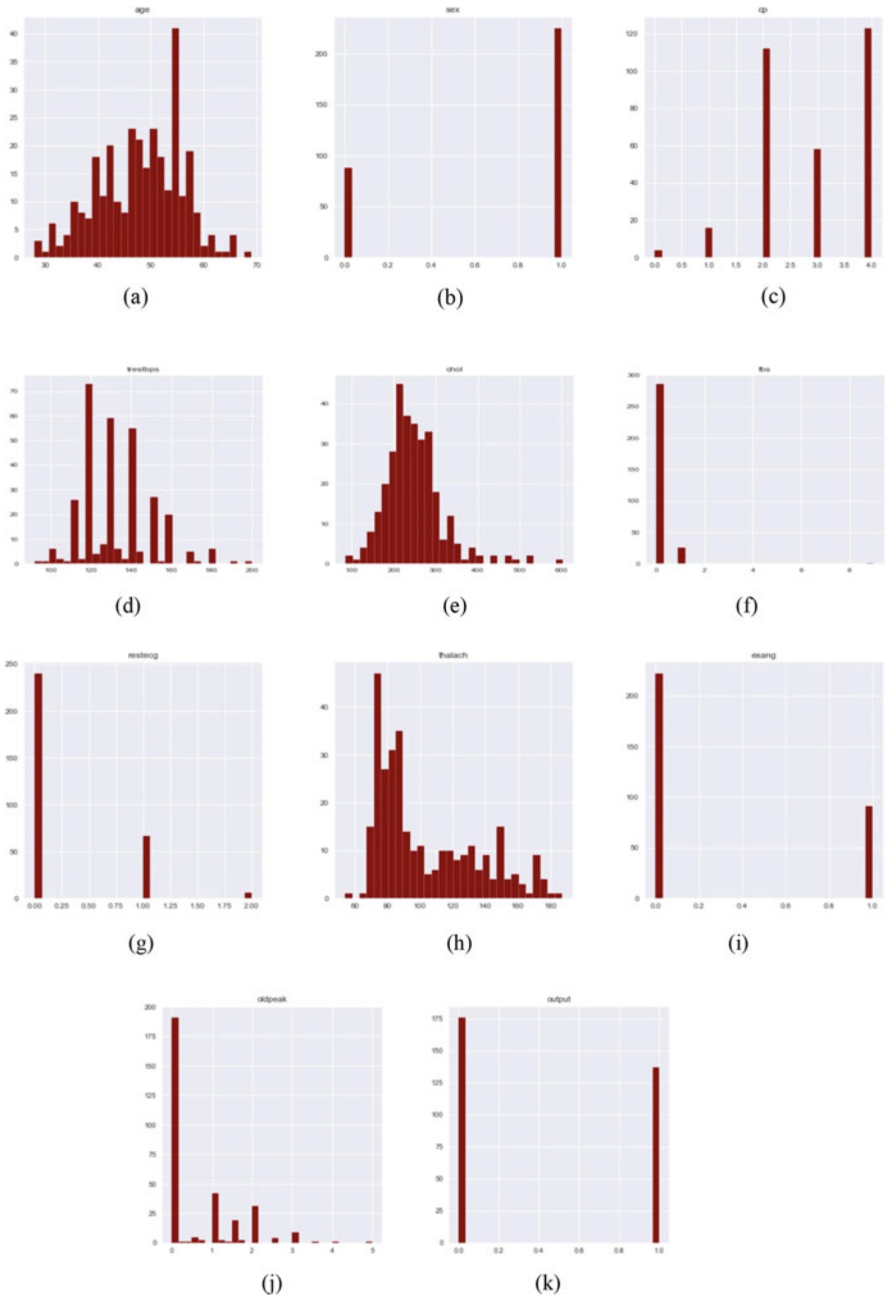


Fig. 7.12 Histplots of the available data (**a**) age (**b**) sex (**c**) CP-Chest Pain (**d**) trestbps – resting-blood-pressure (**e**) -cholesterol- (**f**) -fbs – fasting-blood-sugar (**g**) -Rest-ECG (**h**) thalach – heart rate (**i**) exang – exercise-induced-angina or chest pain (**j**) oldpeak (**k**) output count – 0→ no heart disease 1→ heart disease.

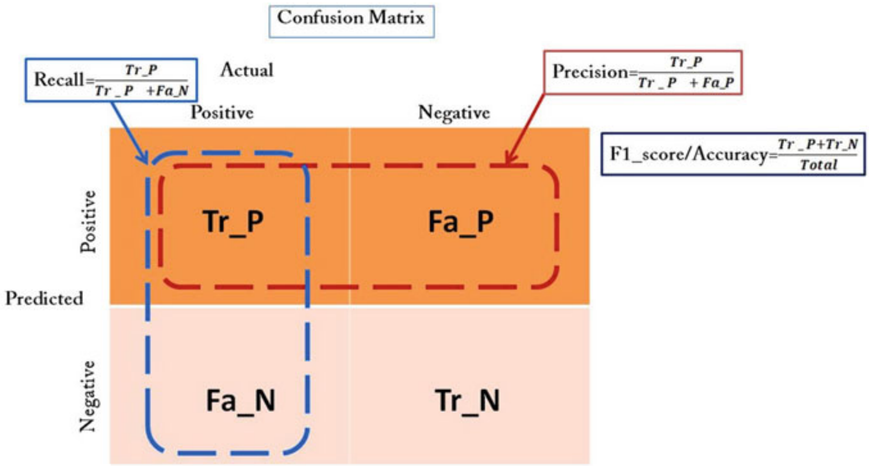


Fig. 7.13 Confusion Matrix sample

$$\text{Recall} = \frac{Tr\_P}{Tr\_P \quad + Fa\_N} \tag{7.2}$$

Precision: Precision represents how many of predicted positives are actually positive and can be calculated as given in Eq. 7.3.

$$\text{Precision} = \frac{Tr\_P}{Tr\_P \quad + Fa\_P} \tag{7.3}$$

Accuracy: From all the positives and negatives how many predictions were correct. It is signified with F1_score. Any model with high accuracy is always preferred. With F1_score recall and precision can be measured at the same time. F1_Score is calculated as given in Eq. 7.4.

$$\text{F1\_score} = \frac{Tr\_P + Tr\_N}{\text{Total}} \tag{7.4}$$

Now let us check the results of the algorithm analysis.

Below are the classification reports of the six different machine learning algorithms under investigation. The Confusion matrix are only shown for the models with the best accuracy.

A. Naïve Bayes:

On performing Naïve Bayes algorithm on the given dataset the accuracy is found to be 86.08% (Fig. 7.14).

	precision	recall	f1-score	support
0	0.93	0.83	0.88	47
1	0.78	0.91	0.84	32
accuracy			0.86	79
macro avg	0.86	0.87	0.86	79
weighted avg	0.87	0.86	0.86	79

Fig. 7.14 Classification Report after performing Naïve Bayes Algorithm

	precision	recall	f1-score	support
0	0.92	0.94	0.93	47
1	0.90	0.88	0.89	32
accuracy			0.91	79
macro avg	0.91	0.91	0.91	79
weighted avg	0.91	0.91	0.91	79

Fig. 7.15 Classification Report after performing Decision Tree Algorithm

B. Decision Tree:

Hence Accuracy with Decision Tree Algorithm is found to be 91.14% (Fig. 7.15).

C. Random Forest:

On performing Random-Forest-Algorithm on the given-dataset, the accuracy was found to be 94.94% (Fig. 7.16).

D. K-Nearest-Neighbor (K-NN):

On performing K-Nearest Neighbour Algorithm on the given dataset, the accuracy was found to be 96.20% (Fig. 7.17).

E. Logistic Regression:

	precision	recall	f1-score	support
0	0.96	0.96	0.96	47
1	0.94	0.94	0.94	32
accuracy			0.95	79
macro avg	0.95	0.95	0.95	79
weighted avg	0.95	0.95	0.95	79

Fig. 7.16 Classification Report after performing Random-Forest-Algorithm

```
              precision    recall  f1-score   support

           0       0.94      1.00      0.97        47
           1       1.00      0.91      0.95        32

    accuracy                           0.96        79
   macro avg       0.97      0.95      0.96        79
weighted avg       0.96      0.96      0.96        79


Confusion Matrix of K-Nearest Neighbour model:
[[47  0]
 [ 3 29]]


Accuracy of K-Nearest Neighbour model: 96.20253164556962
```

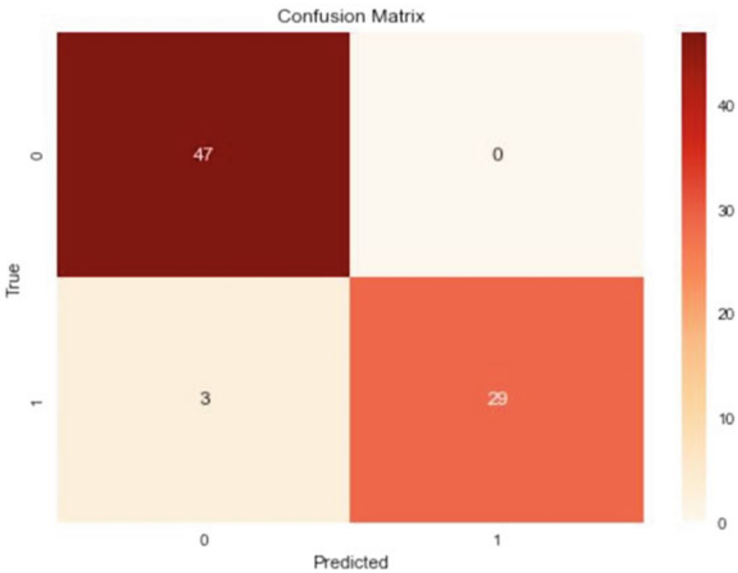


Fig. 7.17 Classification Report after performing K-Nearest-Neighbor Algorithm

The accuracy obtained by Logistic Regression Algorithm is 94.94% (Fig. 7.18).

F. Support Vector Machine:

On performing Support Vector Machine on the given dataset, the accuracy was found to be 96.20% (Fig. 7.19).

Now let us check the comparative dataframe for all the models obtained

	precision	recall	f1-score	support
0	0.92	1.00	0.96	47
1	1.00	0.88	0.93	32
accuracy			0.95	79
macro avg	0.96	0.94	0.95	79
weighted avg	0.95	0.95	0.95	79

Fig. 7.18 Classification Report after performing Logistic Regression Algorithm

	Model	Accuracy (%)	Recall (%)	Precision (%)	F1 (%)	AUC
0	Naïve Bayes	0.860759	0.90625	0.783784	0.840580	0.868019
1	Decision Tree	0.911392	0.87500	0.903226	0.888889	0.905585
2	Random Forest	0.949367	0.93750	0.937500	0.937500	0.947473
4	kNN	0.962025	0.90625	1.000000	0.950820	0.953125
5	Logistic Regression	0.949367	0.87500	1.000000	0.933333	0.937500
6	SVM	0.962025	0.90625	1.000000	0.950820	0.953125

7.7.1 Comparative Analysis of Accuracy of all the Six Models

In the below mentioned graphical plot the accuracy of different supervised-machine learning process is demonstrated (Fig. 7.20) and it is observed that for the given dataset SVM and KNN are the most accurate model with an accuracy of 96.20% for both the algorithms.

7.7.2 ROC Curve

ROC-curve or-Receiver-Operating-Characteristics-Curve or sometimes referred as-AUC ROC-curve where AUC-("Area Under The Curve") is an dependable procedure to analyse the execution of machine learning algorithms. The ROC-is-basically a-probability-curve and-AUC constitutes the degree of separability. So through AUC-ROC curve one can predict the competency of the model for distinguishing between classes. The ROC curve is given in Fig. 7.21.

ROC curve is calculated as:

```
              precision    recall  f1-score   support

           0       0.94      1.00      0.97        47
           1       1.00      0.91      0.95        32

    accuracy                           0.96        79
   macro avg       0.97      0.95      0.96        79
weighted avg       0.96      0.96      0.96        79

Confusion Matrix of SVM model:
[[49  0]
 [ 2 28]]


Accuracy of SVM model: 96.20253164556962
```

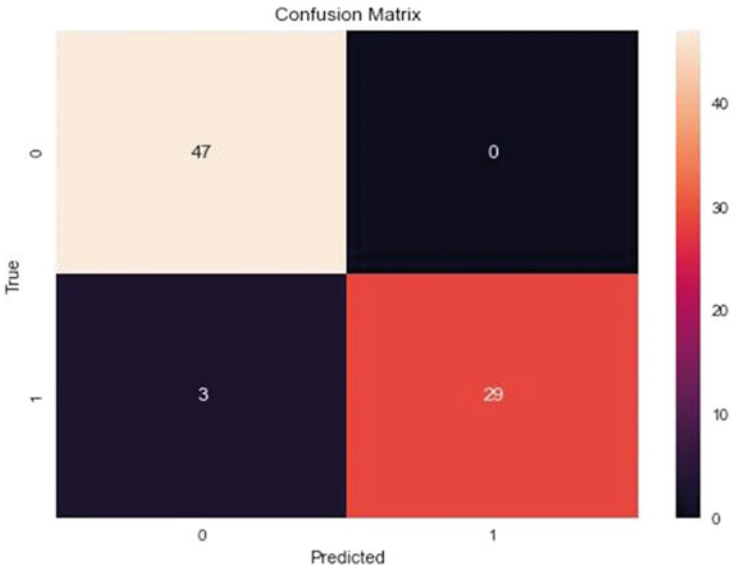


Fig. 7.19 Classification Report after performing Support Vector Machine Algorithm

$$ROC = \frac{Tr\_P}{Tr\_P + Tr\_N} \tag{7.5}$$

As from the ROC curve it is clearly seen that for KNN and SVM algorithm the ROC curve is higher than the rest hence the perform better than other algorithms under consideration (Fig. 7.22).

The whole model is based on data received from affected individuals. To make it more accurate more reliable data is needed. Getting a good number of proper

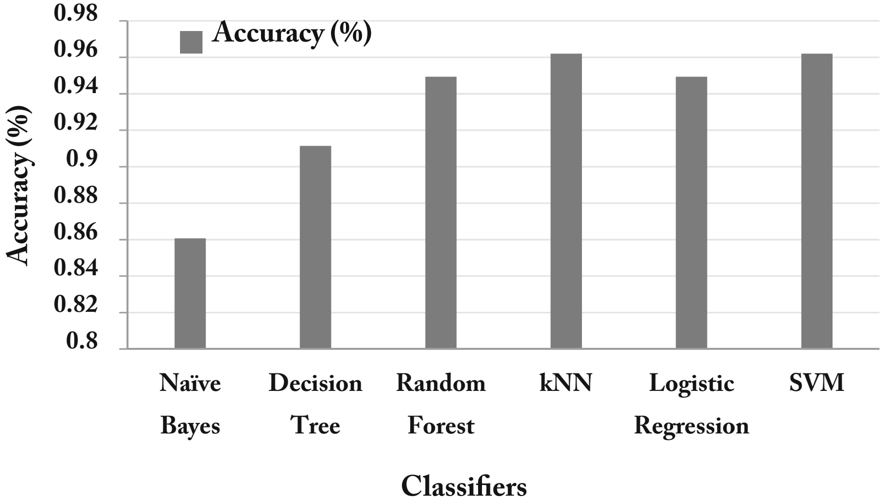


Fig. 7.20 Comparative analysis of accuracy of different algorithm

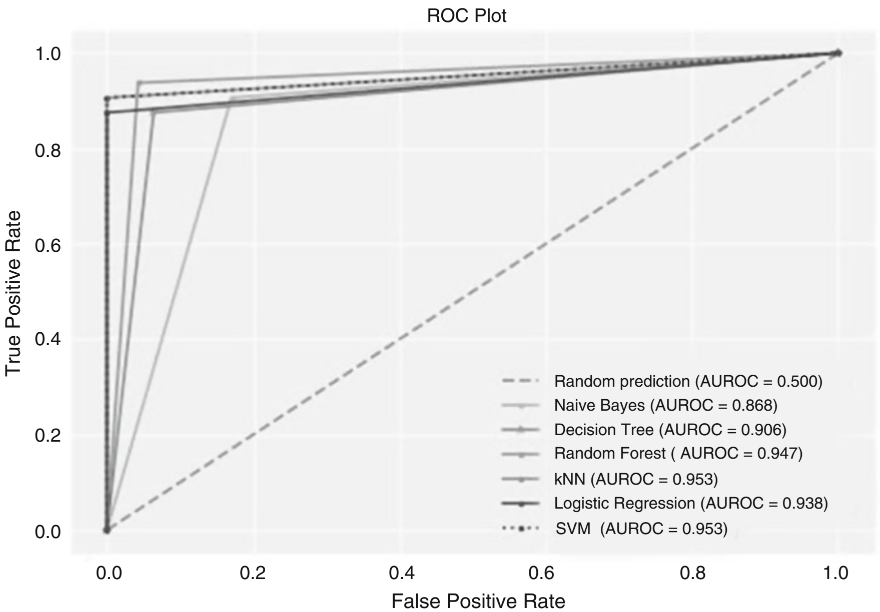


Fig. 7.21 AUC ROC Curve comparing the performance of the applied algorithms

statistics is a very important step. Another challenge while collecting the specifics was that not all information for all the symptoms was present so had to discard those. Having too many null values for one feature may result in less accurate model. After

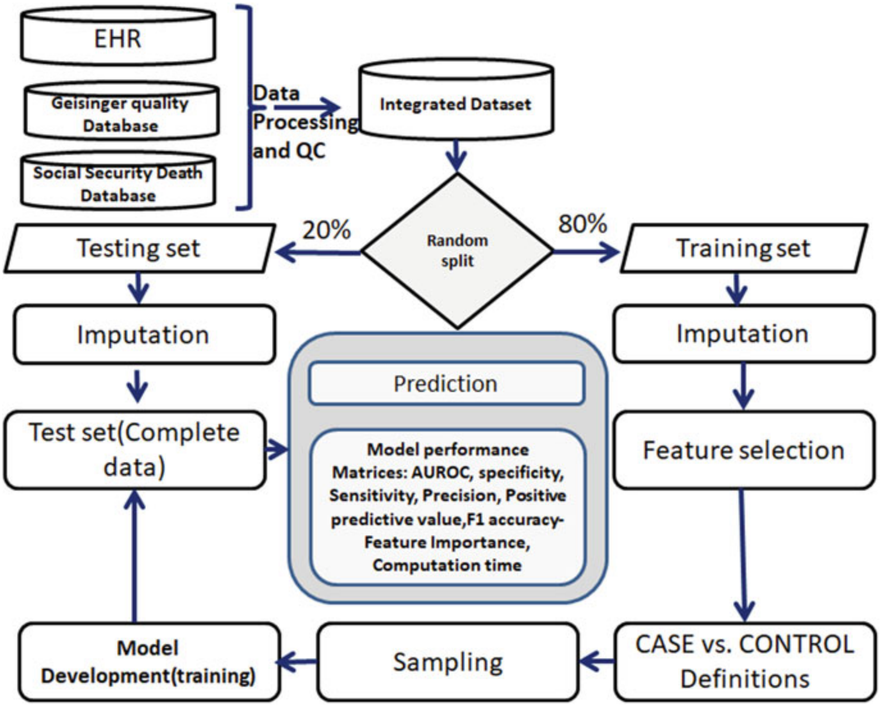


Fig. 7.22 The flow chart of the proposed model

the analysis it was found for the given dataset both SVM and KNN displayed the highest performance with same accuracy. Though it is not a typical challenge but ending up with one single model would have been more accurate.

7.8 Conclusion

In this chapter mainly supervised machine learning technique is discussed along with case study to find the most suitable model to predict heart attack in an individual. Here we observed that for the given dataset total six classifiers are analysed. Naïve Bayes and Decision Tree demonstrated an accuracy of 86.07% and 91.13% respectively. Random forest and Logistic regression were found to be 94.9% accurate. K-Nearest Neighbour algorithm and SVM algorithm is achieving the highest accuracy with a level of 96.2%. So it can easily be comprehended that if Intelligent health care systems get equipped with such machine learning techniques to predict disease occurrences or recurrences that will help to save many lives and also will improve the life styles of the unhealthy individuals.

Future Scope: Implementation of artificial intelligence and machine learning in the health care system is altering the way the whole system operates, maintain information. It not only enhances the performance of the doctors or nurses but also improves the experience of the patients. In the future these models can be incorporated to build computer aided detection systems for diagnosis and prediction of disease. It will improve patient engagement in their self-care. It will fast track the speed and accuracy of treatment. Being able to predict a disease most of the time can improve the individual's life quality and expectancy. Mortality rate can also be decreased with more accurate predictive systems. This kind of models can also be developed for other life threatening disease.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Wadhera, R. K., Shen, C., Gondi, S., Chen, S., Kazi, D. S., & Yeh, R. W. (2021). Cardiovascular deaths during the COVID-19 pandemic in the United States. *Journal of the American College of Cardiology, 77*(2), 159–169.
2. Citroner, G. (2021). *Why heart disease deaths rose during COVID-19 surge*. Retrieved January 13, 2021, from https://www.healthline.com/health-news/why-heart-disease-deaths-rose-during-covid-19-surge#People-needing-care-stayed-home.
3. Zhao, H., Chen, J., Hou, N., Zhang, P., Wang, Y., Han, J., Hou, Q., Qi, Q., & Wang, W. (2011). Discovery of diagnosis pattern of coronary heart disease with Qi deficiency syndrome by the T-test-based Adaboost algorithm. *Evidence-based Complementary and Alternative Medicine, 2011*, 408650, 7 pages, Hindawi Publishing Corporation. https://doi.org/10.1155/2011/408650
4. Zhuye Gao, Siwei Li, Qinghua Shang, Yang Jiao, Xuezhong Zhou, Changgeng Fu, Hao Xu, Dazhuo Shi, And Keji Chen (2015). "Complex networks approach for analyzing the correlation of traditional Chinese medicine syndrome evolvement and cardiovascular events in patients with stable coronary heart disease". *Evidence-Based Complementary and Alternative Medicine*. 2015, 824850, https://doi.org/10.1155/2015/824850. 6 pages, Hindawi Publishing Corporation.
5. Sheelaka, G., & Varghese, A. R. (2020). Machine learning based health monitoring system. *Materials Today: Proceedings, 24*, 1788–1794.
6. Govindarajan, P., Soundarapandian, R. K., Gandomi, A. H., Patan, R., Jayaraman, P., & Manikandan, R. (2020). Classification of stroke disease using machine learning algorithms. *Neural Computing and Applications, 32*, 817–828. https://doi.org/10.1007/s00521-019-04041-y
7. Arji, G., Safdari, R., Rezaeizadeh, H., Abbassian, A., Mokhtaran, M., & Hossein, A. M. (2019). A systematic literature review and classification of knowledge discovery in traditional medicine. *Computer Methods and Programs in Biomedicine, 168*, 39–57. https://doi.org/10.1016/j.cmpb.2018.10.017. Epub 2018 Oct 27.
8. Hijazi, S., Page, A., Kantarci, B., & Soyata, T. (2016). Machine learning in cardiac health monitoring and decision support. *Computer, 49*, 38–48. https://doi.org/10.1109/MC.2016.339

9. Liu, G.-P., Li, G.-Z., Wang, Y.-L., & Wang, Y.-Q. (2010). Modelling of inquiry diagnosis for coronary heart disease in traditional Chinese medicine by using multi-label learning. *BMC Complementary and Alternative Medicine, 10*, 37. http://www.biomedcentral.com/1472-6882/10/37
10. Shi, Q., Zhao, H., Chen, J., Ma, X., Yang, Y., Zheng, C., & Wang, W. (2012). Study on TCM syndrome identification modes of coronary heart disease based on data mining. *Evidence-Based Complementary and Alternative Medicine, 2012*, 697028. https://doi.org/10.1155/2012/697028. 11 pages, Hindawi Publishing Corporation.
11. Zhang, Y., Song, W., Li, S., Lizhen, F., & Li, S. (2018). Risk detection of stroke using a feature selection and classification method. *IEEE, 6*, 31899–31907.
12. Saluja, J., Casanova, J., & Lin, J. (2020). A supervised machine learning algorithm for heart-rate detection using Doppler motion-sensing radar. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, 4*(1), 45–51. https://doi.org/10.1109/JERM.2019.2923673. IEEE Journal.
13. Shanthamallu, U. S., Spanias, A., Tepedelenlioglu, C., & Stanley, M. (2017). A brief survey of machine learning methods and their sensor and IoT applications. In *NXP Semiconductors*. SenSIP Center, School of ECEE, Arizona State University.
14. Sung, S.-F., Lin, C.-Y., & Ya-Han, H. (2020). EMR-based phenotyping of ischemic stroke using supervised machine learning and text mining techniques. *IEEE Journal of Biomedical and Health Informatics, 24*(10), 2922–2931. https://doi.org/10.1109/JBHI.2020.2976931
15. Wang, W., Zhao, H., Chen, J., Chen, J., & Xi, G. (2008). Bridge the gap between syndrome in Traditional Chinese Medicine and proteome in western medicine by unsupervised pattern discovery algorithm. *2008 IEEE International Conference on Networking, Sensing and Control, 2008*, 745–750. https://doi.org/10.1109/ICNSC.2008.4525315
16. Li, J. P., Haq, A. U., Din, S. U., Khan, J., Khan, A., & Saboor, A. (2020). Heart disease identification method using machine learning classification in E-healthcare. *IEEE Access, 8*, 107562–107582. https://doi.org/10.1109/ACCESS.2020.3001149
17. Monteiro, M., Fonseca, A. C., Freitas, A. T., Melo, T. P. e., Francisco, A. P., Ferro, J. M., & Oliveira, A. L. (2018). Using machine learning to improve the prediction of functional outcome in ischemic stroke patients. *IEEE/ACM Transactions on Computational Biology and Bioinformatics, 15*(6), 1953–1959. https://doi.org/10.1109/TCBB.2018.2811471
18. Abedi, V., Avula, V., Chaudhary, D., Shahjouei, S., Khan, A., Griessenauer, C. J., Li, J., & Zand, R. (2021). Prediction of long-term stroke recurrence using machine learning models. *Journal of Clinical Medicine, 10*, 1286. https://doi.org/10.3390/jcm10061286. (Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/)
19. Chaudhary, D., Khan, A., Shahjouei, S., Gupta, M., Lambert, C., Avula, V., Schirmer, C. M., Holland, N., Griessenauer, C. J., Azarpazhooh, M. R., et al. (2021). Trends in ischemic stroke outcomes in a rural population in the United States. *Journal of the Neurological Sciences, 422*, 117339.
20. Yu, J., Park, S., Kwon, S.-H., Ho, C. M. B., Pyo, C.-S., & Lee, H. (2020). AI-Based stroke disease prediction system using real-time electromyography signals. *Applied Sciences, 10*(19), 6791. https://doi.org/10.3390/app10196791
21. Krittanawong, C., Virk, H. U. H., Bangalore, S., et al. (2020). Machine learning prediction in cardiovascular diseases: A meta-analysis. *Scientific Reports, 10*, 16057. https://doi.org/10.1038/s41598-020-72685-1
22. Harrell, F. E. (2001). *Regression modeling strategies, with applications to linear models, logistic regression, and survival analysis*. Springer.

23. Priyanka, D., & Chinmay, C. (2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence, 2021*, 1–24. https://doi.org/10.1080/0952813X.2021.1958063
24. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). BIFM: Big-data driven intelligent forecasting model for COVID-19. *IEEE Access, 9*, 1–13. https://doi.org/10.1109/ACCESS.2021.3094658
25. Chinmay, C. (2019., [SCOPUS, IF-1.09]). Computational approach for chronic wound tissue characterization. *Elsevier: Informatics in Medicine Unlocked, 17*, 1–10. https://doi.org/10.1016/j.imu.2019.100162
26. Chinmay, C., & Arij, N. A. (2021). Intelligent internet of things and advanced machine learning techniques for COVID-19. *EAI Endorsed Transactions on Pervasive Health and Technology, 21*(26), e1–E14. https://doi.org/10.4108/eai.28-1-2021.168505

Chapter 8
A Predictive Analysis for Diagnosis of COVID-19, Pneumonia and Lung Cancer Using Deep Learning

Avali Banerjee and Shobhandeb Paul

Abstract At the end of 2019, the twenty-first century was hit by a serious pandemic that was caused due to “Novel Coronavirus” also known as COVID-19. This virus has no specific symptoms as the symptoms varied from person to person but the main part that is affected is respiratory system of a human body. The virus is capable of multiplying itself, thus the potential of the virus is increasing day by day. Since the Coronavirus attacks the respiratory system, so we have decided to come with a advanced model rather a system that could detect and analyze the impact of coronavirus and other problems related to the deep chest that are being encountered along with the Covid-19 diseases, mainly Pneumonia also known as Covid-19 Pneumonia. Also, the patients with previous history with Lung Cancer are most affected, so this model can be a better or rather a confirmation for the doctors.

With the help of the chest X-Ray, the model will be in a state to detect whether the patient is suffering from Covid-19, Pneumonia or any Lung cancer diseases. To ease the diagnosis process, we have divided the results into categories such as: Covid-19 or non-Covid-19 chest, Covid-19 with active Pneumonia or Non-Covid-19/Bacterial/Non-Bacterial Pneumonia chest. The best way to achieve this is by using Neural Network approaches of deep learning, basically a multiclassification of various deep learning that helps us to compare the performance of the model of different techniques used to train and to choose the best model that fits in the proposed dataset, hence enabling proper and smooth diagnosis process.

Keywords Artificial intelligence · Chest X-Ray · Deep learning · Detection of Covid-19 · Image processing · Lung-Opacity · Machine learning · Optimized neural networks · Viral-Pneumonia

---

A. Banerjee (✉) · S. Paul
Department of ECE, Guru Nanak Institute of Technology, Kolkata, West Bengal, India

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_8

8.1 Introduction

With the advancement of human evolution, the mankind has witnessed various changes, though it may be in the field of Technology, Health, Agriculture and many more. While these are boon to us, but this has led to many side-effects to our mother Earth, that includes production of many harmful viruses, bacteria, etc., that has led to many harmful diseases and it is very obvious that the human race needs time to develop immunity against that, but by that time, everybody faces a number of causalities. To develop latest medications, it needs time. By the end of 2019, the mankind was hit by a serious virus named the Coronavirus, popularly termed as Covid-19 virus, that has made the human race tiresome. The whole world is suffering from this virus and there are lots of causalities being reported. For the professionals, the solution has to be made within no time, thus, to achieve this, the medical records of the affected persons are needed to be analyzed and the best solution is accepted in order to serve the mankind and thus preventing less casualties. This virus has no specific symptoms as the symptoms varied from person to person but the main part that is affected is respiratory system of a human body. The virus is capable of mutating itself very frequent, thus the potential of the virus is increasing day by day. Since the Coronavirus attacks the respiratory system, so we have decided to come with this advanced model. To achieve this, there are various scientific methods present. For the scope of this chapter, we will be dealing with the domain Deep Learning, which is the subset of Artificial Intelligence. The medical records are collected in the form of images of X-Ray for the affected persons and put into the advance image processing techniques to study and analyze not only the persons suffering from Covid-19, but also helps to identify the chest images those who may or may not be suffering from Covid-19, but other chest related diseases such as Viral- Pneumonia, Lung-Opacity, etc. The chapter discusses about solving this dataset with latest architectures of neural networks.

The proposed chapter includes the Introduction, Motivation, Objective, Literature survey, Artificial Intelligence and Neural Network in health care systems, Methodology of the proposed system, Concept of working of the proposed system by including AI and neural networks like CNN, VGG-16, VGG-19, Results, Conclusion, and Future scope.

8.2 Literature Survey

Dina M. Ibrahim et al. [1] proposed a deep learning diagnostic model for COVID-19, pneumonia, and lung cancer. They showed that VGG19 and CNN has given the maximum accuracy. Laure Wynants et al. [2] screened 2690 titles and described 31 prediction models for 27 studies. They identified 3 models for estimating hospital stay due to pneumonia, 18 for detecting COVID-19 and 10 for predicting mortality risk. They showed that the proposed models for COVID-19 gave excellent discriminative performance. Shuo Wang et al. [3] described a model for identifying COVID-19 from other pneumonia and viral pneumonia symptoms based on deep learning system. They also proved that the described model can efficiently segregate the patients into high and low-risk groups and will be helpful in early preventions.

Debanjan Konar et al. [4] proposed a semi-supervised shallow neural network framework based on Parallel Quantum-Inspired Self-supervised Network. They showed that the proposed model gives better performance as it provides fully automated segmentation of lung CT without incorporating pre-trained convolutional neural network- based models. Carlo Augusto Mallio et al. [5] analyzed CT images for different three groups of patients like a pneumonia-free, a COVID-19 and with ICI therapy-related pneumonitis with an AI algorithm based on a deep convolutional neural network structure. They proved that the developed algorithm is not able to identify the three different types of pneumonitis. Hanan Farhat et al. [6] discussed about the advancement of deep learning applications in medical image analysis for pulmonary imaging. They also focused on classification, segmentation, and detection which are the various deep learning tasks.

Jun Chen et al. [7] constructed a deep learning system for detecting COVID-19 pneumonia on high resolution computed tomography (CT). They showed that the efficiency of radiologists in clinical practice has improved by reducing the reading time. Stefanus Tao Hwa Kieu et al. [8] presented a taxonomy of deep learning for lung disease detection in medical images. They mentioned the seven attributes of taxonomy, identified 4 issues of lung disease detection using deep learning and suggested solution are making datasets available to the public, usage of cloud computing, usage of more features and usage of the ensemble. Chang Hee Han et al. [9] proposed a semi-supervised (supervised and unsupervised learning) deep neural network for an improved COVID-19 detection using CT images. Authors described that the demonstrated method could improve the accuracy and robustness of COVID-19 for an improved patient care and management [10, 11].

Adnan Saood et al. [12] developed reliable computer-based techniques for detecting infected tissues present in lung CT scans to assist in the COVID-19 treatment. Authors compared the two deep learning networks SegNet and U-NET in a multiple classification procedure of infected areas in lung images. Stephanie A. Harmon et al. [13] showed various deep learning algorithms to differentiate between COVID-19 associated pneumonia and non-COVID related pneumonia. Noam Tau et al. [14] discussed that the primary tumors with PET images analyzed by CNN model yields high accuracy but the sensitivity of the CNN in predicting distant metastatic potential tumors is limited but specificity is moderately high.

S. H. Kassani [15] described 3ML techniques like support vector machine, artificial neural networks, and regression model to predict the COVID-19 patient's recovery. L. J. Muhammad et al. [16] developed data mining models to predict the recovery from COVID-19 infection and showed that the results obtained with applied decision tree data mining algorithm is more efficient than rest of the algorithms. Chip M. Lyncha et al. [17] applied different supervised learning techniques to classify lung cancer patients. Authors included tumor grade and size, gender, age, stage, and number of primaries as key data attributes. They showed that GBM ensemble with Root Mean Square Error (RMSE) gives the most accurate value among the five different models and Decision Trees may be inapplicable.

Weston C. Roda et al. [18] demonstrated that an SIR model performs much better than an SEIR model for the confirmed-case data among the two different machine learning models. Mohammad M. Sajadi et al. [19] presented a weather model to estimate the zones at a higher risk of spreading of COVID-19 by considering the input parameters like latitude, temperature, and humidity. They showed that the proposed model can accurately predict the higher risk regions of significant community spread of COVID-19. F. Petropoulos et al. [20] introduced a method for forecasting the COVID-19 spreading.

Lin Li et al. [21] introduced a deep learning model (COVNet) to identify COVID-19 using chest CT and evaluated its performances to differentiate from other lung diseases. Hossein Mohammad-Rahimi et al. [22] studied different machine and deep learning models on chest X-ray images and CT scans for COVID-19 diagnosis and also compared the performances. Ilker Ozsahin et al. [23] discussed about the high accuracy evaluation of the chest images to differentiate between the COVID-19 and non-COVID-19 pneumonia using different machine and deep learning models.

Ali Abbasian Ardakani et al. [24] demonstrated different convolutional neural networks to differentiate infection of COVID-19 from non-COVID-19. They showed that the performance achieved by ResNet-101 and Xception was best among all the other convolutional neural networks. V. Perumal et al. [25] applied transfer learning technique to clinical images of different types of pulmonary diseases including COVID-19 for quick prediction by using texture feature extraction using Haralick features. R. M. Pereira et al. [26] implemented multi-class and hierarchical classification extract features using texture descriptors and pre-trained CNN model to determine pneumonia caused by COVID-19 and different pathogens. J. Zhang et al. [27] proposed a confidence-aware anomaly detection (CAAD) model to differentiate between viral pneumonia from non-viral pneumonia. Lawrence O. Hall et al. [28] explained the importance of chest X-ray images for diagnosis of COVID-19 by using pretrained deep convolutional neural network.

Priyanka Dwivedi et al. [29] proposed a system to detect COVID-19 by using supervised/unsupervised learnings. Abdul R. J. et al. [30] developed a telemonitoring system for smart hospital. Anichur Rahman et al. [31] developed a system to maintain the IoT based ecosystems during COVID-19. Sujata Dash et al. [32] designed a model for forecasting the outbreak of COVID-19.

8.3 AI in Health Care Systems

By now it is very clear that the chapter is primarily focused on bringing such a model or rather a system that could be an advantage to the existing health system in order to detect or predict the above mentioned diseases, or other diseases that possesses similar symptoms or rather characteristics so that we can club all of them together and bring an advanced model that could be included in the Healthcare systems. This idea is basically based on Image processing, Machine Learning techniques to process, visualize and predict the disease as the outcome. This is just one of the examples out of many advanced models, there are many healthcare systems that are already existing in the market and in the hospital industry. To highlight or rather enlighten some of those systems that are based on Artificial Intelligence technologies includes hybrid models of IoT (Internet of Things) and Machine Learning, basically in these systems, the data is being captured from the sensors (industry applied sensors), and then using those raw data to process into useful information and visualize using Machine Learning techniques and come to an output and conclusion, also IOMT (Internet of Medical Things) are also coming up and are in application and in testing phase, where there is only use of sensors and cloud applications of Internet of Things (IoT), to fetch and transfer the data from one system to another and produce useful reports, that acts as an aid to the doctors or the health specialist, for present as well as future diagnosis of the diseases. The industry is heading towards modernisation day-by-day, and Artificial Intelligence is such a field, by use of which creation of advanced and accurate model is made possible, this also goes same for the other advanced technologies as well. Although, this chapter focuses on a limited version of such system and gives an idea how advanced systems are planned and made, also how its aid to diagnose better than the present existing system, there are also some more modifications that can be done to this same system, which is discussed in the future scope of this chapter.

8.4 Neural Networks

The main idea behind the Neural Networks is to build an architecture that could mimic a human brain. The whole concept is to develop a system of hardware or a software that could think and perform just as a human brain. Just as in a human brain, there are many neurons, similarly the model has the same. There are many types of Neural Networks, which comes under the domain of Deep Learning and the whole system is the subset of a larger domain, which is Artificial Intelligence. From the concept itself, it is easily understood that, since the hardware or the software behaves like a neuron of a human brain, henceforth, the computational power and most importantly the memory is quite more than traditional Machine Learning models. The Neural Networks is capable of handling very large datasets, though it be any, it may be of speech, image, patterns, etc., it gives user the flexibility to practice with a large scope of ideas.

The architecture of the Neural Networks (Fig. 8.1) is such that, it consists of node layers, which contains an input layer, one or more hidden layers and then at last the output layer, which gives the final result of the input dataset. Now, each node or rather the artificial neuron is connected to one another and hold specified weight and threshold. Likewise, the information is passed from one layer to another with the help of these neurons just as the human brain does.

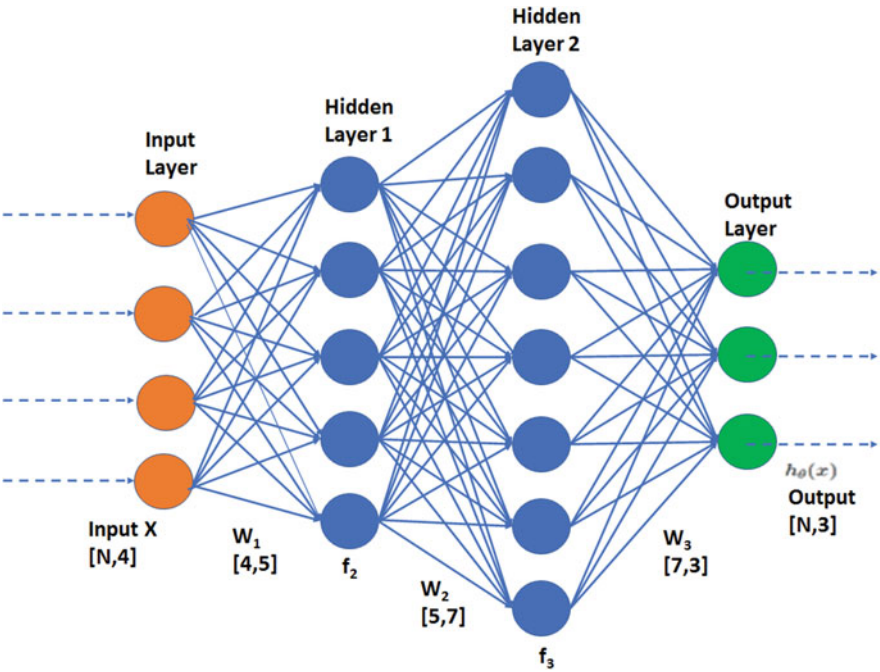


Fig. 8.1 Basic architecture for neural networks

We can think each layer as a separate Linear Regression model that comprises of input data, weights, a bias (or can be considered as a threshold value) and hence an output. The typical formula for a Neural Network can be as given:

$$\sum W_i x_i + bias = W_1 x_1 + W_2 x_2 + W_3 x_3 + bias \tag{8.1}$$

and the output $f(x)$ is given by:

$$\begin{aligned} \text{output} = f(x) &= 1, \text{if} \sum W_1 x_1 + b \geq 0 \\ &= 0, \text{if} \sum W_1 x_1 + b < 0 \end{aligned} \tag{8.2}$$

Now, the important step is determining the input layers and then assigning the weights, so that importance of each of any given variable can be easily understood and can be compared with other variables. The input nodes are then multiplied by their respective assigned weights and later the inputs are fed to summation. At last, the output is fed into the activation function, which determines the final output of the system. In the above-mentioned process, if the output exceeds any given threshold, its "fires" (or activates) the node, aids to pass it to the input of the next layer, which is also known as the feedforward network.

Now, as discussed, the Neural Network can be of various types, available for different applications, aiding flexibility to the user, depending upon the target dataset.

8.4.1 Convolutional Neural Networks (CNN)

CNN (Convolutional Neural Networks) which is popularly known as ConvNets or CNNs is one of the most important part of Neural Networks. There are multiple tasks that can be done such as Image Recognition, Image Classification, Face Recognition, Object Detection and the list goes on. Significantly, CNN models are used to train and test, as when input image passes through a series of convolutional layers with filters. On passing the given input, the important features are extracted by the first layer and then sent to the next second layer for further processing the input data.

There is quite a bit distinction, if we compare the Neural Nets and the CNN’s on the ground that the CNN's are extremely extraordinary are bit different from other Neural Networks in accordance to their extraordinary performance with image, speech, or audio signal inputs. The layers (Fig. 8.2), are divided mainly into three:

Convolutional layer

Pooling layer

Fully connected (FC) layer

Since, the processing of the images are done through several layers of the CNN, shapes and objects become more prominent and thus it finally identifies the given object or shapes. In the same way, there are main three hyperparameters which affects the volume size of the output and needs to be set before the training of the Neural Network initiates. They are discussed below:

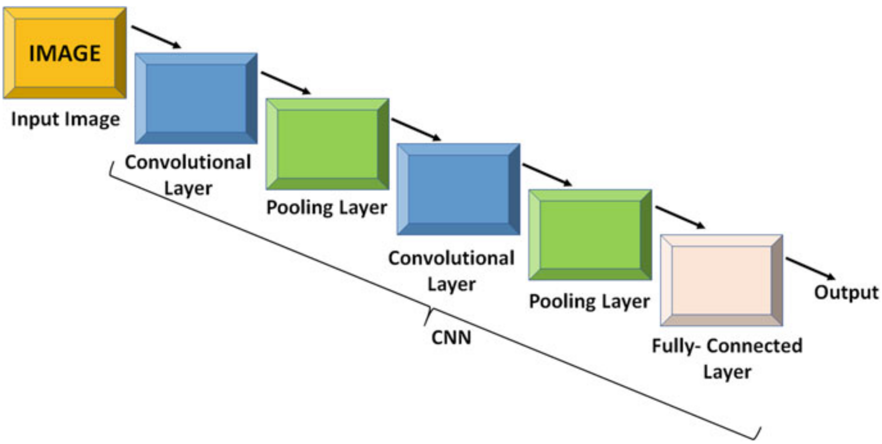


Fig. 8.2 Architecture for convolutional neural networks

The depth of the output is affected by number of filters. For example, the three distinct filters may likely yield three different feature maps, creates a depth of three.

Distance is referred as Stride, or number of pixels, the kernel progress over the input matrix. When stride values of two or greater is rare, a larger stride yields a smaller output.

Zero-padding is usually put into application, when the filters fail to fit the input image. Setting of all elements that fall outside input matrix to zero, thus provides a larger or an equally sized output.

Main three types of padding include the following:

Valid padding: also referred as no padding. Here, the last convolution is dropped if dimensions doesn't align.

Same padding: also referred to as the one that ensures or rather that the output layer has the same size as the input layer.

Full padding: Aids in increasing the size of the output by adding zeros to the border of the input. After each convolution operation, a CNN audits a Rectified Linear Unit (ReLU) transformation to the feature map, henceforth, showing the non-linearity to the model.

8.4.1.1 Advance Architecture

The Visual Geometry Group (VGG) is the successor of AlexNet which was introduced in 2012, the then successor of the traditional Convolutional Neural Networks (CNN). For every significant improvement in the successor, high performance and to dot accuracy came bundled, though we cannot deny the fact that more the improved form of architecture, the hardware requirement mainly the system processor and memory also demands to an optimum level.

8.4.2 VGG-16

In 2014, Simonyan and Zisserman developed the most preferred CNN architectures. It has mainly 16 convolutional layers, a bit complex model, but helps in easier extraction of the preferred result. Just like the LeNet, if compared with the VGG-16, is quite less complex. Mostly, VGG-16 is preferred by most of the developers as it provides a very uniform architecture. It involves a huge number of parameters, i.e., it involves nearly 138 million parameters, which becomes quite difficult to handle.

It has 16 convolutional layers (Fig. 8.3), thus the name VGG-16, and in a structured way. In the VGG-16 architecture, the input is of fixed size i.e., 224×224 RGB image, with an output dimension of $224 \times 224 \times 64$, which then is fed to pooling, with a max pool stride of 2, i.e., size 2, which gives the output dimension as $112 \times 112 \times 64$, and then it passes onto the layers 3 and 4, and the same process, continues until it reaches the flatten and at last the dense layer for the final output. The whole things can be summarized as:

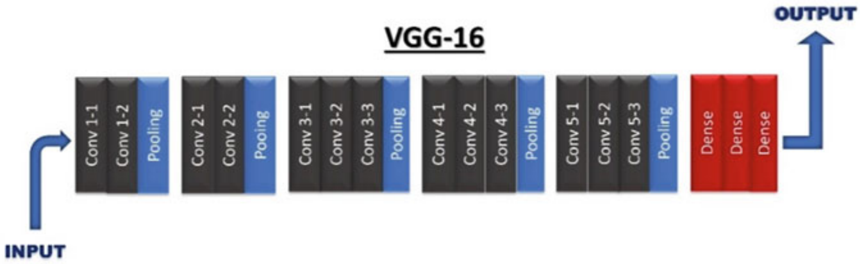


Fig. 8.3 Architecture for VGG-16

Convolution using 64 filters.
Convolution using 64 filters + Max pooling, stride 2 × 2, size 2.
Convolution using 128 filters.
Convolution using 128 filters + Max pooling, stride 2 × 2, size 2.
Convolution using 256 filters.
Convolution using 256 filters.
Convolution using 256 filters + Max pooling, stride 2 × 2, size 2.
Convolution using 512 filters.
Convolution using 512 filters.
Convolution using 512 filters+ Max pooling, stride 2 × 2, size 2.
Convolution using 512 filters.
Convolution using 512 filters.
Convolution using 512 filters+ Max pooling, stride 2 × 2, size 2.
Completely connected with 4096 nodes.
Completely connected with 4096 nodes.
It has an output layer with Softmax activation with 1000 nodes.

The hidden layers are handled with ReLU and one of the networks contains Local Response Normalization (LRN), even though this kind of normalization does not improve the performance on the trained dataset but may lead to increased memory consumption and computation time.

8.4.3 VGG-19

The VGG-19 (Fig. 8.4) is the improved model or rather the modified and the advancement version of VGG-16. The previous model architecture had 16 layers, this model adds 3 more layers which makes it 16 + 3 convolutional layers, for which the name VGG-19. The process remains the same as that of the VGG-16 model, but due to more added layers the performance of the model is quite a bit good compared to its predecessor. This also comes with the fixed size of 224 × 224 RGB image as input, that means the matrix has a shape of (224, 224, 3). The main difference lies,

Fig. 8.4 Architecture for VGG-19

during pre-processing, in this model the RGB value is subtracted from every pixel, while computing over the whole training set. Refer the layers below:

Conv3 × 3 (64)
Conv3 × 3 (64)
MaxPool
Conv3 × 3 (128)
Conv3 × 3 (128)
MaxPool
Conv3 × 3 (256)
Conv3 × 3 (256)
Conv3 × 3 (256)
Conv3 × 3 (256)
MaxPool
Conv3 × 3 (512)
Conv3 × 3 (512)
Conv3 × 3 (512)
Conv3 × 3 (512)
MaxPool
Conv3 × 3 (512)
Conv3 × 3 (512)
Conv3 × 3 (512)
Conv3 × 3 (512)
MaxPool
Completely Connected (4096)
Completely Connected (4096)
Completely Connected (1000)
SoftMax

As usual ReLU is used to establish non-linearity and to make the model aid better and improved performance followed by improved computational time than the previous models that used tanh or sigmoid functions.

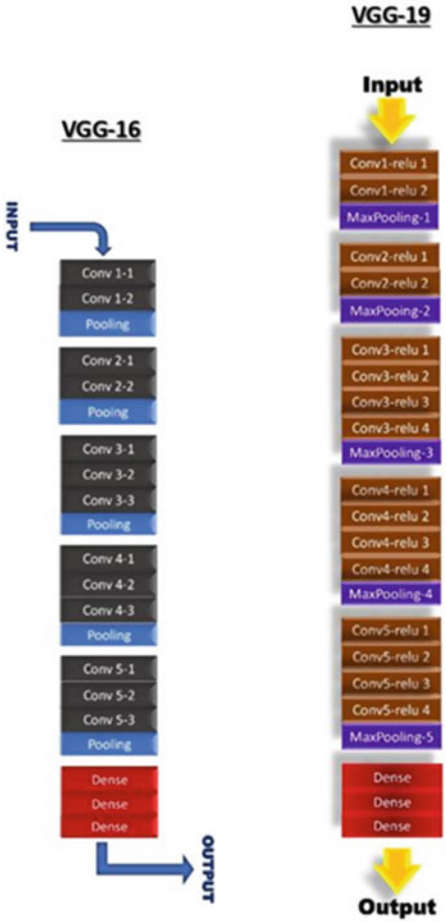


Fig. 8.5 Architecture distinction between VGG-16 vs VGG-19

8.4.4 VGG-16 vs VGG-19

In Fig. 8.5 below, we can clearly distinguish between VGG-16 and VGG-19, as discussed, the VGG-16 is the successor of AlexNet that has 16 convolutional layers and its successor is VGG-19, that has an additional 3 layers for computing the input data. Of course, the later architecture requires more computational energy and large memory to carry out its functioning, but the output is much better than its predecessor. The VGG-16 comprises of 138,357,544 which is roughly 138 million parameters with depth of 23 whereas the VGG-19 comprises of 143,667,240 which is roughly 143 million parameters with depth 26. Both the architectures require very high-speed processor rather an advanced hardware system to perform its optimum level.

8.5 Result Analysis

8.5.1 Dataset Characteristics and Analysis

8.5.1.1 Dataset

The dataset (Fig. 8.6) was collected from Kaggle to perform various Neural Network architectures. The dataset contains images of COVID, Lung-Opacity, Normal and Viral-Pneumonia images. For the scope of this chapter, we have identified, or rather distinguished people infected with COVID-19 with the help of radiographic images using the VGG-16 and VGG-19 learning models.

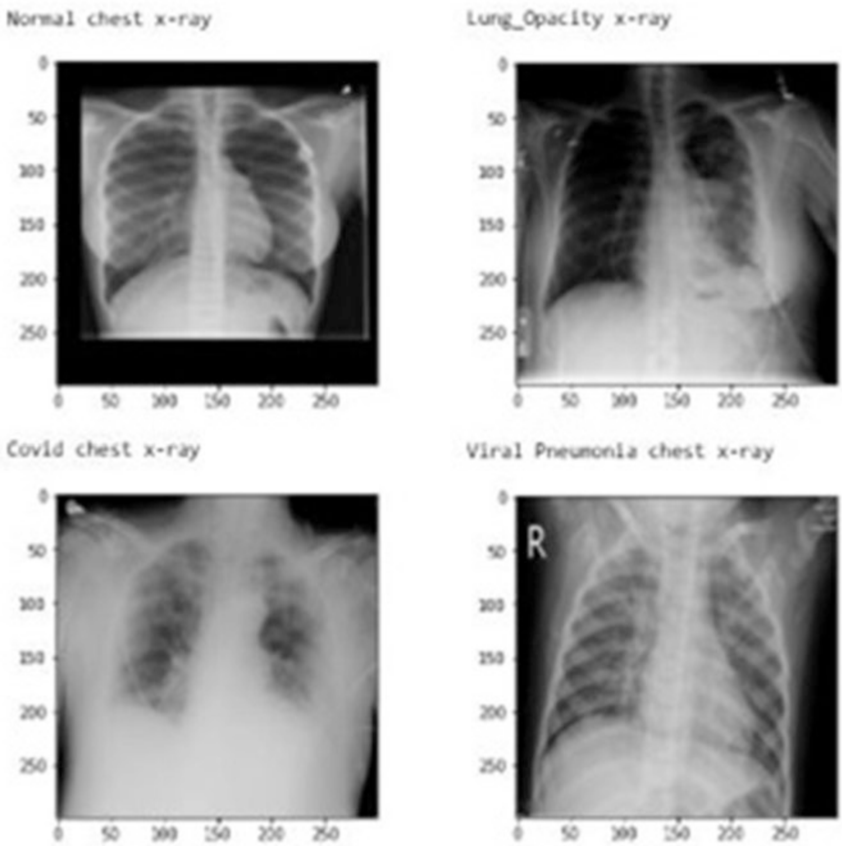


Fig. 8.6 Images from the proposed dataset

8.5.1.2 Image Pre-processing

The images after import shows the clear visualization of the dataset containing the above-mentioned images. The images present are prominent and of high resolution, that aid the model to perform more better. Now let us perform image pre-processing and find out if there is any case of imbalance in the dataset and then we will handle the dataset accordingly.

From the above images in Fig. 8.7, we can see that the proposed dataset is imbalanced. Since our primary focus is on COVID-19 class, under sampling can be done with more examples and keep classes with less examples.

Now, let us try to improve the Absolute and the Relative Frequency by focusing on our primary target, i.e., the COVID class for this proposed dataset. After performing the said method, the improved version comes out to be something like described in the figure (Fig. 8.8) below:

8.5.1.3 Train-Test Split

The proposed dataset (Fig. 8.6) after image pre-processing is allowed to divide into train and test datasets for the later processes to be performed on the dataset. The dataset is divided into 75% for the train and 25% for the test and later a validation dataset to get an optimum outcome out of the dataset. This is one of the crucial steps before proceeding towards the model training, which is dividing the dataset properly into adequate and suitable ratio, so that the architecture performs well, and we are able to obtain good accuracy. After dividing the dataset into train and test data and the validation dataset, the dataset looks something like below, in Figs. 8.9, 8.10 and 8.11:

	id	label
count	21165	21165
unique	21165	4
top	Normal\Normal-8261.png	Normal
freq	1	10192

Label	Absolute Frequency	Relative Frequency
COVID	3616	0.170848
Lung_Opacity	6012	0.284054
Normal	10192	0.481550
Viral Pneumonia	1345	0.063548

Fig. 8.7 Images showing imbalance in the proposed dataset

	Label	Absolute Frequency	Relative Frequency
0	COVID	3616	0.254773
1	Lung_Opacity	4616	0.325231
2	Normal	4616	0.325231
3	Viral Pneumonia	1345	0.094765

Fig. 8.8 Improvement in the absolute and relative frequency for the proposed dataset

	Label	Absolute Frequency	Relative Frequency
0	COVID	2712	0.254791
1	Lung_Opacity	3462	0.325254
2	Viral Pneumonia	1008	0.094701
3	Normal	3462	0.325254

Fig. 8.9 Train data

	Label	Absolute Frequency	Relative Frequency
0	Normal	577	0.325070
1	Lung_Opacity	577	0.325070
2	COVID	452	0.254648
3	Viral Pneumonia	169	0.095211

Fig. 8.10 Test data

	Label	Absolute Frequency	Relative Frequency
0	COVID	452	0.254791
1	Lung_Opacity	577	0.325254
2	Viral Pneumonia	168	0.094701
3	Normal	577	0.325254

Fig. 8.11 Validation data

8.5.1.4 Image Augmentation

One of the open-source software library Keras, that provides an interface for Artificial Neural Networks. It acts as an interface for the Tensorflow library.

The process of expanding the image training data, by using the transformations such as random rotations, shear transformers, flips and so on is what we call Image Augmentation. This method is mainly used, when there is a limited training data to test the proposed model. Actually, new images are created out of the existing images, by applying transformations. The image may be identical to each other, but for the model, it will be entirely new, thus helping us to create a larger dataset, converging efficiently.

Now, comes the concept of Image Data Generator, that aids us to achieve the same by generating batches of tensor image-data with real-time augmentation. For our proposed model the output of the above-mentioned process comes to something like this, keeping the Batch-size = 20, Image-Size = 224, and of course keeping the class-mode as “rgb”, categorical.

```
Creating train generator...
Found 10644 validated image filenames belonging to 4 classes.
Found 1775 validated image filenames belonging to 4 classes.

Creating val generator...
Found 1774 validated image filenames belonging to 4 classes.
```

Fig. 8.12 Output of image data generator

Thus, after creating the train generator, the desired result was obtained as explained in Fig. 8.12.

8.5.2 Model Building and Analysis

8.5.2.1 Creating the Classifier Model Using VGG-16

The VGG-16 was imported from the Keras library, by initializing the basic parameters required such as include top, input shape and weights. The summary of the model comes out to be something like this:

From the summary (Fig. 8.13) itself, it can be understood that each and every step of the VGG-16 proposed architecture is done in a prominent way with a total parameter of 14,714,688.

Now, the final step is to add the fully connected layers of VGG-16, taking "Softmax" as the final activation function. The model summary (Fig. 8.14) for the dense layers is obtained as follows:

A Sequential model (Fig. 8.14) is a relevant and pertinent for a stack of layers (preferably plain) where every layer has exactly one input and output tensor respectively.

Sequential model is not appropriate to use when:

The model has multiple inputs and outputs

Any one of the layers has/have multiple inputs or outputs

Layer sharing is must to perform

When you want non-linear topology (maybe a residual connection or a multi-branch model)

From the summary itself, it can be understood that each and every step of the VGG-16 proposed architecture is done in a prominent way with a total parameter of 41,459,524, trainable params of 26,744,836 and non-trainable params of 14,714,688.

The term "epoch" is used in machine learning and deep learning in order to indicate the number of passes for the entire training dataset of the proposed machine learning or a deep learning algorithm which has been completed. For instance, when the batch size comprises of the whole training dataset then the number of epochs is calculated by the number of iterations.

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

Fig. 8.13 Model summary of VGG-16

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Functional)           (None, 7, 7, 512)         14714688
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
dense (Dense)                (None, 1024)              25691136
_________________________________________________________________
dropout (Dropout)            (None, 1024)              0
_________________________________________________________________
dense_1 (Dense)              (None, 1024)              1049600
_________________________________________________________________
dropout_1 (Dropout)          (None, 1024)              0
_________________________________________________________________
fc_out (Dense)               (None, 4)                 4100
=================================================================
Total params: 41,459,524
Trainable params: 26,744,836
Non-trainable params: 14,714,688
_________________________________________________________________
```

Fig. 8.14 Model summary of fully connected layers of VGG-16

```
50/50 [==============================] - 23s 469ms/step - loss: 0.2140 - recall: 0.9180 - precision: 0.9356 - acc: 0.9280 - v
al_loss: 0.2792 - val_recall: 0.8840 - val_precision: 0.9170 - val_acc: 0.9000
```

Fig. 8.15 Final epoch after training the model for VGG-16

```
50/50 [==============================] - 23s 460ms/step - loss: 0.1645 - recall: 0.9424 - precision: 0.9496 - acc: 0.9472 - v
al_loss: 0.2523 - val_recall: 0.8880 - val_precision: 0.9024 - val_acc: 0.8960
```

Fig. 8.16 Final epoch after fine-tuning for VGG-16

After training the classification model, which we just created, keeping epochs = 50 (Fig. 8.15) and learning rate = 1e − 5, the model accuracy comes to be:

The accuracy we obtained is roughly 92%, the accuracy can be improved by applying some fine-tuning methods.

8.5.2.2 Fine Tuning

Unfreezing of quite a few of the top layers for a frozen model and combine train both the new classifying layers and the last layers of the model. Henceforth, allowing us to "fine-tune" the high-order feature representations in the proposed model in order to make them more relevant for the specified task. The model will be fine-tuned (Fig. 8.16) unfreezing the VGG-16 layers and trainings. The accuracy of the final-tuned model is:

The accuracy we obtained is roughly 94%, the accuracy can be improved by applying some fine-tuning methods. Thus, the accuracy quite a bit increased after fine-tuning it.

8.5.2.3 Evaluating the Model

In this very step the model is evaluated using the vgg16_model_evaluate (Fig. 8.17). The output of the step is as:

8.5.3 Classification Report

The classification report provides detailed report that comprises of the precision, recall, F1, and support scores for the model.

There are mainly four types to check whether the predictions are right or wrong:

(TN) / True Negative: observation against negative and predicted negative

(TP) / True Positive: observation against positive and predicted positive

(FN) / False Negative: observation against positive but predicted negative

(FP) / False Positive: observation against negative but predicted positive

Precision: This is defined as the number of correct output/outputs made available by the model or out of the total positive classes that are correctly predicted by the model, out of how many of them were actually true. The formula for the same is given below:

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Postive} + \text{False Positive}} \tag{8.3}$$

Recall: This is defined as the output of total positive classes, which basically indicates how our given proposed classifier model is predicted correctly. The value of the recall compulsorily should be as high as possible. The formula for the same is given below:

$$\text{Recall} = \frac{\text{True Positive}}{\text{True Postive} + \text{False Negative}} \tag{8.4}$$

```
vgg16_model.evaluate(test_generator)
60/60 [==============================] - 62s 1s/step - loss: 0.2599 - recall: 0.9048 - precision: 0.9156 - acc: 0.9104
[0.2598646879196167,
 0.9047887325286865,
 0.915621459484l003,
 0.9104225635528564]
```

Fig. 8.17 Evaluated model of VGG-16

8.5.3.1 F1 Score

For an instance, given any two models which have high recall and low precision or vice-versa, it is quite complex to compare these models. Hence to solve this, use of F-Score can be initiated. The value of this score is very useful that helps us to calculate and assess the precision and recall at the same time. The F-score becomes maximum when the recall is equivalent to the precision. The formula for the same is given below:

$$\mathrm{F} - \mathrm{measure} = \frac{2 \times \mathrm{Recall} \times \mathrm{Precision}}{\mathrm{Recall} + \mathrm{Precision}} \tag{8.5}$$

8.5.3.2 Support

The number of actual instances of the for a given dataset is actually known by the term “Support”. Ill-balance in the data, here we're considering the trained data to be precise, could signify structural weakness and hence indicate to the application of rebalancing and stratified sampling, to keep in mind it also doesn't switches between the models rather goes through diagnosis and evaluation process. The classification report (Fig. 8.18) for the proposed model after training the dataset is comes out to be something like this:

8.5.3.3 Confusion Matrix

The confusion matrix is mainly used to assess the proficiency or rather the achievement of the trained classification models for the proposed test data. It only indicates, if the true values for test data are known to the model. The visualization of the confusion matrix is easy and simple to understand, though some of keywords or terminologies may stand out to be confusing. As it gives the errors within the model

	precision	recall	f1-score	support
0	0.94	0.96	0.95	452
1	0.90	0.88	0.89	577
2	0.88	0.89	0.88	577
3	0.95	0.97	0.96	169
accuracy			0.91	1775
macro avg	0.92	0.92	0.92	1775
weighted avg	0.91	0.91	0.91	1775

{'COVID': 0, 'Lung_Opacity': 1, 'Normal': 2, 'Viral Pneumonia': 3}

Fig. 8.18 Classification Report of the proposed model after training the dataset for VGG-16 performance as form of a matrix, henceforth can also be referred as an error matrix. Salient features of Confusion matrix are as follows:

Consider a case where there are two prediction classes of given classifiers are present, and the given matrix consists of 2 × 2 table, for 3 classes, 3 × 3 table, and it goes on.

The matrix is further being split into two dimensions, which are basically the predicted values and actual values accompanying the total number of predictions.

Various calculations can be performed, for instance- model's accuracy, with the help of this matrix. Some of the calculations are described below:

8.5.3.4 Classification Accuracy

One of the important specifications is to determine the accuracy of the given classification problems. It is defined as how often the model predicts the correct output. This can be calculated as the ratio of the number of correct predictions made by the proposed classifier to all number of predictions made by the classifiers. The formula is given below:

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{True Postive} + \text{False Positive} + \text{False Negative} + \text{True Negative}} \tag{8.6}$$

8.5.3.5 Misclassification Rate

Also termed as the Error rate, defines how often the proposed model gives the wrong predictions. The evaluation of error rate can be predicted or rather calculated as the number of incorrect instances to all number of the instances made by the classifier. The formula is given below:

$$\text{Error Rate} = \frac{\text{False Positive} + \text{False Negative}}{\text{True Postive} + \text{False Positive} + \text{False Negative} + \text{True Negative}} \tag{8.7}$$

8.5.3.6 Precision

This is defined as the number of correct output/outputs made available by the model or out of all positive classes which are correctly predicted by the model, out of how many of them were actually true. The formula is given below:

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Postive} + \text{False Positive}} \tag{8.8}$$

8.5.3.7 Recall

This is defined as the output of total positive classes, how our given proposed model predicted correctly. The value of recall must be as high as possible. The formula is given below:

$$\text{Recall} = \frac{\text{True Positive}}{\text{True Postive} + \text{False Negative}} \tag{8.9}$$

8.5.3.8 F-Measure

For instance, given any two models have low precision and high recall or vice-versa, it is quite difficult to compare these models. Hence to solve this, use of F-Score can be initiated. The value of this score is very useful that helps us to evaluate the recall and precision at the same time. The F-score becomes maximum when the recall is equal to the precision. The formula is given below:

$$\text{F} - \text{measure} = \frac{2 \times \text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}} \tag{8.10}$$

The Confusion Matrix for the proposed model (Fig. 8.19) of VGG-16 is visualized as below:

As explained above, the confusion matrix depicts completely all the mentioned parameters very well, relations among them and their respective values.

8.5.4 Creating the Classifier Model Using VGG-19

The VGG-19 was imported from the Keras library, by initializing the basic parameters required such as include top, input shape and weights. This is more of a complex but faster model than VGG-16. It is expected to give better accuracy than VGG-16. The summary of the model comes out to be something like this:

From the summary itself as given in (Fig. 8.20), it can be understood that each and every step of the VGG-19 proposed architecture is done in a prominent way with a total parameter of 20,024,384.

Now, the final step is to add the fully connected layers of VGG-19, taking "Softmax" as the final activation function. The model summary obtained as follows:

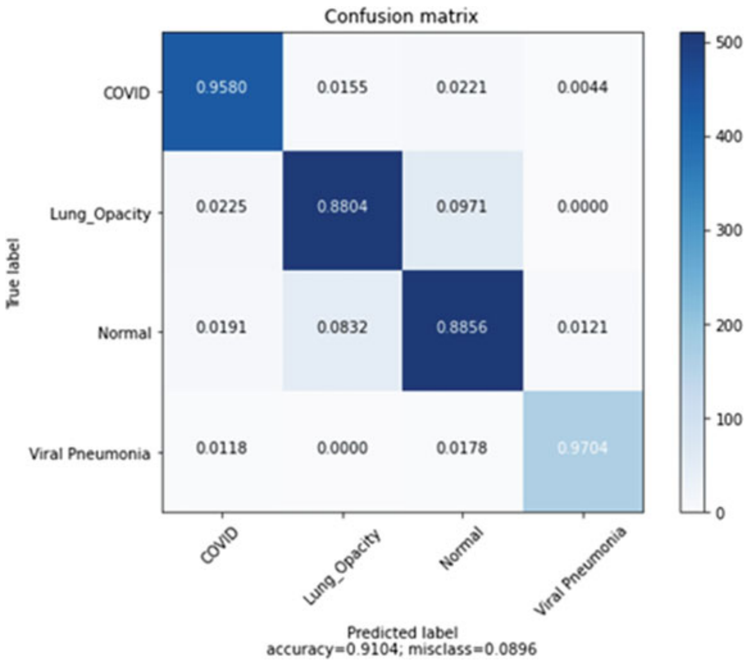


Fig. 8.19 Confusion matrix for VGG-16 model

From the summary itself of fully connected layers as shown in Fig. 8.21, it can be understood that each and every step of the VGG-19 proposed architecture is done in a prominent way with a total parameter of 46,769,220, trainable params of 26,744,836 and non-trainable params of 20,024,384. It is quite obvious as the VGG-19 model has more parameters than the VGG-16 model and thus this many parameters requires good computational power.

After training the classification model, which we just created, keeping epochs = 50 and learning rate=1e − 5, the model accuracy (Fig. 8.22) comes to be:

The accuracy we obtained is roughly 94%, the accuracy can be improved by applying some fine-tuning methods.

8.5.4.1 Fine Tuning

The model will be fine-tuned, unfreezing the VGG-19 layers and trainings. The accuracy of the final-tuned model is:

The accuracy we obtained is roughly 94%, the accuracy (Fig. 8.23) can be improved by applying some fine-tuning methods. Thus, the accuracy quite a bit increased after fine-tuning it.

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kerne
ls_notop.h5
80142336/80134624 [==============================] - 21s 0us/step
Model: "vgg19"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv4 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv4 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv4 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
=================================================================
Total params: 20,024,384
Trainable params: 0
Non-trainable params: 20,024,384
```

Fig. 8.20 Model summary of VGG-19

8.5.4.2 Evaluating the Model

In this very step the model is evaluated (Fig. 8.24), using the vgg19_model_evaluate. The output of the step is as:

8.5.4.3 Classification Matrix

The classification report in Fig. 8.25 below, for the proposed model after training the dataset is comes out to be something like this, comparing with the VGG-16 model the accuracy VGG-19 model is bit less, but this is not seen very often.

8.5.4.4 Confusion Matrix

The concept of the confusion matrix remains the same as discussed above. The reader is advised to go through details of both the Confusion Matrix i.e., for the

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg19 (Functional)           (None, 7, 7, 512)         20024384
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
dense (Dense)                (None, 1024)              25691136
_________________________________________________________________
dropout (Dropout)            (None, 1024)              0
_________________________________________________________________
dense_1 (Dense)              (None, 1024)              1049600
_________________________________________________________________
dropout_1 (Dropout)          (None, 1024)              0
_________________________________________________________________
fc_out (Dense)               (None, 4)                 4100
=================================================================
Total params: 46,769,220
Trainable params: 26,744,836
Non-trainable params: 20,024,384
_________________________________________________________________
```

Fig. 8.21 Model summary of fully connected layers of VGG-19

```
50/50 [==============================] - 31s 614ms/step - loss: 0.3359 - recall: 0.8540 - precision: 0.8903 - acc: 0.8752 - v
al_loss: 0.3480 - val_recall: 0.8720 - val_precision: 0.8971 - val_acc: 0.8840
```

Fig. 8.22 Final epoch after training the model for VGG-19

```
50/50 [==============================] - 25s 510ms/step - loss: 0.2800 - recall: 0.8884 - precision: 0.9125 - acc: 0.9040 - val
_loss: 0.3219 - val_recall: 0.8680 - val_precision: 0.8821 - val_acc: 0.8720
```

Fig. 8.23 Final epoch after fine-tuning for VGG-19

```
60/60 [==============================] - 34s 558ms/step - loss: 0.3111 - recall: 0.8777 - precision: 0.8949 - acc: 0.8839
[0.3110973536968231,
 0.8777464628219604,
 0.8948879837989807,
 0.8839436769485474]
```

Fig. 8.24 Evaluated model of VGG-19

proposed model of VGG-16 and VGG-19, to get clear idea about the results obtained from both the advanced architectures, confusion matrix for VGG-19 is visualized as below in Fig. 8.26:

	precision	recall	f1-score	support
0	0.95	0.88	0.91	452
1	0.86	0.88	0.87	577
2	0.84	0.88	0.86	577
3	0.95	0.95	0.95	169
accuracy			0.88	1775
macro avg	0.90	0.89	0.90	1775
weighted avg	0.89	0.88	0.88	1775

{'COVID': 0, 'Lung_Opacity': 1, 'Normal': 2, 'Viral Pneumonia': 3}

Fig. 8.25 Classification Report of the proposed model after training the dataset of VGG-19

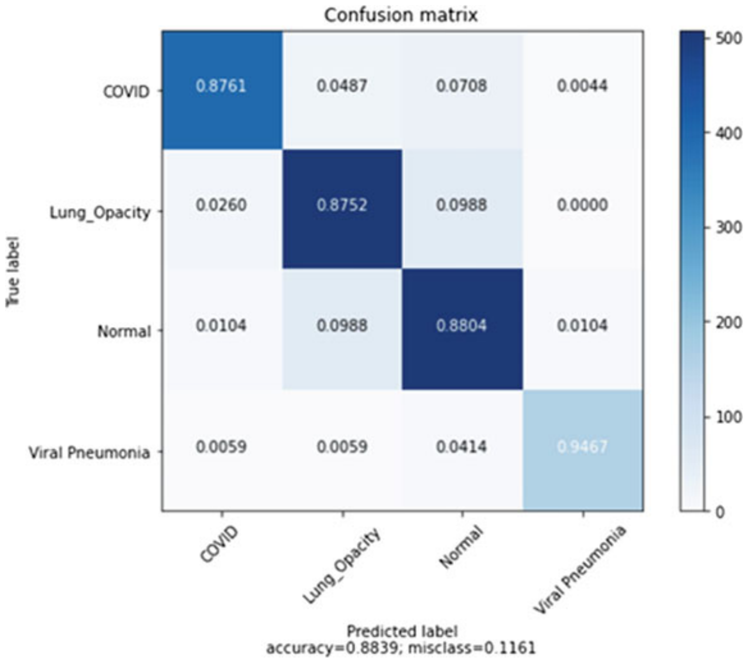


Fig. 8.26 Confusion matrix for VGG-19 model

8.6 Conclusion

To conclude while analyzing the results derived is with the simple use of transfer learning method for a model trained in a dataset (say, imagenet) quite different from the given problem, we can obtain satisfactory results while training only the fully connected layerand reaching an average accuracy of 0.9242. But after performing a fine-tuning, the accuracy got increased by approximately 2%.

While analyzing the accuracy and recall of the COVID-19 class in the test set of the proposed dataset, we can observe that for most of the cases are found to be COVID-19, which in reality is, as the recall value is 0.97.

To draw an overall conclusion, the model discussed in this chapter is capable to meet the requirements that are being highlighted as per the scope of the chapter. From identifying the type of diseases from the collected image dataset, filtering and optimizing the image dataset and then selecting some key features and discarding the unwanted features so that the image dataset available to us is clean and can be processed for further steps. The chapter also satisfies the use of advanced Image Processing algorithms for training and prediction of the image dataset for the discussed diseases as mentioned earlier. The model training is also done very fine as we can obtain almost correct predicted output, as discussed.

The Classification Report and the Confusion Matrix is also given to assess, and aid the reader to distinguish between various parameters, which is taken into account for measuring the performance of the two models that we have performed the model training and prediction on, which also meet our requirements, as mentioned earlier. Several other modifications can also be made to this proposed system, which is discussed in the future scope of this chapter.

The chapter is based on building an advanced model based on Image processing techniques of Deep Learning and basic Machine Learning techniques, that comes under the domain of Artificial Intelligence. For the future scope the same model can be more optimized and trained using some more advanced Image processing algorithms, that will act as an advantage for the model overall. By optimization and using more advanced Deep Learning techniques, indicates that prepare such a model that could be put into use to train any image dataset and can get a good accuracy, indicating that the model is able to identify the type of diseases properly and that too with good accuracy. Also, for creating a overall system of all diseases, basically that takes time for the doctors to diagnose based on the X-Ray reports or related to that, those diseases can also be added into this existing model so that a complete package will be available for the medical services, in order to serve the mankind quickly, with correct and proper diagnosis and the whole process is done through Artificial Intelligence, where the industry is now heading to.

Conflict of Interest

There is no conflict of interests.

Funding There is no funding support.

Data Availability Not applicable.

References

1. Ibrahim, D. M., Elshennawy, N. M., & Sarhan, A. M. (2021). Deep-chest: Multi-classification deep learning model for diagnosing COVID-19, pneumonia, and lung cancer chest diseases. *Computers in Biology and Medicine, 132*, 104348. https://doi.org/10.1016/j.compbiomed.2021.104348
2. Wynants, L., Van Calster, B., Bonten, M. M. J., Collins, G. S., Debray, T. P. A., De Vos, M., Haller, M. C., Heinze, G., Moons, K. G. M., Riley, R. D., Schuit, E., Smits, L. J. M., Snell, K. I. E., Steyerberg, E. W., Wallisch, C., & van Smeden, M. (2020). Prediction models for diagnosis and prognosis of covid-19 infection: systematic review and critical appraisal, the bmj. *BMJ, 369*, m1328. https://doi.org/10.1136/bmj.m1328
3. Wang, S., Zha, Y., Li, W., Wu, Q., Li, X., Niu, M., Wang, M., Qiu, X., Li, H., Yu, H., Gong, W., Bai, Y., Li, L., Zhu, Y., Wang, L., & Tian, J. (2020). A fully automatic deep learning system for COVID-19 diagnostic and prognostic analysis. *European Respiratory Journal, 56*, 2000775. https://doi.org/10.1183/13993003.00775-2020
4. Konar, D., Panigrahi, B. K., Bhattacharyya, S., Dey, N., & Jiang, R. (2021). Auto-diagnosis of COVID-19 using lung CT images with semi-supervised shallow learning network. *IEEE Access, 9*, 28716–28728. https://doi.org/10.1109/ACCESS.2021.3058854
5. Mallio, C. A., Napolitano, A., Castiello, G., Giordano, F. M., D'Alessio, P., Iozzino, M., Sun, Y., Angeletti, S., Russano, M., Santini, D., Tonini, G., Zobel, B. B., Vincenzi, B., & Quattrocchi, C. C. (2021). Deep learning algorithm trained with COVID-19 pneumonia also identifies immune checkpoint inhibitor therapy- related pneumonitis. *Cancers, 13*, 652. https://doi.org/10.3390/cancers13040652. MDPI.
6. Farhat, H., Sakr, G. E., & Kilany, R. (2020). Deep learning applications in pulmonarymedical imaging: recent updates and insights on COVID-19. *Machine Vision and Applications, 31*, 53. https://doi.org/10.1007/s00138-020-01101-5
7. Chen, J., Wu, L., Zhang, J., Zhang, L., Gong, D., Zhao, Y., Chen, Q., Huang, S., Yang, M., Yang, X., Hu, S., Wang, Y., Hu, X., Zheng, B., Zhang, K., Wu, H., Dong, Z., Xu, Y., Zhu, Y., . . . Yu, H. (2020). Deep learning-based model for detecting 2019 novel coronavirus pneumonia on high-resolution computed tomography. *Scientific Reports, 10*, 19196. https://doi.org/10.1038/s41598-020-76282-0
8. Kieu, S. T. H., Bade, A., Hijazi, M. H. A., & Kolivand, H. (2020). A survey of deep learning for lung disease detection on medical images: state-of-the-art, taxonomy, issues and future directions. *Journal of Imaging, 6*, 131. https://doi.org/10.3390/jimaging6120131
9. Han, C. H., Kim, M., & Kwak, J. T. (2021). Semi-supervised learning for an improved diagnosis of COVID-19 in CT images. *PLoS One, 16*(4), e0249450. https://doi.org/10.1371/journal.pone.0249450
10. Sujata, D., Chinmay, C., Sourav, K. G., & Subhendu, K. P. (2021). Intelligent computing on time-series data analysis and prediction of COVID-19 pandemics. *Pattern Recognition Letters, 151*, 69–75. https://doi.org/10.1016/j.patrec.2021.07.027
11. Lalit, G., Chinmay, C., Said, M., & Victor, S. (2021). Healthcare informatics for fighting COVID-19 and future pandemics. In *EAI/Springer innovations in communication and computing*. Springer Nature. ISBN: 978-3-030-72751-2.
12. Saood, A., & Hatem, I. (2021). COVID-19 lung CT image segmentationusing deep learning methods: U-Netversus SegNet. *BMC Med Imaging, 21*, 19. https://doi.org/10.1186/s12880-020-00529-5
13. Harmon, S. A., Sanford, T. H., Xu, S., Turkbey, E. B., Roth, H., Xu, Z., Yang, D., Myronenko, A., Anderson, V., Amalou, A., Blain, M., Kassin, M., Long, D., Varble, N., Walker, S. M., Bagci, U., Ierardi, A. M., Stellato, E., Plensich, G. G., . . . Turkbey, B. (2020). Artificial intelligence for the detection of COVID-19 pneumonia on chest CT using multinational datasets. *Nature Communications, 11*, 4080. https://doi.org/10.1038/s41467-020-17971-2
14. Tau, N., Stundzia, A., Yasufuku, K., Hussey, D., & Metser, U. (2020). Convolutional neural networks in predicting nodal and distant metastatic potential of newly diagnosed non–small cell

lung cancer on FDG PET images. *Nuclear Medicine and Molecular Imaging, AJR, 215*, 1–6. https://doi.org/10.2214/AJR.19.22346
15. Kassani, S. H., Kassasni, P. H., Wesolowski, M. J., Schneider, K. A., & Deters, R. (2020). Automatic detection of coronavirus disease (COVID-19) in X-Ray and CT images: A machine learning-based approach, *arXiv*, 2004.10641. [cs, eess]. Retrieved from http://arxiv.org/abs/2004.10641
16. Muhammad, L. J., Islam, M. M., Usman, S. S., & Ayon, S. I. (2020). Predictive data mining models for novel coronavirus (COVID-19) infected patients' recovery. *SN Computer Science, 1*(4), 206. https://doi.org/10.1007/s42979-020-00216-w
17. Lyncha, C. M., Abdollahib, B., Fuquac, J. D., de Carloc, A. R., Bartholomaic, J. A., Balgemannc, R. N., van Berkeld, V. H., & Frieboes, H. B. (2017). Prediction of lung cancer patient survival via supervised machine learning classification techniques. *International Journal of Medical Informatics, 108*, 1e8. https://doi.org/10.1016/j.ijmedinf.2017.09.013
18. Roda, W. C., Varughese, M. B., Han, D., & Li, M. Y. (2020). Why is it difficult to accurately predict the COVID-19 epidemic? *Infectious Disease Modelling, 5*, 271–281. https://doi.org/10.1016/j.idm.2020.03.001
19. Sajadi, M. M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F., & Amoroso, A. (2020). Temperature, humidity and latitude analysis to predict potential spread and seasonality for COVID-19. *JAMA Network Open, 3*(6), e2011834. https://doi.org/10.1001/jamanetworkopen.2020.11834
20. Petropoulos, F., & Makridakis, S. (2020). Forecasting the novel coronavirus COVID-19. *PLoS One, 15*(3), e0231236. https://doi.org/10.1371/journal.pone.0231236
21. Lin, L., Qin, L., Xu, Z., Yin, Y., Wang, X., Kong, B., Bai, J., Lu, Y., Fang, Z., Song, Q., Cao, K., Liu, D., Wang, G., Xu, Q., Fang, X., Zhang, S., Xia, J., & Xia, J. (2020). Artificial intelligence distinguishes COVID-19 from community acquired pneumonia on chest CT. *RSNA Radiology, 296*, E65–E71. https://doi.org/10.1148/radiol.2020200905
22. Mohammad-Rahimi, H., Nadimi, M., Ghalyanchi-Langeroudi, A., Taheri, M., & Ghafouri-Fard, S. (2021). Application of machine learning in diagnosis of COVID-19 through X-Ray and CT images: A scoping review. *Frontiers in Cardiovascular Medicine, 8*, 638011. https://doi.org/10.3389/fcvm.2021.638011
23. Ozsahin, I., Sekeroglu, B., Musa, M. S., Mustapha, M. T., & Ozsahin, D. U. (2020). Review on diagnosis of COVID-19 from chest CT images using artificial intelligence. *Hindawi Computational and Mathematical Methods in Medicine, 2020*, 9756518. https://doi.org/10.1155/2020/9756518
24. Ardakani, A. A., Kanafi, A. R., Acharya, U. R., Khadem, N., & Mohammadi, A. (2020). Application of deep learning technique to manage Covid-19 in routine clinical practice using CT images: results of 10 convolutional neural networks. *Computers in Biology and Medicine, 121*, 103795. https://doi.org/10.1016/j.compbiomed.2020.103795
25. Perumal, V., Narayanan, V., & Rajasekar, S. J. S. (2021). Detection of Covid-19 using CXR and CT images using transfer learning and haralick features. *Applied Intelligence, 51*, 341–358. https://doi.org/10.1007/s10489-020-01831-z
26. Pereira, R. M., Bertolini, D., Teixeira, L. O., Silla, C. N., Jr., & Costa, Y. M. (2020). Covid-19 identification in chest x-ray images on flat and hierarchical classification scenarios. *Computer Methods Programming Biomedicine, 194*, 105532. https://doi.org/10.1016/j.cmpb.2020.105532
27. Zhang, J., Xie, Y., Li, Y., Shen, C., & Xia, Y. (2020). Covid-19 screening on chest X-Ray images using deep learning based anomaly detection, *arXiv*, 2003.12338. arXiv preprint.
28. Hall, L. O., Paul, R., Goldgof, D. B., & Goldgof, G. M. (2020). Finding Covid-19 from chest X-Rays using deep learning on a small dataset, *arXiv*, 2004.02060. arXiv preprint.

29. Priyanka, D., & Chinmay, C. (2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence*, 1–24. https://doi.org/10.1080/0952813X.2021.1958063
30. Abdul, R. J., Chinmay, C., & Celestine, W. (2021). Exploratory data analysis, classification, comparative analysis, case severity detection, and internet of things in COVID-19 Telemonitoring for smart hospitals. *Journal of Experimental & Theoretical Artificial Intelligence*, 1–24. https://doi.org/10.1080/0952813X.2021.1960634
31. Anichur, R., Chinmay, C., Adnan, A., Karim, R., Islam, J., Dipanjali, K., Ziaur, R., & Shahab, S. B. (2021). SDN-IoT empowered intelligent framework for industry 4.0Applications during COVID-19 pandemic. *Cluster Computing*, 1–18. https://doi.org/10.1007/s10586-021-03367-4
32. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). BIFM: Big-data driven intelligent forecasting model for COVID-19. *IEEE Access, 9*, 97505–97517. https://doi.org/10.1109/ACCESS.2021.3094658

Part III
Privacy and Security in Healthcare

Chapter 9
Internet of Things in the Healthcare Applications: Overview of Security and Privacy Issues

Soufiene Ben Othman, Faris A. Almalki, and Hedi Sakli

Abstract Current advances in technology have led to the emergence of networks of small and low-cost devices that incorporate sensors with embedded processing and limited wireless communication capabilities. IoT is used in healthcare for monitoring patients via wearable sensors for measuring many physiological information. These collected information's can be stored, processed, and make it available to doctors to give a consultation at any time which improves the efficiency of the traditional medical systems. Indeed, due to multiple design faults and a lack of effective security measures in healthcare equipment and applications, the healthcare industry based in IoT is increasingly confronting security challenges and threats. For this reason, big security measures should be taken to ensure that patients' data can only be accessed by legitimate users. In this chapter, we offer a comprehensive overview of many potential attacks and explore their implications. In addition, we examine and debate the existing security solutions proposed for healthcare systems.

Keywords Smart healthcare · Medical IoT · Security · Privacy

S. B. Othman (✉)
PRINCE Laboratory Research, ISITcom, Hammam Sousse, University of Sousse, Sousse, Tunisia

F. A. Almalki
Department of Computer Engineering, College of Computers and Information Technology, Taif University, Taif, Saudi Arabia

H. Sakli
MACS Research Laboratory, National Engineering School of Gabes, Gabes University, Gabes, Tunisia

EITA Consulting, Montesson, France

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_9

9.1 Introduction

In recent years, the coming out of the Internet of Things (IoT) has taken a significant impact on science and technology [1]. The Internet of Things is defined as a network of identifiable and unique elements that communicate without human interaction using IP connectivity [1]. These items can perceive, control, analyze, and make decisions independently, as well as in collaboration with other objects [2]. At the end of 2019, there were around 9.5 billion connected IoT devices, according to IoT Analytics estimates [3]. The concept of the Internet of Things is evolving exponentially and covering more and more domains every day [4]. It will change the way we live and work by making different aspects of life smart. Through the development of new applications in fields such as smart homes, smart health, smart cities, industry 4.0, Wireless Sensor Networks (WSN), smart agriculture, and others, IoT has the potential to introduce and establish a smart world [5]. The interested reader is referred to [1–19] for a deeper understanding of the IoT.

The healthcare 4.0 is a combination between the Internet of Things and modern Information and Communication Technologies [6]. The Smart health plays an important role in health applications by integrating sensors and actuators into patients' bodies for monitoring and follow-up. The global IoT medical device market is expected to grow at a compound annual growth rate of 4.5 percent, reaching $409.5 billion in 2025 [7]. The IoT is used in health care to monitor the physiological status of patients. On-board sensors can collect information directly from the patient's body and transmit it to the physician. These collected information's can be stored, processed, and make it available to doctors to give a consultation at any time and from any devices that connected to the Internet (e.g., Smartphone or Tablet) [8–15]. Further, the doctor is alerted in real time of any sudden change concerning the condition of his patient, as well as take actions like advising patients, and interrogate the sensors to have the current values. This technology can fully isolate the patient from the hospital's centralized system while yet allowing them to communicate with their physician. Aremote medical surveillance system employing IoT is depicted in Fig. 9.1.

The IoT deploys a very large number of small intelligent devices to collect detailed information about the environment [10]. Despite miniaturization and reducing the manufacturing cost, these devices generally have limited resources in terms of power transmission, data processing, bandwidth, storage capacity, and energy. Where, the transmission and reception operations consume a large part of the energy of the node devices [11]. Unsurprisingly, when it comes to evaluate the performance of a sensor network, service life is probably the most important metric, especially since the most low-power devices have limited lifetime, besides continuous battery replacement of thousands of these devices deployed in areas with difficult access is often impractical and even impossible [12]. Therefore, energy consumption is a key challenge in sensors. To this end, several approaches have been proposed to conserve the energy resource at the sensory level and overcome the challenges inherent in its limitation [13].

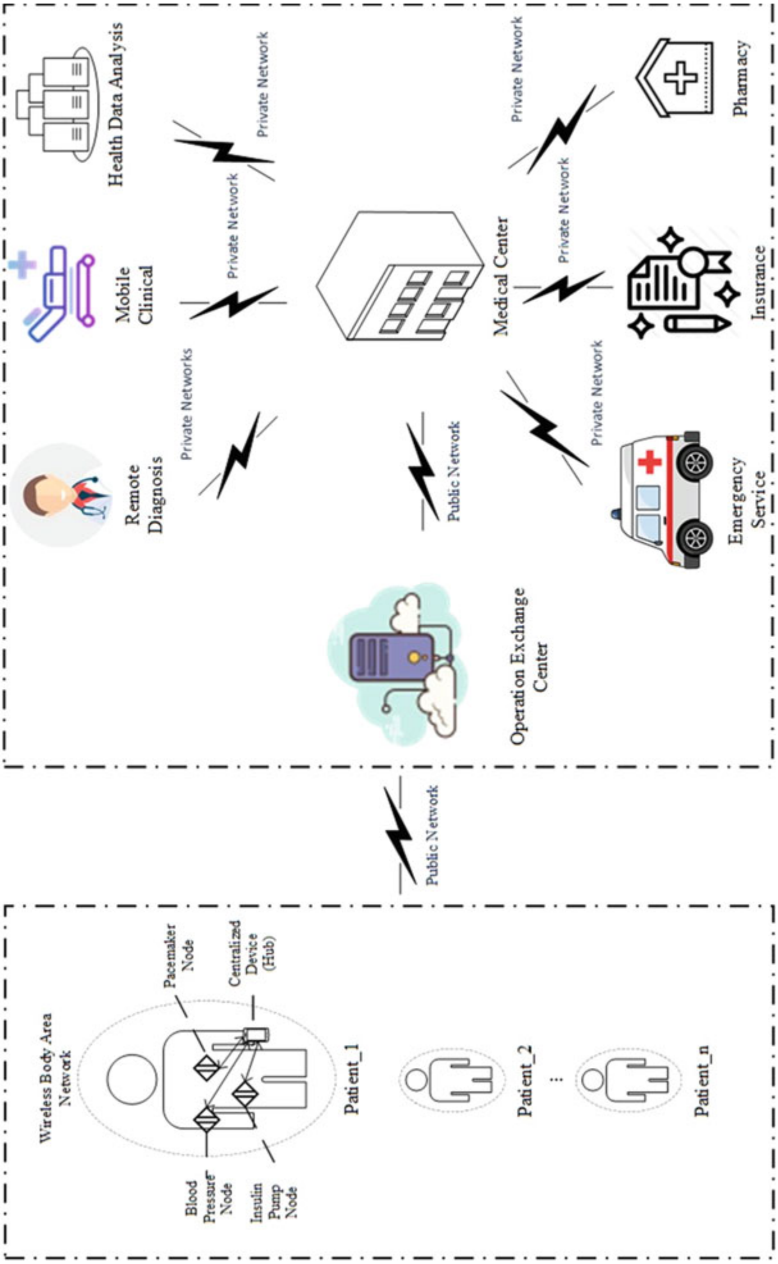


Fig. 9.1 IoT-based healthcare monitoring architecture [3]

Many other issues have been explored in relation to IoT, one of the most significant is the security issue [14]. The existence of a huge network with a big number of interconnected devices will almost certainly suggest a variety of attack and eavesdropping scenarios that could endanger those entities and their users [15]. The threat posed by these Internet-connected Things affects not only IoT systems, but the entire eco-system, including websites, applications, social networks, and servers. In the healthcare application using IoT, we add more devices to our clothes and bodies, more personal information will be collected. As the number of IoT devices grows at an exponential rate, so do the technological and security challenges [13]. For example, an attack may rationally modify a drug dose that would kill or have catastrophic health consequences for a certain patient. Furthermore, the healthcare devices can be remotely exploited through the many communications medium (e.g., Wi-Fi, Zigbee, Bluetooth, 6LowPAN, NFC, etc.). The attackers can easily eavesdrop on the communication channel in this instance and obtain the transmitted data [16]. It is critical to develop new security frameworks that prevent hostile or unauthorized objects from getting access to IoT systems, reading, or altering the data collected [17].

The purpose of this chapter is to review the current literature on the challenges and approaches to security and privacy in IoT-Based Healthcare applications. To demystify the roots of dangers in IoT, we introduce and categorize the IoT security threat categories as well as defense techniques in order to provide the reader with the security necessary background for a better understanding of this area. We present a taxonomy of IoT attacks as well as an analysis of IoT security concerns at various tiers. We also give a security requirements taxonomy depending on the goals of the assaults. Then, we present the solutions to increase IoT security. The remainder of this chapter is organized as follows: We give a full taxonomy of current security and privacy attacks on healthcare systems in Sect. 9.2. The security needs taxonomy for healthcare systems is provided in the next section. In Sect. 9.3, we look at some of the existing ways to securing healthcare systems that have been offered by researchers. Finally, we conclude the chapter in Sect. 9.4.

9.1.1 The Security Attacks in IoT-Based Healthcare Applications

As mentioned previously, the present healthcare equipment and applications do not meet security and privacy standards. The attackers can use many components of healthcare systems to carry out unwanted operations [18]. To carefully incorporate security needs into IoT systems, it is first required to investigate IoT vulnerabilities and attacks. An attack is any attempt to break an encryption scheme, and a successful attack implies that the security of the data encrypted under this scheme has been compromised [19]. In this section, we discuss several types of attacks on different parts of healthcare systems (e.g., sensor, device, network, etc.) and how attackers can undermine the security and privacy of targeted healthcare systems. A detailed summary in Table 9.1.

9.2 Security Requirements in IoT-Based Healthcare Applications

We divide IoT security requirements into three categories based on the aims of IoT attacks shown in Sect. 9.2: data security, communication security, and device security. Table 9.2 summarizes the security requirements.

9.3 Security Solutions in IoT-Based Healthcare Applications

One of the hottest study topics in healthcare systems based-IoT is security, which has drawn many researchers from academia, business, and standardization bodies. There has been a slew of solutions aimed at addressing IoT security issues to date. To improve IoT security, several new technologies and methodologies were presented. In the following subsections, we discuss different existing security measures for healthcare systems by categorizing in six broad categories, including Fog Computing, Software-defined Networking, Blockchain, Lightweight Cryptography, Homomorphic and Searchable Encryption, and Machine Learning.

9.3.1 Fog Computing-Based Solutions

Fog computing has been introduced as a new paradigm for extending Cloud computing's processing resources. At the network's edge, it provides storage, processing, and networking/communication [19]. Fog computing is made up of fog nodes that are placed near IoT devices and connected to a cloud server. Because IoT devices have limited resources, fog nodes can help protect IoT settings by providing authentication, privacy preservation, and encryption. Several security schemes to protect healthcare systems based-IoT using Fog computing are available in the literature. A state-of-the-art review is outlined in this subsection. Hassen et al. [20] proposed a home hospitalization system by combining IoT applications like fog computing and cloud computing. The goal of the study was to propose a smart-based model for usage in the healthcare system during a coronavirus pandemic. Pham et al. [22] conducted another study to build the "Cloudbased smart home environment (CoSHE)," which aided in the health assessment and monitoring of patients in order to provide them with healthcare at home. Tuli et al. [24] aimed to investigate the

Table 9.1 The security attacks for IoT-based healthcare

Attacks	Description	Security goals	Target layers	Attack types					
				PA	AA	IA	EA	HA	SA
Sybil Attack [20]	Sybil attack is the generation of multiple fake identities by a malicious device.	• Authentication • Privacy	• Multi-Layer		✓		✓		
DoS Attack [21]	Dos attacker can breakdown the network and block exchanging messages between devices.	• Authentication • Availability • Confidentiality • Integrity	• Multi-Layer			✓			
DDos Attack [19]	This attack over-sends Requests or messages to the target node with the intention to make this node busy and disable it.	• Authentication • Availability • Confidentiality • Integrity	• Multi-Layer		✓	✓			
MITM Attack [20]	MITM attacker eavesdrops to the communication between legitimate devices. It behaves like one of them to reply to the other with false information.	• Confidentiality • Integrity • Non-repudiation	• Transport-Layer		✓	✓			
Black Hole Attack [22]	The Black Hole Attack is a kind of denial of servicein which the attacker drops all the data packets.	• Authentication • Availability • Confidentiality • Integrity	• Network Layer		✓	✓			
				✓	✓				

Wormhole Attack [2]	In this attack, two or more malicious devices linked by a low-latency communication channel form a tunnel to transfer packets. Data gathered by attackers will be sent to the other end of the wormhole to influence devices existing close to these tunneled nodes.	• Authentication • Availability • Confidentiality • Integrity	• Network Layer						
Gray Hole Attack [23]	The gray hole attack can be defined as a particular variation of the black hole attack with unpredictablebehaviour.	• Authentication • Availability • Confidentiality • Integrity	• Network Layer		✓		✓		
Spoofing Attack [21]	An attacker uses spoofing to provide fake information about the location of nodes.	• Authentication • Privacy	• Physical Layer	✓					
Timing Attack [20]	Through Timing attack, malicious node adds additional time to received message to delay it. Therefore, messages will not be distributed at the normal time which makes them useless.	• Integrity			✓				
Jamming Attack [24]	Jamming attack is a type of DOS attack in which a malicious node generates a noise to interfere with the radio frequencies used by devices.	• Availability	• Physical Layer		✓		✓		
Replay Attack [20]	Replay attack, also known as playback attack, consists of replaying the transmission of old valid messages and injecting them in the network.	• Authentication • Integrity • Non-repudiation	• Multi-Layer		✓				
Masquerading Attack [22]	In this attack, a spiteful node is hidden using a spoofing identityand produces false messages in the network.	• Authentication • Non-repudiation	• Multi-Layer		✓				

(continued)

Table 9.1 (continued)

Attacks	Description	Security goals	Target layers	Attack types					
				PA	AA	IA	EA	HA	SA
Illusion attack [18]	The malicious node transmits false traffic warning messages to its neighbors. Normal devices will follow the fake traffic messages received which changes their behaviors and causes illusion in the network.	• Authentication • Integrity	• Applications Layer				✓		
Social attack [16]	The main idea of social attack is to alter the behaviour of normal devices in the network using immoral messages.	• Authentication • Integrity	• Network Layer		✓	✓			
Spamming Attack [20]	Consuming the network bandwidth and increasing the transmission latency in the network are the principal aim of the spamming attack.	• Authentication • Availability • Confidentiality • Integrity	• Network Layer			✓			
Malware Attack [24]	The Malware attack is software produced to gain access or damage the network.	• Availability • Confidentiality	• Network Layer		✓	✓			✓
Eavesdrop Attack [20]	Eavesdrop Attack is an attack which threatens confidentiality in IoT aimed to get unauthorized access to obtain confidential information which must be inaccessible to malicious nodes.	• Confidentiality	• Physical Layer	✓					

PA Passive Attacks, *AA* Active Attacks, *IA* Internal Attackers, *EA* External Attackers, *HA* Hardware Attacks, *SA* Software Attacks

Table 9.2 The security requirements for IoT-based healthcare

Features		Description
Data security	Confidentiality [3]	Only authorized persons or entities should have access to device information, system settings, and healthcare data. Before accessing any healthcare-related confidential information, these entities must be authorized. However, existing healthcare devices, such as an insulin pump communication route, can be eavesdropped on to obtain patient data and device-related information.
	Integrity [4]	Integrity is achieved when exchanged messages are protected against unauthorized modifications. It is a process of transmitting data from devices, applications, or infrastructure in a secure manner without the falsification of the original data.
	Privacy [6]	The concealing of personal information, as well as the power to control what occurs with it, are all examples of privacy. During data collection, transmission, and storage, data privacy must be considered. Many practical solutions to the problem of data privacy have been offered. Anonymization-based solutions, pseudo-random number generators, block ciphers, and stream ciphers are examples of these techniques.
Communication security	Authentication [8]	The authentication is the mechanism of verifying whether someone or something is who (or what) it is declared for allowing access to resources in an information system that prevents unauthorized access to a program, system, network, or device, only authenticated peers can participate in the process. There are two kinds of authentication mechanism which are node authentication for whose has a right of accessing into network information and message authentication to guarantee its integrity and privacy by authenticating it.
	Access control [12]	Access control is a security element that checks whether people and systems have permission to perform operations on other systems and resources. The access control algorithms are divided in five distinct types: Role-based, organization-based, capability-based, attribute-based, and trust-based algorithms.
	Non-repudiation [4]	Different procedures are performed by a healthcare system, and this procedure is normally kept private in an access log. Any changes to this log should be traced and monitored, and only confirmed users should make them. To hide their tracks, the attackers may seek to remove these logs. Many resource-constrained medical equipment does not have a log in place, and attackers may try to gain access to the system without leaving any traces.
Device security	Trust [8]	The process of making decisions about communicating with unknown entities is known as trust management. In order to secure an IoT system, it is required to engage with trusted IoT devices to prevent rogue nodes from doing undesirable actions. There are two types of trust

(continued)

Table 9.2 (continued)

Features		Description
		management techniques: Deterministic trust and non-deterministic trust.
	Availability [13]	In normal and emergency scenarios, the healthcare system's service should always be available to authorized users for accessing device systems and patient data. In the availability network, the information shall be available 24 by 7 to the authentic users for preventing several attacks in the network.

utility of fog computing systems for the development of a framework called Health fog for deep learning and real-time analysis of heart disorders. The study was effective in developing the Health Fog model's system architecture in conjunction with the IoT system. Table 9.3 summarizes this several works.

9.3.2 Software Defined Networking-Based Solutions

Because of the programmability and intelligence, it has put into the network, Software Defined Networking (SDN) is a new paradigm that has transformed the world of networking. Correspondingly, in an SDN-based network, there exist a data plane, a control plane, and a monitoring plane [25]. Each of these functional planes has its unique challenge in reducing or protecting their corresponding resources. Software-defined networking enables healthcare organizations to take advantage of virtualization, resulting in increased network agility and lower total cost of ownership. As a result of its design, SDN provides security advantages [26]. Because the SDN controller can see all network data at the same time, it is easier to spot unexpected behavior in network traffic created by an intruder. Once a new danger has been identified, operators can instantly design new software to assess and address the vulnerability, rather than waiting for an operating system or application software update for manufacturer-proprietary devices. Several security schemes to protect healthcare systems based-IoT using Software Defined Networking are available in the literature. In IoT applications, the SDN can be an excellent solution for key management [27], identity management, authentication, confidentiality, and intrusion detection. The authors demonstrated an OpenFlow SDN architecture for IoT devices in [28]. The suggested architecture incorporates IoT gateways that are managed to detect assaults and anomalies in order to figure out which devices are malfunctioning and which nodes in the network are affected. Aydeger et al. in [29] proposed an MTD (moving target defense) mechanism based on SDN for defending against specific DDoS attacks known as Crossfire. Table 9.3 summarizes this several works.

Table 9.3 Comparison of some IoT security solutions

Solutions (references)		Challenges						
		Computation	Communication	Memory	Mobility	Heterogeneity	Scalability	QoS
Fog computing	[19]	+	–	+	+	–	- -	–
	[20]	++	+	+	–	+	–	+
	[21]	+	++	++	–	–	–	+
	[22]	+	–	–	+	+	+	–
	[24]	+	–	+	–	–	+	+
	[23]	++	+	++	- -	+	+	+
SDN	[25]	+	+	+	+	–	–	+
	[26]	+	+	+	–	+	–	–
	[27]	++	–	–	+	–	+	+
	[28]	++	- -	–	–	+	–	–
	[29]	+	++	+	–	–	+	+
	[30]	+	++	+	+	–	+	+
Blockchain	[31]	++	+	+	++	–	–	++
	[32]	+	++	++	–	+	- -	+
	[33]	+	++	+	–	–	–	–
	[34]	++	–	+	+	–	–	+
	[35]	++	- -	+	–	+	–	–
	[36]	++	++	+	++	- -	+	+
Lightweight cryptography	[3]	+	++	–	+	–	–	+
	[4]	+	+	+	+	–	+	–
	[6]	+	++	–	+	+	–	+
	[8]	++	+	+	+	+	+	–
	[11]	++	+	+	+	+	–	+
	[12]	++	+	–	++	+	–	–

(continued)

Table 9.3 (continued)

Solutions (references)		Challenges						
		Computation	Communication	Memory	Mobility	Heterogeneity	Scalability	QoS
Machine learning-	[37]	++	++	−	+	−	−	+
	[38]	++	−	+	+	−	+	−
	[39]	+	−	−	+	+	−	−
	[40]	++	++	+	+	−	+	+
	[41]	++	+	−	−	+	+	−
	[42]	++	+	+	++	+	−	−
HE and SE	[43]	+	+	−	−	+	−	+
	[44]	+	−	+	+	−	+	−
	[45]	+	−	−	+	++	−	−
	[46]	++	+	+	+	−	+	+
	[47]	+	−	−	−	+	+	−
	[48]	++	+	+	−	+	−	+

++Good; +Average; −Poor(limited) and - -Bad

9.3.3 Blockchain-Based Solutions

Many other issues have been explored in relation to IoT, one of the most significant is the security issue. The existence of a huge network with a big number of interconnected devices will almost certainly suggest a variety of attack and eavesdropping scenarios that could endanger those entities and their users. As previously stated, typical security measures cannot be directly applied to IoT devices due to their physical constraints in terms of processing and storage. Furthermore, mutual authentication and authorisation between the device/user and the IoT system must be performed in line with preset security regulations before a device or user can access IoT services. The proposed security measures, on the other hand, must consider the restricted resources of IoT devices. The major issues can be solved by blockchain technology [31]. Researchers are increasingly turning to blockchain-based security frameworks to protect healthcare data from unauthorized parties. To ensure the security of communication in IoT-based healthcare applications, the authors in [30] present an effective multilayer authentication protocol and a secure session key generation mechanism for wireless body area networks (WBANs). In the work [31], the authors have proposed a medical data storage scheme based on blockchain technology in order to ensure the secure storage and sharing of personal medical data. To enable safe communication in healthcare applications, Deebak et al. [32] proposed a Secure and Anonymous Biometric Based User Authentication Scheme (SAB-UAS) based on ECC and cryptographic hash function. Table 9.3 summarizes this several works.

9.3.4 Lightweight Cryptography-Based Solutions

Cryptographic solutions are all the security services which cryptography gave. Cryptography awards various security techniques and can provide confidentiality, authentication and integrity and many other benefits in the healthcare application using IoT. To achieve these security services, cryptography uses different methods such as encryption/decryption method, Keys generation method, hash functions [3], digital signature, etc. The lightweight cryptographic techniques can be adopted to achieve key security requirements including confidentiality, integrity, and authentication [4]. Many approaches based on Cryptography were built to detect and block attacks in the healthcare application using IoT. In [6], Authors proposed a framework named MADAR against Dos attack. Madar can resist Dos attack that effect the communication using the combination of ID-based signature schemes and self-generated pseudonym. It can also detect Dos attack which attacks the communication based on the use of the strength-alterable message specific puzzle. Kiho et al. [8] introduced a key management protocol based on group signature to ensure authentication in protect healthcare systems based-IoT. Utilizing this concept, the devices having the same group of signatures can securely communicate. The authors in [10] used the hash function to build a HCPA-GKA scheme for healthcare systems based-IoT. The group key management mechanism distribution for devices is done through the Chinese Remainder Theorem (CRT). IT can be update when a device accedes and quits the group. Table 9.3 summarizes this several works.

9.3.5 Artificial Intelligence-Based Solutions

Machine learning (ML) is a data analytics technology that allows healthcare systems to learn from data and perform specific tasks like anomaly detection, behavior analysis, and more. There are two main kinds of machine learning: supervised and unsupervised learning. Supervised learning occurs when humans manually categorize training data as harmful or genuine, and then feed that data into an algorithm to develop a model with “classes” of data against which the traffic being analyzed is compared [37]. Unsupervised learning avoids the use of training data and manual labeling in favor of grouping comparable pieces of data into classes and then classifying them based on data coherence within each class and data modularity between classes [38]. Machine learning is used to create complicated algorithms that defend networks and systems, including Internet of Things devices. The research community has investigated machine learning techniques to detect assaults on healthcare systems [39]. A decision tree approach was utilized by Saeedi et al. to detect malicious assaults in healthcare devices in [40]. Vhaduri et al. used support vector machine (SVM) characteristics to detect illegal access to a healthcare device and its acquired data using multiple physiological and behavioral indicators such as calorie burn, average step counts, and minute heart rate [41]. HealthGuard, an ML-based security framework presented by Newaz et al. to detect hostile behaviors in a connected healthcare system [42]. HealthGuard collects vital signs from various healthcare equipment and applies machine learning algorithms to connect changes in the patient’s biological processes in order to discern between benign and malignant activity. Table 9.3 summarizes this several works.

9.3.6 Homomorphic and Searchable Encryption-Based Solutions

The advances technology has now made it possible to monitor heart rate, body temperature and sleep patterns; continuously track movement; record brain activity using IoT devices. Classical encryption techniques have been used very successfully to protect data in transit and in storage [43]. However, the process of encrypting data also renders it unusable in computation. Recently developed fully homomorphic encryption (FHE) techniques improve on this substantially. Unlike classical methods, which require the data to be decrypted prior to computation, homomorphic methods allow data to be simultaneously stored or transferred securely and used in computation [44]. However, FHE imposes serious constraints on computation, both arithmetic (e.g., no divisions can be performed) and computational (e.g., multiplications become much slower), rendering traditional statistical algorithms inadequate. Secure search over encrypted data stored on a cloud server is possible using searchable encryption (SE). Asymmetric SE, symmetric SE, and attribute-based SE are examples of SE techniques [45]. Several security schemes to protect healthcare systems based-IoT using homomorphic encryption and searchable encryption are available in the literature. Almalki et al. [8] proposes EPPDA: An Efficient and Privacy-Preserving Data Aggregation Scheme with authentication for IoT-Based healthcare applications. EPPDA verifies data integrity during data aggregation and forwarding processes, so that false data can be detected as early as possible at the verification and authorization phase. In another work, Helen et al. [45]. highlights Enhanced MAC-based secure delay-aware Healthcare Monitoring System (E-MHMS) for Wireless Body Area Network (WBAN) systems. The proposed solution ensures secure and efficient data aggregation, where data are classed into three types: critical data, nearly critical, and normal data. Firstly, Base Station (BS) sends keys to all authorized nodes. Mahender et al. [47] shade the light on a new contribution called “Escrow-Free Identity-based Aggregate Sign-encryption scheme to secure data transmission (EF-IDASC)” to assure the privacy-preserving access control on the Internet-of-Medical-Things (IoMT).

9.4 Conclusion

The IoT-based healthcare offers continuous health monitoring, especially elderly people and patients who are suffering from chronic diseases, which lead medical teams and/or health services to faster and more accurate responses to patients. Indeed, due to multiple design faults and a lack of effective security measures in healthcare equipment and applications, the healthcare industry based in IoT is increasingly confronting security challenges and threats. The consequences of inadequate security in the healthcare system can be, for example, some health records may contain information about the address, name, and family details that can be used to infer or reveal the patients’ identities to unauthorised users causing privacy compromise. This overview is meant to act as a knowledgebase that will provide unique insight to assist users and administrators in placing themselves and their organizations in ways that are consistent with their overall objectives, mission, and vision for exceptional results.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support

Data Availability
Not applicable

References

1. Goyal, S., Sharma, N., Bhushan, B., Shankar, A., & Sagayam, M. (2021). IoT enabled technology in secured healthcare: Applications, challenges and future directions. In A. E. Hassanien, A. Khamparia, D. Gupta, K. Shankar, & A. Slowik (Eds.), *Cognitive internet of medical things for smart healthcare* (Studies in systems, decision and control) (Vol. 311). Springer. https://doi.org/10.1007/978-3-030-55833-8_2
2. Bhushan, B., & Sahoo, G. (2020). Requirements, protocols, and security challenges in wireless sensor networks: An industrial perspective. In *Handbook of computer networks and cyber security* (pp. 683–713). Springer. https://doi.org/10.1007/978-3-030-22277-2_27
3. Othman, S. B., Bahattab, A. A., Trad, A., & Youssef, H. (2019). LSDA: Lightweight secure data aggregation scheme in healthcare using IoT. In *10th International Conference on Information Systems and Technologies*, Lecce, Italy, Dec 28, 2019–Dec 30, 2019, Tunisia. https://doi.org/10.1145/3447568.3448530.
4. Othman, S. B., Bahattab, A. A., Trad, A., et al. (2015). Confidentiality and integrity for data aggregation in WSN using homomorphic encryption. *Wireless Personal Communications, 80*, 867–889. https://doi.org/10.1007/s11277-014-2061-z
5. Soufiene, B. O., Bahattab, A. A., Trad, A., & Youssef, H. (2019). RESDA: Robust and efficient secure data aggregation scheme in healthcare using the IoT. In *2019 International Conference on Internet of Things, Embedded Systems and Communications (IINTEC)* (pp. 209–213). IINTEC. https://doi.org/10.1109/IINTEC48298.2019.9112125
6. Onesimu, J. A., Karthikeyan, J., & Sei, Y. (2021). An efficient clustering-based anonymization scheme for privacy-preserving data collection in IoT based healthcare services. *Peer-to-Peer Networking and Applications, 14*, 1629–1649. https://doi.org/10.1007/s12083-021-01077-7
7. Almalki, F. A., & Soufiene, B. O. (2021). EPPDA: An efficient and privacy-preserving data aggregation scheme with authentication and authorization for iot-based healthcare applications. *Wireless Communications and Mobile Computing, 2021*, 5594159. 18 pages. https://doi.org/10.1155/2021/5594159
8. Arul, R., Al-Otaibi, Y. D., Alnumay, W. S., et al. (2021). Multi-modal secure healthcare data dissemination framework using blockchain in IoMT. *Personal and Ubiquitous Computing*. https://doi.org/10.1007/s00779-021-01527-2
9. Kumar, M., & Chand, S. (2020). A secure and efficient cloud-centric internet-of-medical-things-enabled smart healthcare system with public verifiability. *IEEE Internet of Things Journal, 7*(10), 10650–10659. https://doi.org/10.1109/JIOT.2020.3006523
10. Almalki, F. A., Othman, S. B., Almalki, F. A., & Sakli, H. (2021). EERP-DPM: Energy efficient routing protocol using dual prediction model for healthcare using IoT. *Journal of Healthcare Engineering, 2021*, 9988038, 15 pages. https://doi.org/10.1155/2021/9988038
11. Soufiene, B. O., Bahattab, A. A., Trad, A., & Youssef, H. (2020). PEERP: An priority-based energy-efficient routing protocol for reliable data transmission in healthcare using the IoT. *Procedia Computer Science, 175*, 373–378. https://doi.org/10.1016/j.procs.2020.07.053
12. Goyal, S., Sharma, N., Kaushik, I., & Bhushan, B. (2021). Blockchain as a solution for security attacks in named data networking of things. In *Security and privacy issues in IoT devices and sensor networks*, 211–243. https://doi.org/10.1016/B978-0-12-821255-4.00010-9.

13. Saxena, S., Bhushan, B., & Ahad, M. A. (2021). Blockchain based solutions to secure IoT: Background, integration trends and a way forward. *Journal of Network and Computer Applications, 181*, 103050. https://doi.org/10.1016/j.jnca.2021.103050
14. Haque, A. K., Bhushan, B., & Dhiman, G. (2021). Conceptualizing smart city applications: Requirements, architecture, security issues, and emerging trends. *Expert Systems*. https://doi.org/10.1111/exsy.12753
15. Kumar, A., Abhishek, K., Bhushan, B., & Chakraborty, C. (2021). Secure access control for manufacturing sector with application of Ethereum blockchain. *Peer-to-Peer Networking and Applications, 14*, 3058–3074. https://doi.org/10.1007/s12083-021-01108-3
16. Bhushan, B., Sahoo, C., Sinha, P., & Khamparia, A. (2020). Unification of blockchain and internet of Things (BIoT): Requirements, working model, challenges and future directions. *Wireless Networks, 27*, 55–90. https://doi.org/10.1007/s11276-020-02445-6
17. Bhushan, B., Sinha, P., Sagayam, K. M., & Onesimu, J. A. (2021). Untangling blockchain technology: A survey on state of the art, security threats, privacy services, applications and future research directions. *Computers & Electrical Engineering, 90*, 106897. https://doi.org/10.1016/j.compeleceng.2020.106897
18. Paul, A., Pinjari, H., Hong, W.-H., Seo, H. C., & Rho, S. (2018). Fog computing-based IoT for health monitoring system. *Journal of Sensors, 2018*, 1386470., 7 pages. https://doi.org/10.1155/2018/1386470
19. Kraemer, F. A., Braten, A. E., Tamkittikhun, N., & Palma, D. (2017). Fog computing in healthcare–A review and discussion. *IEEE Access, 5*, 9206–9222. https://doi.org/10.1109/ACCESS.2017.2704100
20. Awaisi, K. S., Hussain, S., Ahmed, M., Khan, A. A., & Ahmed, G. (2020). Leveraging IoT and fog computing in healthcare systems. *IEEE Internet of Things Magazine, 3*(2), 52–56. https://doi.org/10.1109/IOTM.0001.1900096
21. Ijaz, M., Li, G., Lin, L., Cheikhrouhou, O., Hamam, H., & Noor, A. (2021). Integration and applications of fog computing and cloud computing based on the internet of things for provision of healthcare Services at Home. *Electronics, 10*, 1077. https://doi.org/10.3390/electronics10091077
22. Qi, Q., & Tao, F. (2019). A smart manufacturing service system based on edge computing, fog computing, and cloud computing. *IEEE Access, 7*, 86769–86777. https://doi.org/10.1109/ACCESS.2019.2923610
23. Wang, T., & Chen, H. (2017). SGuard: A lightweight SDN safe-guard architecture for DoS attacks. *China Communications, 14*(6), 113–125. https://doi.org/10.1109/CC.2017.7961368
24. Fu, J., Liu, Y., Chao, H., Bhargava, B. K., & Zhang, Z. (2018). Secure data storage and searching for industrial IoT by integrating fog computing and cloud computing. *IEEE Transactions on Industrial Informatics, 14*(10), 4519–4528. https://doi.org/10.1109/TII.2018.2793350
25. Wang, T., Chen, H., Cheng, G., & Lu, Y. (2018). SDNManager: A safeguard architecture for SDN DoS attacks based on bandwidth prediction. *Security and Communication Networks, 2018*, 7545079., 16 pages. https://doi.org/10.1155/2018/7545079
26. Wang, T., & Chen, H. (2021). A lightweight SDN fingerprint attack defense mechanism based on probabilistic scrambling and controller dynamic scheduling strategies. *Security and Communication Networks, 2021*, 6688489., 23 pages. https://doi.org/10.1155/2021/6688489
27. Shu, Z., Wan, J., Li, D., et al. (2016). Security in software-defined networking: Threats and countermeasures. *Mobile Networks and Applications, 21*, 764–776. https://doi.org/10.1007/s11036-016-0676-x
28. Ahvar, E., Ahvar, S., Raza, S. M., Manuel Sanchez Vilchez, J., & Lee, G. M. (2021). Next generation of SDN in cloud-fog for 5G and beyond-enabled applications: Opportunities and challenges. *Network, 1*, 28–49. https://doi.org/10.3390/network1010004
29. Li, Y., Su, X., Ding, A. Y., Lindgren, A., Liu, X., Prehofer, C., Riekki, J., Rahmani, R., Tarkoma, S., & Hui, P. (2020). Enhancing the internet of things with knowledge-driven

software-defined networking technology: Future perspectives. *Sensors, 20*, 3459. https://doi.org/10.3390/s20123459
30. Kamboj, P., Khare, S., & Pal, S. (2021). User authentication using Blockchain based smart contract in role-based access control. *Peer-to-Peer Networking and Applications, 14*, 2961–2976. https://doi.org/10.1007/s12083-021-01150-1
31. Patil, P., Sangeetha, M., & Bhaskar, V. (2021). Blockchain for IoT access control, security and privacy: A review. *Wireless Personal Communications, 117*, 1815–1834. https://doi.org/10.1007/s11277-020-07947-2
32. Mubarakali, A. (2021). An efficient authentication scheme using blockchain technology for wireless sensor networks. *Wireless Personal Communications*. https://doi.org/10.1007/s11277-021-08212-w
33. Ren, Y., Zhao, Q., Guan, H., et al. (2020). A novel authentication scheme based on edge computing for blockchain-based distributed energy trading system. *Journal on Wireless Communications and Networking, 2020*, 152. https://doi.org/10.1186/s13638-020-01762-w
34. Andola, N. R., Yadav, V. K., et al. (2021). SpyChain: A lightweight Blockchain for authentication and anonymous authorization in IoD. *Wireless Personal Communications, 119*, 343–362. https://doi.org/10.1007/s11277-021-08214-8
35. Kuzlu, M., Fair, C., & Guler, O. (2021). Role of artificial intelligence in the internet of things (IoT) cybersecurity. *Discov Internet Things, 1*, 7. https://doi.org/10.1007/s43926-020-00001-4
36. Meneghello, F., Calore, M., Zucchetto, D., Polese, M., & Zanella, A. (2019). IoT: Internet of threats? A survey of practical security vulnerabilities in real IoT devices. *IEEE Internet of Things Journal, 6*(5), 8182–8201. https://doi.org/10.1109/JIOT.2019.2935189
37. Farivar, F., Haghighi, M. S., Jolfaei, A., & Alazab, M. (2020). Artificial intelligence for detection, estimation, and compensation of malicious attacks in nonlinear cyber-physical systems and industrial IoT. *IEEE Transactions on Industrial Informatics, 16*(4), 2716–2725. https://doi.org/10.1109/TII.2019.2956474
38. Wang, S., & Qiao, Z. (2019). Robust pervasive detection for adversarial samples of artificial intelligence in IoT environments. *IEEE Access, 7*, 88693–88704. https://doi.org/10.1109/ACCESS.2019.2919695
39. Liang, F., Hatcher, W. G., Liao, W., Gao, W., & Yu, W. (2019). Machine learning for security and the internet of things: The good, the bad, and the ugly. *IEEE Access, 7*, 158126–158147. https://doi.org/10.1109/ACCESS.2019.2948912
40. Kumar, M., & Chand, S. (2021). MedHypChain: A patient-centered interoperability hyperledger-based medical healthcare system: Regulation in COVID-19 pandemic. *Journal of Network and Computer Applications, 179*, 102975. https://doi.org/10.1016/j.jnca.2021.102975
41. Li, J., Jin, J., Lyu, L., Dong, Y., Yang, Y., Gao, L., & Shen, C. (2021). A fast and scalable authentication scheme in IOT for smart living. *Future Generation Computer Systems, 117*, 125–137. https://doi.org/10.1016/j.future.2020.11.006
42. Sharmila, A. H., & Jaisankar, N. (2020). E-MHMS: Enhanced MAC-based secure delay-aware healthcare monitoring system in WBAN. *Cluster Computing, 23*, 1725–1740. https://doi.org/10.1007/s10586-020-03121-2
43. Sangeetha Priya, N., Sasikala, R., Alavandar, S., et al. (2018). Security aware trusted cluster based routing protocol for wireless body sensor networks. *Wireless Personal Communications, 102*, 3393–3411. https://doi.org/10.1007/s11277-018-5374-5
44. Haseeb, K., Islam, N., Saba, T., Rehman, A., & Mehmood, Z. (2020). LSDAR: A light-weight structure based data aggregation routing protocol with secure internet of things integrated next-generation sensor networks. *Sustainable Cities and Society, 54*, 101995. https://doi.org/10.1016/j.scs.2019.101995

45. Sachin, D., Chinmay, C., Jaroslav, F., Rashmi, G., Arun, K. R., & Subhendu, K. P. (2021). SSII: Secured and high-quality steganography using intelligent hybrid optimization algorithms for IoT. *IEEE Access, 9*, 1–16. https://doi.org/10.1109/ACCESS.2021.3089357
46. Chinmay, C., & Arij, N. A. (2021). Intelligent internet of things and advanced machine learning techniques for COVID-19. *EAI Endorsed Transactions on Pervasive Health and Technology, 21*(26), e1. https://doi.org/10.4108/eai.28-1-2021.168505
47. Chinmay, C. (2020). Joel JPC Rodrigues, A comprehensive review on device-to-device communication paradigm: Trends, challenges and applications. *Springer: International Journal of Wireless Personal Communications, 114*, 185–207. https://doi.org/10.1007/s11277-020-07358-3
48. Chinmay, C. (2019). Performance analysis of compression techniques for chronic wound image transmission under smartphone-enabled tele-wound network. *International Journal of E-Health and Medical Communications (IJEHMC), IGI Global, 10*(2), 1–20.

Chapter 10
Secure and Privacy-Aware Intelligent Healthcare Systems: A Review

J. Antony Vijay, C. D. Prem Kumar, and B. Gomathi

Abstract Due to raise of patients, the ancient system not able to handle the situation. To avoid such issues in medical field, Internet of Medical Things (IoMT) system has introduced. It is a modern technology to improve the reliability and effectiveness of e-health care system by satisfying the needs of the patients on time. In spite of that IoMT devices suffer from various security threats that leads to patients at risk. To preserve security of IoMT against Cyber Attack, this chapter presents the overview of security threats and importance of building potential solutions for IoMT network. Moreover, various existing security countermeasures are discussed and creates an intent to implement a novel intrusion detection system to protect the privacy of personal health data.

Keywords Internet of medical things (IoMT) · Body area network (BAN) · Electrocardiogram (EKG) · Mobile Base station (MBS) · Privacy · Attackers · Security · Threats · Intruder · Malicious attack · Virus · Medical devices · Health care

10.1 Introduction

The unification of medical equipment within Internet of Things (IoT) communication environment leads to the development of Internet of Medical Things (IoMT) [1]. The enhancement in healthcare era in the way of more suitable adaptability and mobility, IoT devices which are utilized for smart healthcare monitoring devices and applications are associated through networks. This smart health maintenance system leads to advance the treatment, manage the diseases and drugs and enhance the experience of patients by tracking the health of the patients in real time. However, IoMT devices are susceptible to cyber-attacks since IoMT devices are not properly secured in opposition of the adversaries. Hence, broad implementation of IoMT would be obstructed by adversarial attack on IoMT devices that provokes to frighten

J. A. Vijay (✉) · C. D. P. Kumar · B. Gomathi
Department of Information Technology, Hindusthan College of Engineering and Technology, Coimbatore, India

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_10

the lives of the patients. In addition, the sensitive information like personal details of patients and their present health conditions in Smart Healthcare system are more in danger by different adversarial attacks since IoMT devices are vulnerable against latest cyber-attacks. Maintaining the privacy of patient with proper security feature is the major challenge overlooked by IoMT environment. Furthermore, Solutions against cyber-attacks should utilize minimal resources with less computations. In Sect. 10.1.1 discusses the objectives of the system and Sect. 10.2 is about various types of communication devices involved in IoMT devices. In Sect. 10.3 explains the various concerns in IoMT.

10.1.1 Objectives

Now-a-days, Recent Medical technologies are more advanced by using IoMT devices. This advancement enables to expand medical services by monitoring patients at remote location. Furthermore, it has an ability to recognize the medical health conditions earlier and saves lives and health of the patients. Many sensors and actuators in IoMT environment are more exposed against malicious mistreatment attempts. Hence, it is necessary to take action towards to improve efficiency and accuracy of devices in IoMT environment. Furthermore, preserving the privacy of the medical data against cyber-attacks that targets towards the privacy and confidentiality of sensitive information of patients. That severely degrades the development and deployment of IoMT environment. Hence, our main objective is to recognize the cyber-attacks against IoMT devices in Smart Medical Environment and recognize various counter measures against cyber-attacks.

10.1.2 Related Works

Nowadays, IoMT health care systems are highly essential to monitor and maintain the patient health status with the help of internet itself. This system has various medical devices, that connected with multiple sensors to ensure the betterment of patient healthiness. In [2] the system discussed with various threats but those threats weren't effectively connected with Internet of Medical Things. In Ref. [3] discussed with different types of inside attackers and authorization [4] issues to guide a better platform for wireless medical devices in IoMT. A complete survey was discussed on cloud computing [5] based security issues with various countermeasures [6] stated providing real time practice sessions to nurses for avoiding accidents in health-care systems.

10.1.3 Contributions

In this paper we proposed the overview of various privacy and security attacks in IoMT Systems. It summarizes various issues and challenges in maintaining the personal data of a patient and also depicts various cryptographic algorithms to protect the personal information of a patient. In order to improve the authentication in IoMT medical devices various security measures are also mentioned. Here we summarized the list of contributions made for this paper as follows:

- Insights and Future scope of Internet of Medical Things with connectivity between medical devices and applications are discussed.
- Merits and Demerits of IoMT health care devices are mentioned.
- Proposed a qualitative risk analysis for identifying the risks in various IoMT systems.
- Presented the sources of various attacks and influence of attacks on patient data.
- Prevention metrics are discussed to avoid leaking of patient data either carelessly or purposely.
- Acknowledgements are mentioned to improve the Intelligent health care system to resist the intruder.

10.2 IoMT Communications

The following are the different types of communication among IoMT devices for real time data transmission between medical devices.

10.2.1 Body Area Network (BAN)

The basic and important body signals are assessed by make use of wearable or portable sensors connected with patient's body using Body Area Network. The communication among sensors and actuators in Body Area Network can be protected using Biomedical signals. Hence, Inter-Pulse Interval are used to authenticate the patients to protect communication data among sensors in BAN. In other way, physiological signals [7] can be utilized as undisclosed key of symmetric key cryptography systems for sensors communication in BAN. In this regard, composed medical data from patients are sent to the controller in BAN in the subsequent ways: The collected medical information from patients in mobile network is routed to Medical data-centre through base station.

- The collected medical information from patients in mobile network is routed to Medical data centre through base station.

- The wireless communication protocols Zigbee or Wi-Fi, are utilized to transfer among the Body Area Network.
- In patient's house, the controller can gather data and direct it through access point in patient's home using Wi-Fi.
- The neighbourhood areas are linked to internet to make communication among different homes and their nearby homes. Based on the antenna utilized, either transmission of data is enhanced in omnidirectional or bidirectional by using access point in Body Area Network. It allows to transmit data between Access Point and Mobile Base Station (MBS).
- The communication among Mobile Base station and Access point in remote medical infrastructure are established using Wide Area Network. At the same time, emergency details are shared with emergency team through Wide Area Network and then Access Point in patient's home are used to transmit the data to Cloud environment for storage purpose.

10.2.2 IoMT Devices and Protocols

Medical equipments are categorized based on the utilization. These devices can be utilized as gadget or useful for real time health monitoring purpose. The smart medical devices can be used to estimate sugar level and pressure level of the patients. IoMT gives the assurance that blood pressure and other tests can be taken from patient's home. It reduces the patients crowd to do the test in Hospitals and global death rate. The following are devices in IoMT network that can operated in home or hospital based on the requirement.

- Wearable medical equipment [8] can be utilized to accumulate, observe and improve the health condition of the patients at low cost. The wearable devices can be utilized for fitness track, blood pressure monitoring and heart rate monitoring purpose. In addition, tele-home healthcare system is drastically improved due to this pandemic situation. The fitness devices are utilized to monitor and maintain the proper lifestyle of the patients. Furthermore, fitness devices are utilized to monitor the daily workout routine of the patient. The Smart Blood Pressure instrument are utilized to observe the blood pressure level of the patient remotely. If there is any variation in measurement, it is informed to hospital through medical centre immediately. In the same way, Glucose level and heart rate are tracked and observed at real time to maintain appropriate insulin level and predict heart-attack earlier.
- Medical equipment in home like ventilators, infusion pumps and dialysis machines are utilized to provide health care monitoring and communicate with hospital through email.
- The medical instruments like defibrillators, anaesthesia machines, patient monitors, Electrocardiogram (EKG) Machines, surgical tables, blanket and fluid

warmers, electro-surgical units, surgical tables and lights must provide right treatments to the patients.

10.3 Various Concerns in IoMT

In various concerns, there is a possibility of risks have been occurred that can be categorized as follows: (1) Security-based (2) Privacy-based (3) Trust-based (4) Accuracy-based.

10.3.1 Security-Based Risks

Usually security-based risks are happened because of open wireless communication (Mobile Communication). In Mobile communication the devices are easily affected or attacked by various attacks due to strength of authentication. In this concern, attackers can easily spy the communication and chance to obstruct and modify the message content between sender and receiver. Another important problem is the attackers are trying to access the patient data by any wireless devices without their knowledge. This issue may lead to damage the whole system badly because unauthorized access even without being detected will spread some harmful codes to the system, it means that hacks the whole system (i.e.) it takes over the control of the whole system. If any IoMT devices are hacked based on this issue, it will lead to no response in server-side system even lot of requests from sender side. i.e. denial on service. In [9] Ayala, L suggested that wireless devices related with medical process can be easily attacked by intruders and that will be harmful to human while giving treatment. For example, if a medical device is hacked by intruders, i.e. it will modify the proportion of drug in creating a medicine and open-heart surgery. It leads to serious health issue to the humans.

All the manufacturers of Health care devices that involves in development of various aspects like surgery, Health monitoring devices and tablets should give their entire effort and to produce the devices effectively without affecting from any of the hacking issues.

10.3.2 Privacy-Based Risks

In this concern, the records of patients have been breached easily by various ways [10], as per the statistical of Privacy based risk analysis report, patient records are breached increased by 33%. The reports states that most of the mistakes i.e. 52% are happened due to employees' mistakes and carelessness and 48% of breaches due to stolen or loss of computing devices.

Using of mobile devices in collecting, storing and transmitting of patient Health Information in that 81% of people don't know how to protect their health record, only 19% of people are aware of the safeguard their health record.

In hospital there is not sufficient technical expertise, staff and end users to protect patient data. So that it is easily been hacked by attackers.

Due to data breach there is huge loss in patient lifetime as well as lot of tiredness in patient. At the same time, it reduces the reputation and productivity loss of Hospital.

10.3.3 Trust-Based Risks

In [11] Kevin Kelly stated that Patients are not having trust on medical robots about the patient health monitoring, controlling the health conditions, treatments and the evaluation of results.

10.3.4 Accuracy-Based Risks

In [9] Ayala, Lstated that Humanoids are doing lot of accidental mistakes in monitoring and controlling the health conditions on patients due to that 145 patients lost their lives, around 1500 patients are seriously injured and more than 9000 malfunctions within 13 years from 2000 to 2013 in United States [12, 13]. Another issue is that false accuracy, precision and wrong prescription in diagnosing diseases by medical robot. Some of the patients are affected by neuron issue in brain due to this malfunction [14]. In Sect. 10.4 discusses about various challenges in IoMT and Sect. 10.5 explains various countermeasures of IoMT. In Sect. 10.6 about procedures involved in securing medical devices and Sect. 10.7 about Techniques to guarantee IoMT data and systems security. Section 10.8 mentioned summary about conclusion and finally in Sect. 10.8 discussed about the Future Scope of Intelligent Health care system and its challenges.

10.4 Challenges in IoMT

In [15] Moeen Hassanalieragh et al. stated that when the humanoid entered in to IoMT field lot of problems and challenges are came. In order to avoid these challenges, we need to enhance the security to the medical devices that becomes less prone to hacking attacks. These challenges are related to each other with various conditions in security aspects (see Fig. 10.1).

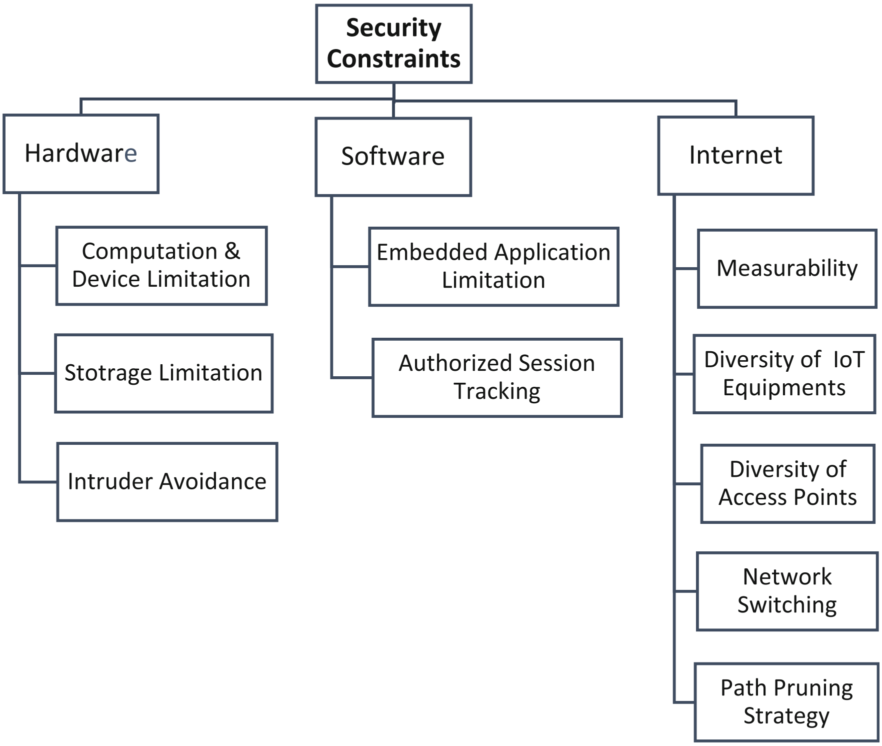


Fig. 10.1 IoMT security constraints

10.4.1 Risks in IoMT

Due to leakage of important patient information about the patient will lead to serious problems to the patient by attackers Due to leakage of important information about the patient will lead to serious problems to the patient by attackers.

Adding noises (i.e.) false information to the data that will bring up wrong doses in medicine creation and wrong prescription will harmful to the patients.

Theft of Medical details is happened by employee working in hospital, who carelessly keeping the details of patients so that the details are easily hacked which makes risk to patients' lives.

In order to avoid from these risks, we need new risk evaluation system to improvise the security system. Initially we need to identify the threats and its associated risks during wireless communication. The analysis of various threats and risks have been clearly defined in Ref. [16] and that can be managed by Threat, Risks, Vulnerability, and Analysis technique [17]. In that one attack that leads to another attacks. Using this TRVA technique we can identify the harmfulness of the risk.

The security constraints have been categorized based on damaging the system assets in Fig. 10.1. In the next chapter, we see the detailed study about various types of attacks and its causes and effects.

10.4.2 Various Attacks against IoMT

These attacks are well organized, planned, professionally to be done by the hackers and it damages the whole system characteristics in terms of privacy, trustworthy and consent.

10.4.3 Features of Attacks

Before finding and differentiating the various attacks, we should know the capability and qualities of attacks. Every attack can be categorized based on its essence, objective, harmfulness, capability and consequence (see Fig.10.2). These features are depending upon the capability, ability and powerful software tool of attackers.

Attackers can be classified based on its harmfulness (i.e.) In-Active Attackers, Active Attackers, Inside Attackers and Outside Attackers.

In-Active attackers are not a harmful attack to the system because it doesn't damage any devices but it hacks the medical equipment's' through wireless communication and this activity is usually happened in the background of all the devices without known to the user. This attacker usually works with other attackers for theft the information to accessing the devices.

Active attackers usually will be in the middle of the sender and receiver. It will catch the information from the sender and modify the data without their knowledge and send to receiver. Here the sender and receiver will not know the change of information during the communication. This modification leads to a lot of impact in medical field like changes in drug dosage in mg and wrong drug will harm the health condition of the patient. It may lead to sudden death.

Inside Attackers may be a doctor or receptionist or nurse, they try to destroy the recognition of the hospital because they work as a secret agent for an attacker. They steal, send or sell the confidential data from the hospital to spoil the specific patients' health condition due to the competition regarding political or financial.

Outsider attacker will intrude the system through the malicious programs like Trojan horse, viruses, ransomware, spyware, adware and E-Mail. This will affect the computers by attached as macros to all files, browsers as well as operating system. Objective of these attackers are to receive all the information about the hospital as well as patient to sell their information to the black market. The main objective of this attack is to fix a target either a hospital, patient, small group of people and people from other nation for various reasons like Political Affairs, Disseminating the Terrorism, cultural or ethnic. Harmfulness is a category of attack that is used to

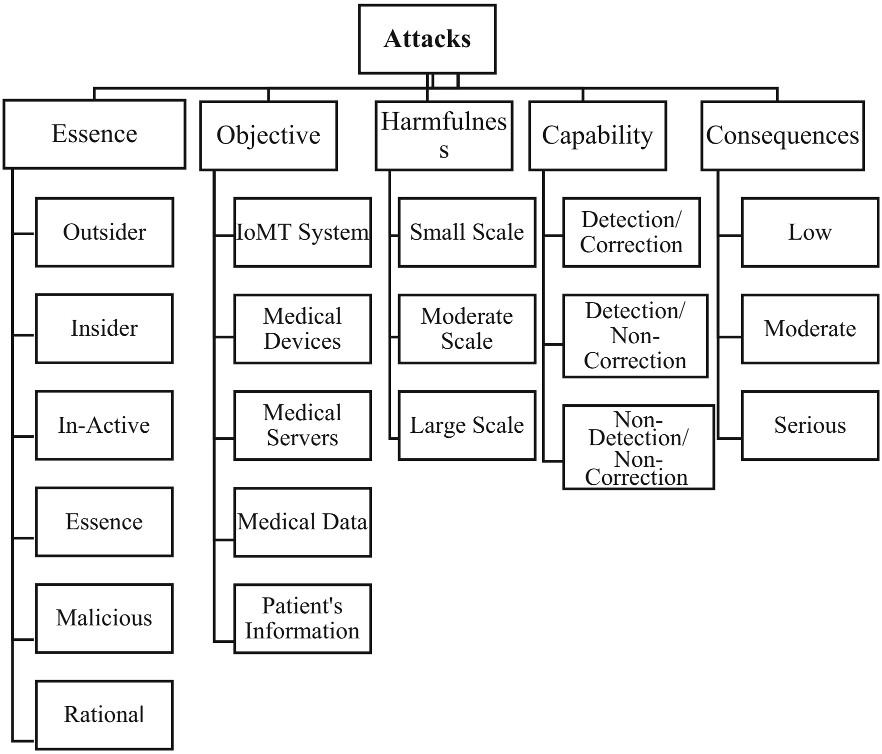


Fig. 10.2 Features of attackers and its consequences

rapidly increase the count of people suffered or died based various above-mentioned attacks.

Capability attacks are so dangerous to all species in all aspects and in order to escape from this, we should know the weakness and loop hole of certain attacks. The attackers always think high about the damage and consequences in count. So that they try to spread the harmful action in various areas at a time [13, 14] due to that lot of lives may be affected.

10.4.4 Various Challenges in IoMT

As per security aspect, IoMT in dangerous situation, so that we are in need to protect our medical devices while we are in wireless communication process. In Fig. 10.3 we analysed the various harmful attacks that related to privacy, threats and unavailability.

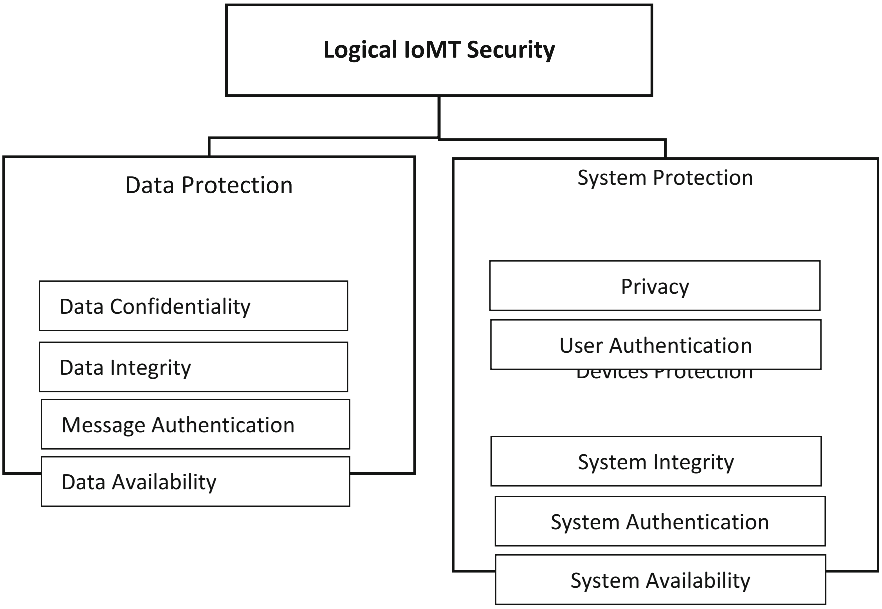


Fig. 10.3 IoMT security goals

Table 10.1 Various privacy attacks and its solutions

Various challenges in IoMT	Solutions	Reasons
Privacy attacks	Encryption	Sending multicast messages via mobile communication Non-secured communication medium
Tapping communication	Encryption	Unsecure mediums Open access communications channel
Man in the middle attack	Encryption	Open wireless communications Sensitivity less medium Data security issues
Data trapping attack	Safe connection Locked connection	Unsecure WIFI communication Open wireless medium
Surveillance attack	Giving coaching about security preaches Digitized process	Skill less nurses Carelessness of employees in hospital

10.4.4.1 Privacy Attacks

In order to achieve this privacy-based attack, the attackers expect to receive private or confidential information of patients by external sources like staff nurse, doctor and receptionist. This type of attacks can be done by In-Active attacks. Table 10.1 displayed the various privacy attacks.

Tapping Communication attack usually done through the Mobile communication. The attack tries to spy the communication through their powerful tool according they will collect the information. Man-in-the-Middle attack usually happens because of weak encryption mechanism in wireless access points. In this unauthorized person will try to access the medical devices through WAP. If that person connects to the network, they try to control the medical equipment and may modify the drug dosage in treatment. This led to health issue to the patient.

Data Trapping attack damage the medical data and secret information related to medical devices, patient data can be easily intercepted because of weak encryption in wireless communication. There are various data trapping tools available in online such as TCP dump, Network Miner etc.. Surveillance attack includes tapping up the telephone communications either incoming or outgoing call and based on that, attackers perform their intercepting information.

Integrity or Position Tracking attack, is used to hack and track the patient data by Medical devices for identifying its home working place to collect the basic and personal information.

In order to maintain its security, the patient should make use of virtual private network to keep changing the IP Address and MAC Address periodically using proxy servers [18, 19].

10.4.4.2 Sociology Attacks

Sociology Attack is a method to track and handle the human beings based on its physiological behaviours from that they will identify or guess the password for all related information. Attackers track the people's interest, desire and forward the harmful images to victim person to access the medical details. Various attacks related to sociology is mentioned in Table 10.1.

Simulation attack is also called as straight forward attack [20]. It is used to gather the patient details by act like a technician to the hospital and identify the loop hole and vulnerability of the hospital. In other way the attacker will go to the hospital and to stay with patient to gather the details of security process and devices. Troubleshooting attack usually happened due to mishandling and wrongly repairing the medical devices that leads to increase the vulnerability of medical equipment.

Password attacker guesses the password based on brute force process. It used to access the medical system. Actually, it is an exhaustive search i.e.it searches for the PIN to access the patient information. Cheat table attack includes all the possibilities of password and its hash code. Attackers will check the password with its hash code by using trial and error method. The process of identifying the password extends until get the solution. Cryptographic attacks usually happen when same hash code will be generated for two different passwords, that makes collision as well as makes the medical system easy to prone. In order to escape from this attack, we need to protect the medical system with Secure Hash Algorithm of version 256 or 512 [20].

10.4.4.3 Malicious Attacks

There are various malicious attacks that are severely damage the Medical Equipments such as Keyloggers, Klez, MS Blast and so on [21, 22].

Keystroke logging otherwise called as Keyloggers. This attack can be done by installing the keylogging tools in patient's computer to identify the password. Once the password has been detected, all the files in the computer have been easily hacked and finally spread a malicious program in it to destroy the whole system.

Klez attack is also called as computer worm. This can be spread out by the E-mail Messages. Usually this type of mail contains some text content with one or two attachments. The text context will automatically compile the virus program and while opening the attachments, the worm program will initially spread in to operating system that makes all the text files in to HTML files i.e. the text file will not be opened as .txt instead it will open as .html and the content of text will also be removed.

MS Blast also known as Blaster and it is coming under the category of computer worm. This attack usually affects the operating system, through that it will spread to all the drives in computer. Humanoid attack will damage the medical devices initially. This attack accordingly will spread to humanoid devices that used for treatment purpose in the hospital [23, 24]. So that IoMT devices will lead a wrong command to bot, accordingly it will do harmful mistakes while treating a patient.

10.4.4.4 Hardware Attacks

In concern with hardware attacks, it is used to damage or make the hardware device inefficient i.e. prone the attacks. Here mentioned some of the attacks that belongs to hardware attacks. In embedded system attacks there are much bounded properties so that it is not able to recovery important information like password and sensitive information. It makes easy for attackers to destroy the hardware.

Malfunction attackers influence the hardware device by wireless mode then control over on it and destroy the electronic device by increasing or decreasing the input voltage repeatedly for some time. It makes the device so heat, at one moment the device lose its control and burst it [20, 25]. Session attacker tries to damage the whole cryptographic system by session-based attack. That is the attacker needs some time for executing their harmful task in any of the system so that this attack will make the system hang for some time in the recipient end. During that time whole system data and important files will be easily received by the intruder [26].

10.5 Counter Measures of IoMT

`

To lower the risk factor in IoMT, the following countermeasures are used. Besides, most concerns can be remedied by integrating security measures. This security measures include teaching medical personnel about cyber-attacks and safeguarding patients' confidential medical records. The medical staff and IT employees could be successful if they were given the proper training by considering the upcoming ways:

Increasing awareness, Conducting Security awareness program, organizing technical training, and increasing the level of education.

10.5.1 Increasing Awareness

Healthcare Chief Information Security Officers are constantly progressing the latest and greatest security technologies ready to help them monitor their environments, due to the increasing number of dangers that threaten healthcare in today's scenario. Raising alertness among healthcare professionals and trainers, particularly an Information Technology branch, is critical and advised to detect and find an ongoing violence from routine hub activity. Alertness is used to define what constitutes a danger, or weakness. It gives those with opportunity to distinguish between the threat and risk. This knowledge also allows you to consider the likelihood and consequences of a danger. After analysing the risk, it's crucial to figure out how to ease alertness and deploy the exact countermeasures to compact with most of the danger and decrease the threat.

10.5.2 Conducting Security Awareness Program

Users that behave properly should be rewarded in a high-quality security awareness program. However, as other firms should consider, security awareness programs seek to expressly highlight rewards. When an employee examines something that secures the organization's significant resources, such as identifying and reporting a potential assault, the employee should be rewarded, and the person's actions, including the payment, should be made known to everyone in the entity. Conducting this type of awareness program emphasizes the significance of excellent security habits and also encourages everyone to take similar steps.

10.5.3 Organizing Technical Training

Increasing awareness is insufficient; thus, immediately following the teaching stage, it is vital to initiate and motivate Medical Employees and Information Technology Department Employees [27]. The training must be divided into seven parts, the first of which is:

- **Recognition stage**: This stage is all about the information technology that distinguishes between suspicious and aberrant conduct.
- **Authorization stage**: This stage tells about the skill to check that an attack is happening.
- **Categorization stage**: This stage tells about the capacity to identify the various types of the on-going attack.
- **Approachable stage**: This stage describes the Computer Emergency Team's ability to respond quickly to a given outbreak by means of appropriate preventive actions and to stop an outbreak from causing problems.
- **Suppression stage**: This stage tells about holding the attack incident and disabling it.
- **Analysis stage**: This stage describes the application of legal evidences in which an inquiry procedure is Carried out to determine the cause of the attack [28], its influence, and harm.
- **Development stage**: This step explains how to learn from past attacker training.

10.5.4 Increasing the Level of Education

As the number of cyberattacks on medical care and the costs associated with them continues to climb, it is vital for the medical care industry, from private carry out to large companies, to have proactive, possibly the best cybersecurity strategies. Staff employees are an important means in averting cyberattacks and also, they can be a big company liability. Furthermore, medical care for individual is the only industry in which the danger from within the organization outweighs the threat from the outside. Human error plays a significant role in those figures [29]. "Many physicians, providers, also employees use their home and work computers to indulge in risky behaviour." Breach scenarios include misplaced or laptops that have been stolen, sharing of information across insecure networks, unauthorized access to systems and sloppy security policies. Ransomware, phishing, malware, distributed DOS occurrences [29], Trojan horses, worms are all examples of common cyber dangers. The preceding is some of the effective tactics for minimizing data breaches and cyberattacks [30]:

- Encrypting data, using Authentication with many factors, and creating secure Passwords or passes, and system lockouts as technical precautions.
- Using permitted, secure communication channels to share private or delicate data

- Avoid using community systems or unprotected wireless connections to access confidential or sensitive information.
- Knowing the warning signs of a cyberattack, like mistrustful locator or labels of domain, unwanted mails demanding private evidence, that appears too noble to be truthful, mails with strange language or syntactic difficulties, needs for cash, and danger.
- Trying to bypass virus safeguard warnings, pressing on adverts in the form of pop-up windows, and visiting a website that has a security vulnerability, making use of the unique password for several spots, allowing mail supplements from unidentified senders be opened, and all of these unsafe online practices should be avoided, including failing to sign out of collective processors
- To be aware of just how hackers may use social media to obtain sensitive details that may aid in password cracking and account penetration.
- Passwords should not be written down or shared, and privacy screens should be used, after each use of a system, log out, and adhering to procedures relating to carrying hand-held devices or original print of information external of organization based to prevent mistakenly releasing protected information.
- Damage of organisations, breaks in human treatment and operations, potential human injury, business sufferers, and effect on the administration's status are all possible outcomes of cybersecurity lapses. In Table. 10.2 summarized the various categories of attacks and its countermeasures.

10.6 Establishing Procedures

By laying down defined protocols for dealing with information and networks, both real and virtual, and ensuring that they are followed. By stating a clear expectation, the process becomes more consistent, allowing network security monitors to collect more data. Developing suitable penalties for failing to follow the processes not only discourages reckless behaviour that could endanger your ability to comply with HIPAA, but it also highlights the importance you place on maintaining patient data safe.

10.6.1 Software Update

Cybercriminals frequently take advantage of flaws in outdated software or other vulnerable entry points. Force software upgrades on devices, use two-factor authorization, and conduct monthly password updates that require characteristics of a strong password on a frequent basis to avoid this. Employees can be aided by setting business equipment to need such changes on a regular basis, so they only have to come up with a new password or click to approve upgrades. Repeating this process

Table 10.2 Various categories of attacks and its countermeasures

Various categories of attacks	Attacks	Reasons	Countermeasures
Data confidentiality	Eavesdropping	Random key pre-distribution schemes with link-layer encryption	1. Messages are broadcasted across wireless channels 2. Unsecured communication channel
	Packet capturing	3DES and blowfish encryption algorithms	1. Wireless Communications in an Open Environment 2. Improper encryption
	Wiretapping	1. Encrypted communication through communication channel 2. Closed communication	
Data integrity attacks	Data alteration	No data protection and authorization services followed	1. Hash message authentication code
	Malware added content		
	Spreading virus code		2. Message Digest-5 algorithm
Mis-information attacks	Denying the service	No devices for backing up data	Need storage devices to backup
	Flooding	Due to hackers' multiple requests at a single time	Intruder detection system is required
Password attacks	Trial and error	Sometimes password may be easily guessable	Give highly sensitive password for accessing devices
	Proxy	Less reliability on medical devices	Improve the authentication and authorization service
	Recursive		Generate unique session number
	Dictionary	Password insensitivity	Provide sensitivity password

on employees' own devices can be incredibly difficult, thus employees must be educated on the importance of updating.

10.6.2 *Setting Strong Enforcement Rules of Personal Device Regulations*

A rigorous protocol for the usage of mobile devices should be established, as well as the disposal of technology that has previously limited important information. Mobile device management software can be used by IT managers to secure, control, and also apply limits to tablets, smartphones, and other devices to prevent sensitive data from being re-displayed.

10.6.3 Training Consideration

Personnel who takes care of establishing and forming a system of staff education should think about several training formats and events to preserve employees, motivated, also informed. Staff can learn to recognize cybersecurity warning signs by using simulated phishing emails. Reviewing real-life instances of healthcare breaches and hacks, containing what happened, how it happened, and how this to be avoided in future events, could be beneficial. Periodic e-mail prompts, interactive courses, prints, team conversations, and title role playing are some of the other alternatives.

10.7 Techniques to Guarantee IoMT Data and Systems Security

Facial traits, eye structure, finger parameters, hand form, wrist vein pattern, and heat pattern are all examples of physical biometrics [31].

10.7.1 Facial Recognition

To determine an equivalent, a facial recognition system examines the form and position of several features of the face [32]. Surface features, such as the skin, are occasionally taken into account. Surface features, such as the skin, are occasionally taken into account. Face exposure technology, which is used to recognize faces in complicated photos with several faces, has resulted in facial recognition for security purposes. This technology has advanced rapidly in recent years, making it a great candidate for a remote identification system. Another key aspect is that technology allows for fake identification or the exclusion of faces, making it much easier to search a large area for suspicious people.

10.7.2 Retina Scan

A retinal scan is a biometric technology that determines a person's identity by analysing unique patterns on the retina blood vessels [33]. Person retina is a thin tissue in the back of the eye that is made up of neural cells. Because of the intricate assembly of the vessels that supply blood to the retina, each person's retina is unique, making retinal scans a growing identifying tool.

10.7.3 Iris Identification

Iris identification is a method of usual biometric technique that focus on mathematical model identification algorithms resting on video footage of one or both of a person's irises, which exhibit complex patterns that are distinctive, stable, and noticeable from afar [34]. This type of scan works in examining and look over the highlighted tissue surrounding an exact opening in the centre of the iris to see whether this fits into data warehoused in order to approve or deny right of access.

10.7.4 Authentication with Many Factors

Authentication with many factors are a technique of logon authentication that necessitates the use of at least two independent proof factors [35, 36]. MFA is also known as two-factor authentication (sometimes known as 2FA). MFA adds an extra layer of security to your data or assets, helping to keep them safe. Authentication factors are classified into three categories:

- First method includes Keys, PINs, groupings, code words, and private handshakes. This category includes everything a person can recall and then type, tell, do the task, accomplish, else recollect if it is necessary.
- Second method includes all usage objects, such as digital badges, Mobile phone, flash storage, Tap card and keys. (A digital badge can generate a session password or calculate a reply from a server-issued challenge number.)
- Third method includes Biometric process like voice verification, facial recognition, retina scans, palm scanning, iris scans, and fingerprints, as well as any other parts of body meant recognition purpose.

Two-factor authentication adds an extra layer of protection and assurance to your account [37] Two-factor authentication is now widely assumed to be required in order to offer acceptable security for remote access to sensitive or confidential information and, in fact, the Health Services provides recommendations for companies that must comply with HIPAA security rules for remotely accessing Electronic Protected Health Information.

10.7.5 To Reduce Vulnerability, Take the Following Counter Measures

There is already an assault affecting the current scenario, but there is also a remedy that could prevent the weakness from being used by hackers. Although there is no way to completely eliminate the vulnerability, these suggestions can help prevent hackers from discovering it. If they are successful in discovering this proposal, it will make things very difficult for them. Various recommendations pertaining to the four vulnerabilities mentioned in the previous section will be made in the stages that follows [31].

The first suggestion for a lack of authentication method is to use a password. This means that in today's internet age, a password is required for every internet of things. Having a password ensures that the account or data is always secure. They should encrypt the password to make it more difficult for hackers to guess. For enhanced security, these passwords will need to be redesigned every 6 months. This may be considered the most fundamental precaution or tip someone could offer to keep data secure. For instance, when the doctor increase right of entry to the patient data [30], the doctor will need to enter the encrypted password. People nowadays might argue that using a password is a bad idea, although it was a common practice in the late 1990s. These activities were deemed to be the most desirable, and as a result, these devices will require an authentication password to keep them secure.

The second suggestion would be the security patches would be recommended for the software problem. That is to state, every 3–6 months, a security patch would be advised to close any loopholes that hackers may have discovered. These patches will protect the device from any flaws that could expose it to attack [29]. These security patches will need to be applied in order to prevent any device failures. This is because these updates would be like closing over a hole made by hackers, and this is necessary to ensure that there are no vulnerabilities. While this patch is not permanent, it may act as a temporal constraint in the meanwhile, allowing it to be saved until the next patch. Failure to update patches may provide an avenue for hackers to carry out their malware attack.

The third suggestion, having the computer in a protected closed area is recommended for external computer access. This means that any computer that allows the doctor to access the patient's gadgets must be kept separate. This means that the computer should not be accessible to the public and should be kept in a room with the servers and other equipment. This may prevent hackers from discovering the computer's location, and it may be a useful step in preventing them from obtaining the computer's IP address in order to conduct the snooping event. For example, if the computer is visible to the public, hackers can easily hack it physically and obtain the computer's IP address, which they can use to gain access to the machines backdoor and perform snooping.

Finally, a proper understanding of the goal of security patches would be a recommendation for security patches. It indicates that today's technology consumers are unaware of the importance of having security patches installed, and this will educate users and help them to understand why security patches should be updated. For instance, publishing a news update on social media about the necessity of security patches and the consequences of not upgrading them could prevent people from having their devices compromised by hackers.

10.7.6 Recommended Counter Measures to Guard Against Attacks

IoMT devices that share a network with certain other devices may be damaged by other machines' faults. To circumvent this, it is recommended that you use a specialized communications infrastructure rather than a shared LAN or Wi-Fi network [35, 38]. Instead, cellular communication, which separates the communication of the various machines, is advised.

A few malware cases show the need of utilizing random and exclusive log-in IDs for multiple devices, which could have prevented the above-mentioned attack. The gadgets allowed their owners to access them remotely, however this was done using an unprotected public internet connection. It's worth noting that using IPSec or Intra-Cloud Connect, which eliminates the public Internet's coverage, is the most secure way to connect to IoT devices remotely [29].

A cellular firewall concept is used to block tries to giveaway remote contact to IoMT devices and also to fully obstruct attacks. Machines are only allowed to interact with a specific subset of IP addresses within a cellular firewall. The firewall is not on the separable devices, but somewhat on the cellular connection, which is beyond of the attacker's reach. A cellular firewall concept is used to block tries to giveaway remote contact to IoMT devices and also to fully obstruct attacks. Machines are only allowed to interact with a specific subset of IP addresses within a cellular firewall. The firewall is not on the separable devices, but somewhat on the cellular connection, which is beyond of the attacker's reach.

10.7.7 CSRF for Healthcare Domain Internet of Things (IoT) Devices

A Cyber Threat Scoring Method that considers a doctor's duty of a health equipment. A doctor's who don't produce best-case valuation of a medical device's ability to contact a patient is taken into account. For these devices, a STRIDE model is utilized to determine risk scores. The approach of assessing cyber risk for medical equipment has been improved using this rating system. The three main goals of this method are easiness of usage, minimal price, and automatically pleasing outputs. This would be applicable in order to likely capture the impact factors in the event of any unhelpful events, which is done using a medical risk assessment model.

The infection caused by haemodialysis is provided as an example. To explain, de-sign, and deploy healthcare IoMT, a systematic framework has been proposed. This procedure aids in the organization of knowledge and the capacity to use it effectively. A method for assessing IoT risk has been reported. The assault detectors and immune principles are simulated by the system. Measuring the risk of IoT security al-lows for a more accurate and reliable risk assessment. This ideal framework should also be capable of prioritizing risks and taking the required steps to mitigate them.

The National Institute of Standards and Technology's (NIST) standards help critical infrastructures manage their cyber risks [30, 39]. The courses include Health In-formation Policy, International Organization, NIST threat organization structure, and Expense Card Industry Information Security Standard. A few changes to the NIST framework are required to meet healthcare norms and laws. The fundamental components of the perceive function, including defect detection, should be continuously monitored to detect a healthcare breach in real time. Healthcare organizations must advance in technology in order to understand when and how breaches occur, as well as how to mitigate the risk.

10.7.8 Management of Authentication and Identity

This metric assesses the device's ability to authenticate the identity of stakeholders (patients, doctors, devices, and applications). A user's identity is tied with a unique username or ID. Authentication is the process of proving a user's identity, such as by the use of a password or a key. Because it determines how effective the authentication mechanism is at preventing unauthorized access to the device and data. The authentication procedure entails taking extra steps to verify the user's identity.

10.7.9 Profiling and Access Control

This metric assesses the device's capacity to offer users access and privileges to re-sources. Data or the device can be used as these resources. The rights and permissions assigned based on the authorization to the data and the device determine this access. Because it allows the device's owner to control who has access to the device and what capabilities each user has. Only the device's owner should have the greatest level of access [40]. It also assesses the ability to develop and adjust stakeholder profiles based on the patient's needs.

10.7.10 Location of Storage

The device's ability to store data in numerous secure locations is measured by the storage location. Cloud storage, mobile storage, and device storage are all options for storing data. For the reason that it allows the user to see where the data is stored and so reduce the number of storage places, which promotes redundancy. If data can be controlled from any storage site, storing it in numerous locations helps to back up the data but also expands the attack surface.

10.7.11 Encryption

This metric assesses a device's ability to render data unreadable at several levels, including data at rest, data in transit, and data in use. Only the user with the encryption key can read the data, which is then converted back to clear text. Because it informs the user about the security of the data**.** When data is kept in plain text, it can be viewed by anybody if the device is lost, or not.

10.7.12 Intelligent Healthcare System

AI based Cloud computing methodology to take care of patient health from intruders by giving high protection to medical devices as well as patient data. This system is more protective than IoT based health care system because the health care data should be kept confidential in cloud with highly encrypted algorithm SHA-256. Secure hash algorithm is one of the most protective hash algorithms in all the aspects. This system can easily detect the privacy and security attacks like virus, worm attack by converting the smart medical devices into intelligent devices. So that medical devices will only allow the authorized person to access patient's personal health data. In existing system lot of sensors are required to monitor the patient in remote. But now with the development of artificial intelligence, it will create a virtual interface in nervous system to control the patient mind. This can help the patient to come out of stress easily.

In the development of Artificial intelligence, cloud computing and Block Chain technologies various innovations in health care system have discovered. Here we summarized some of the recent innovations in health care system:

- Recent version of radiology tool to predict the tissue in correct position of the body.
- Clinical services are improved by giving voice as an input with the help of Natural Language processing.
- Remote monitoring on patient health and data status.
- Providing learning to medical equipments and kits.
- Immunotherapy for cancer treatments

Aslam, B et al. stated that [31, 41], as increase in cost of medical expenses, patients expect lot of health monitoring activities due to spread of various viruses like COVID-19 [33]. This Intelligent healthcare system reduces the time to create drug, diagnose the issue as well as speedup the treatment process. Due to COVID-19 lot of patients are died every day we make use of intelligent system to increase the speed of drug production, that help lot of lives.

As of now, in the medical field, the following platforms are in trend to develop intelligent healthcare system that are Bigdata, Blockchain and Machine Learning algorithms. Due to huge count of IoT medical devices in the world that makes lot of data need to be stored. That data storage process can be effectively handled by cloud based Bigdata platform [42]. The medical datasets are divided into two separate sets for training and testing to machine learning algorithms. Based on testing it will create a model for diagnosing the diseases of all the patients as well as create a drug for patients. At the same time, we are in need to protect the medical datasets from cloud platform-based Block-chain Technology has been used extensively.

10.8 Conclusion and Future Scope

There are few benefits in Internet of Medical Things at the same time it is easily attackable to various categories of attacks such as insider, External, Active and In-Active. In order to escape from these malicious attacks, people related with healthcare industry to improve the highly authenticated security system for medical devices to access in Internet. Here we represented the various issues, expectation and limitation of Internet of Medical Things in addition to that various counter measures to be followed in medical devices to protect the patient's confident information from attackers. Moreover, it is highly needed to enhance the security measures to various wireless protocols that especially involved in Medical Equipments. Eventually, all the medical people they must aware of the security issues according they maintain and handle the confidential information of patient health reports.

In future, IoMT systems are associated with AI based 5G System in healthcare domain to increase the speed of curing the patient's health and rapid growth in count of COVID patients, doctors are not able to spend time for diagnose and heal only in the hospital. So that IoMT devices help them to monitor their health even at home. Eventually various smart devices are there to monitor themselves. Finally, IoMT with AI based 5G system will be very helpful in all aspects for taking care of patients' health.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Yaacoub, J. P. A., Noura, M., Noura, H. N., Salman, O., Yaacoub, E., Couturier, R., & Chehab, A. (2020). Securing internet of medical things systems: Limitations, issues and recommendations. *Future Generation Computer Systems, 105*, 581–606.

2. Kumar, J. S., & Patel, D. R. (2014). A survey on internet of things: Security and privacy issues. *International Journal of Computer Applications, 90*(11).
3. Zarpelão, B. B., Miani, R. S., Kawakani, C. T., & de Alvarenga, S. C. (2017). A survey of intrusion detection in internet of things. *Journal of Network and Computer Applications, 84*, 25–37.
4. Trnka, M., Cerny, T., & Stickney, N. (2018). Survey of authentication and authorization for the internet of things. *Security and Communication Networks, 2018*, 4351603.
5. Challoner, A., & Popescu, G. H. (2019). Intelligent sensing technology, smart healthcare services, and internet of medical things-based diagnosis. *American Journal of Medical Research, 6*(1), 13–18.
6. Adhikary, T., Jana, A. D., Chakrabarty, A., & Jana, S. K. (2019). The internet of things (IoT) augmentation in healthcare: An application analytics. In *International Conference on Intelligent Computing and Communication Technologies* (pp. 576–583). Springer.
7. Venkatasubramanian, K. K., Banerjee, A., & Gupta, S. K. S. (2009). PSKA: Usable and se-cure key agreement scheme for body area networks. *IEEE Transactions on Information Technology in Biomedicine, 14*(1), 60–68.
8. Gao, Y., Li, H., & Luo, Y. (2015). An empirical study of wearable technology acceptance in healthcare. *Industrial Management & Data Systems, 115*(9), 1704–1723.
9. Ayala, L. (2016). Active medical device cyber-attacks. In *Cybersecurity for hospitals and healthcare facilities* (pp. 19–37). Apress.
10. https://www.healthcareitnews.com/news/5-current-issues-patient-privacy-and-data-security
11. Kelly, K. (2012). Better than human: Why robots will—and must—take our jobs. *Wired*. Retrieved August 4, 2014, from http://www.wired.com/2012/12/ff-robots-will-take-our-jobs/.
12. Clark, G. W., Doran, M. V., & Andel, T. R. (2017, March). Cybersecurity issues in robotics. In *2017 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA)* (pp. 1–5). IEEE.
13. Birkmeyer, J. D., Stukel, T. A., Siewers, A. E., Goodney, P. P., Wennberg, D. E., & Lucas, F. L. (2003). Surgeon volume and operative mortality in the United States. *New England Journal of Medicine, 349*(22), 2117–2127.
14. Sensmeier, J. (2017). Harnessing the power of artificial intelligence. *Nursing Management, 48*(11), 14–19.
15. Hassanalieragh, M., Page, A., Soyata, T., Sharma, G., Aktas, M., Mateos, G., Kantarci, B., & Andreescu, S. (2015). Health monitoring and management using Internet-of-Things (IoT) sensing with cloud-based processing: Opportunities and challenges. In *2015 IEEE International Conference on Services Computing* (pp. 285–292). IEEE.
16. Xu, W., Wood, T., Trappe, W., & Zhang, Y. (2004). Channel surfing and spatial retreats: defenses against wireless denial of service. In *Proceedings of the 3rd ACM work-shop on wireless security* (pp. 80–89). ACM.
17. Moalla, R., Labiod, H., Lonc, B., & Simoni, N. (2012). Risk analysis study of its communication architecture. In *2012 Third International Conference on the Network of the Future (NOF)* (pp. 1–5). IEEE.
18. Nurse, J. R., Erola, A., Agrafiotis, I., Goldsmith, M., & Creese, S. (201). Smart insiders: exploring the threat from insiders using the internet-of-things. In *2015 Inter-national Workshop on Secure Internet of Things (SIoT)* (pp. 5–14). IEEE.
19. Bagnall, P. (1998). *Taxonomy or communication requirements for large-scale multicast applications*. IETF Draft.
20. Conteh, N. Y., & Schmick, P. J. (2021). Cybersecurity risks, vulnerabilities, and countermeasures to prevent social engineering attacks. In *Ethical hacking techniques and countermeasures for cybercrime prevention* (pp. 19–31). IGI Global.
21. Costin, A., & Zaddach, J. (2018). *Iot malware: Comprehensive survey, analysis framework and case studies*. BlackHat USA.
22. Ferguson, P., & Senie, D. (2000). *rfc2827: Network ingress filtering: Defeating denial of service attacks which employ ip source address spoofing*. RFC 2827.

23. Bertino, E., & Islam, N. (2017). Botnets and internet of things security. *Computer, 50*(2), 76–79.
24. Kambourakis, G., Kolias, C., & Stavrou, A. (2017). The mirai botnet and the IoT zombie armies. In *MILCOM 2017–2017 IEEE Military Communications Conference (MILCOM)* (pp. 267–272). IEEE.
25. Turner, A., Glantz, K., & Gall, J. (2013). A practitioner-researcher partnership to develop and deliver operational value of threat, risk and vulnerability assessment training to meet the requirements of emergency responders. *Journal of Homeland Security and Emergency Man-agement, 10*(1), 319–332.
26. Dhem, J. F., Koeune, F., Leroux, P. A., Mestré, P., Quisquater, J. J., & Willems, J. L. (1998). A practical implementation of the timing attack. In *International Conference on Smart Card Research and Advanced Applications* (pp. 167–182). Springer.
27. Piret, G., & Quisquater, J. J. (2003). A differential fault attack technique against SPN structures, with application to the AES and KHAZAD. In *International workshop on cryptographic hardware and embedded systems* (pp. 77–88). Springer.
28. Noura, H. N., Salman, O., Chehab, A., & Couturier, R. (2020). DistLog: A distributed log-ging scheme for IoT forensics. *Ad Hoc Networks, 98*, 102061.
29. Bellare, M., & Kohno, T. (2004). Hash function balance and its impact on birthday at-tacks. In *International conference on the theory and applications of cryptographic techniques* (pp. 401–418). Springer.
30. Ala, I., Al-Fuqaha, M. G., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys and Tutorials, 17*(4), 2347–2376.
31. Douglas, M., Bailey, K., Leeney, M., & Curran, K. (2018). An overview of steganography techniques applied to the protection of biometric data. *Multimedia Tools and Applications, 77*(13), 17333–17373.
32. Woodward, J. D., Jr., Horn, C., Gatune, J., & Thomas, A. (2003). *Biometrics: A look at facial recognition*. RAND CORP SANTA MONICA CA.
33. Aslam, B., Javed, A. R., Chakraborty, C., Nebhen, J., Raqib, S., & Rizwan, M. (2021). Blockchain and ANFIS empowered IoMT application for privacy preserved contact tracing in COVID-19 pandemic. *Personal and Ubiquitous Computing*, 1–17.
34. George, J. P. (2012). *Development of efficient biometric recognition algorithms based on fingerprint and face*. Doctoral dissertation, Christ University.
35. Li, C. T., Weng, C. Y., & Lee, C. C. (2013). An advanced temporal credential-based security scheme with mutual authentication and key agreement for wireless sensor networks. *Sensors, 13*(8), 9589–9603.
36. Rahman, A., Chakraborty, C., Anwar, A., Karim, M., Islam, M., Kundu, D., Ziaur, R. & Band, S. S. (2021). SDN–IoT empowered intelligent framework for industry 4.0 applications during COVID-19 pandemic. *Cluster Computing*, 1–18.
37. Bowen, B. M., Devarajan, R., & Stolfo, S. (2011). Measuring the human factor of cyber security. In *2011 IEEE International Conference on Technologies for Homeland Security (HST)* (pp. 230–235). IEEE.
38. Chen, T. H., & Shih, W. K. (2010). A robust mutual authentication protocol for wireless sensor networks. *ETRI Journal, 32*(5), 704–712.
39. Chakraborty, C., Banerjee, A., Garg, L., & Rodrigues, J. J. (2020). *Internet of medical things for smart healthcare. Studies in big data* (p. 80). Springer.
40. Ahmadi, H., Arji, G., Shahmoradi, L., Safdari, R., Nilashi, M., & Alizadeh, M. (2019). The application of internet of things in healthcare: A systematic literature review and classification. *Universal Access in the Information Society, 18*(4), 837–869.
41. Dash, S., Chakraborty, C., Giri, S. K., Pani, S. K., & Frnda, J. (2021). BIFM: Big-data driven intelligent forecasting model for COVID-19. *IEEE Access, 9*, 97505–97517.
42. Abbasi, A., Javed, A. R., Chakraborty, C., Nebhen, J., Zehra, W., & Jalil, Z. (2021). El-stream: An ensemble learning approach for concept drift detection in dynamic social big data stream learning. *IEEE Access, 9*, 66408–66419.

Chapter 11
Secure Data Transfer and Provenance for Distributed Healthcare

Anna Lito Michala, Hani Attar, and Ioannis Vourganas

Abstract The rise of the Internet of Things (IoT) has enabled a shift to a smart, remote, and more distributed healthcare ecosystem supported by learning-based secure Internet of Medical Things (IoMT). Infrastructure availability is a barrier. The distributed and layered architecture of IoMT another. Trust must be addressed across the full stack and involves challenges in security, privacy, and edge intelligence. This chapter's objective is to examine the state-of-the-art in security, privacy preservation and provenance of data generated by the IoMT and identify challenges and opportunities. The chapter highlights the existing security and challenges and how they can be addressed from the incorporation of blockchain technologies. Also, it discusses the challenges generated by infrastructure availability and suggests edge computing and federated learning as opportunities to address IoMT service provision where infrastructure is lacking. To demonstrate the feasibility of the proposed solutions a state-of-the-art exemplar system is examined. The system is designed with trustworthy Artificial Intelligence (AI) principles in mind and the results demonstrate not only the benefit for remote diagnostics but also the improvements in security, privacy preservation and provenance when transferring and processing data. The chapter proposes future directions of research to enhance transfer and provenance in distributed healthcare data.

Keywords IoT · IoMT · Distributed healthcare · Data transfer · Data provenance · Trustworthiness · Security

A. L. Michala (✉)
School of Computing Science, University of Glasgow, Glasgow, UK
e-mail: annalito.michala@glasgow.ac.uk

H. Attar
Faculty of Engineering, department of Energy Engineering, Zarqua University, Zarqa, Jordan
e-mail: hattar@zu.edu.jo

I. Vourganas
School of Design and Informatics, Abertay University, Dundee, UK
e-mail: i.vourganas@abertay.ac.uk

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_11

11.1 IoT and Distributed Healthcare Systems

The landscape of health and care provisioning is rapidly transformed by the introduction of Internet of Things and distributed systems. However, to support such use we still need to address challenges in security and privacy as well as the fundamental science behind these analytical approaches and technological solutions. In other words, we are witnessing a sift to smart remote healthcare ecosystem supported by learning-based secure Internet of Medical Things (IoMT).

This expected siftaims to improve preventive health and care. Its low-cost aids in wider adoption in Low and Middle Income Countries (LMICs) that have traditionally suffered from lack of technological integration. These are also the countries that stand to gain the most from remote health and care support. For example, the early diagnosis of malaria could help tackle the ~228 million cases and 405,000 deaths globally each year, where more than 90% is reported in Africa [1]. Particularly for Africa, according to the World Health Organisation (WHO) a considerable proportion of the population lives in rural locations where early diagnosis of infectious disease cannot be easily delivered by the country's healthcare system [2]. Recognising this challenge and the opportunity offered by IoMT, sub-Saharan Africa is leading the race in the domain by developing and adopting new technologies [3].

However, there are a few open challenges in establishing wider adoption. Those include better understanding of learning algorithms limitations and establishing commonly accepted and standardised infrastructure and management solutions for these systems. Especially in LMICs infrastructure is fragmented and ranges from connected systems in urban areas to distributed and/or absent in rural [1]. Connectivity between rural and urban areas is a challenge for IoMT data gathering. On the other hand, IoMT is forecasted to generate massive data that—even if infrastructure is available– cloud computing may not be able to cope with [4]. Particularly in for the intelligent healthcare systems information must be processed to support and/or automate decision making at a higher abstraction level. Thus, distributed intelligence and hence federated intelligence might be the only feasible solution. This could address the lack or fragmented nature of the infrastructure while supporting lower dependency on could. However, it requires new capabilities of IoMT including data analytics, Machine Learning (ML) and federated decision making. But such a far-reaching mesh of constant information transmission will require new approaches in security and privacy protection especially when communicating highly protected personal information. The contributions of this chapter are:

1. Areview of challenges and associated opportunities for research in data transfer and provenance targeting IoMT
2. An analysis on the security and data provenance requirements of IoMT beyond the state of the art.

This chapter is organised as follows. Section 11.2 will introduce the fundamental research questions associated with trust in the new generation of distributed health and care systems. Section 11.3 will elaborate on the challenges and opportunities brought forward by this sift to federated learning, distributed Artificial Intelligence (AI) and the IoMT. Section 11.4 will then focus on the specific aspects of trust, challenges and opportunities that link to data transfer and provenance in this new environment and will present recent advancements in the domain. Particularly the conversation will elaborate on the integration of IoMT with databases and blockchain as an area that has attracted keen interest by the research community particularly expedited during the COVID-19 pandemic. Then the chapter will conclude with a discussion of the chapter's sections and with suggestions for further research.

11.2 Trustworthiness in Healthcare Systems

To support the envisaged sift to distributed IoMT-based health and care services, several system components must be integrated. These include:

- Machine learning and data processing on/for IoMT;
- Cloud/Fog/Edge computing infrastructure including data warehousing;
- Distributed and secure transfer through variable communication channels and across stacks.

Asking users of these systems to place trust on both the system and the decision support interfaces demands trust across the stack and across a variety of concerns. WHO has recently published guidance on ethics and governance in AI for healthcare systems [5] which is a starting point. Similarly the EU has published guidelines [6] and large companies have already compiled lists of principles for Responsible AI (e.g. Microsoft [7]). However, these considerations only cover the first system component; namely ML and data processing. This processing may take place on the IoMT component or in a centralised service provider such as the Cloud. Trust in the analysis of information is an important angle that expands beyond the notions of security and privacy preservation. This links directly to the notion of trust in AI which is a vibrant research domain with multiple open research questions. Much of the research in healthcare applications has primarily focused on deployment of intelligence from ambient environments [8] to wearable devices. However to enable trust these devices need to take under consideration a multitude of factors that enable users to effectively integrate this technology into their everyday lives [9]. Particularly stemming from the conversation in [9], individualisation is a major field for AI and imposes further requirements in terms of transparency, ethics, responsibility, reliability and accountability [10]. Distilling all these we conclude that such systems must:

- respect data protection regulation and applicable laws;
- protect autonomy;

- promote human well-being, safety and public interest, and respect all ethical values and principles;
- ensure transparency, explainability and intelligibility;
- foster responsibility and accountability;
- ensure inclusiveness and equality (bias free decision making);
- promote AI that is responsive and sustainable;
- and be robust.

As a result, trust is invertedly linked with all the components of the system and all stages of the data pipeline. Achieving all these requirements is not a trivial task. Particularly with the potent use of deep learning methods in healthcare applications, several of the goals (e.g., transparency and intelligibility) are hardly possible. Research in the past decades has focused on constantly improving prediction accuracy and this has been at the expense of understandable algorithms. However, as evident data protection is at the heart of generating trust in future healthcare systems and indeed it has been one of the first aspects to be covered by the General Data Protection Regulation (GDPR) [11]. These goals of data protection cannot be achieved without explicitly addressing security and privacy preservation across the full system stack from IoMT to the user interface platform. In this chapter we will focus particularly on the aspects of AI that pertain to privacy preservation, security and data transfer and provenance. Specifically, we will discuss open challenges in warehousing data at cloud servers to enable AI processing versus the merits of moving AI to the data collection site and avoiding data exposure.

To establish a focal point for the remaining of the discussion in this chapter we first must specify the terms privacy and security in the scope of IoMT. According to [12]:

> "Privacy refers to protecting the confidentiality of the . . . device and its collected . . . data"

Following from this definition privacy protection includes the protection of GDPR [11] data but also the geolocation of the IoMT device. In many industries a bridge of privacy is associated with a security and/or safety threat [13]. In terms of security there are aspects that affect trustworthiness. These aspects are the impact of attack, the security in terms of communication, the authentication and authorisation of access, and the accountability of the various system components. For IoMT there are open challenges in all four aspects of security [14, 15]. Recent reviews and security incidents have demonstrated how vulnerable IoT and as a result IoMT systems are to cyber-attacks. Such an attack can have significant impact due to the critical nature of an interconnected health provisioning system [12].

Communication channels play a pivotal role in security. A vast variety of communication protocols have been used ranging from smartphone applications (e.g. 3G, 4G) to IoMT devices (e.g. Wi-Fi, Zigbee, GPRS, SMS, BLE) with varied physical layer security provisions and even more varied security implementations in the software stack. Unsecure communications can hurt the security of the full stack and lead to leakage of sensitive information for specific individuals or large groups and communities. The industry has recognised the need for authentication and authorisation, but it is challenging to deliver these requirements within the constraints of IoMT devices.

Generalising beyond healthcare applications, IoT systems have evolved to be depended on the Cloud. Data management and processing tends to be centralised. In a centralised scenario, not using the Cloud imposes scalability limitations. Using the Cloud on the other had imposes privacy and security concerns. Further in both cases there are transparency implications and single point of failure implications [4]. To move away from the centralised architecture most recently blockchain has been investigated as a solution to address security and accountability particularly relating to provenance of data in a variety of industries [1, 4, 15, 16].

The benefits includestoring information in a "tamperproof" digital ledger, secured by unique digital signatures. Systems using blockchain as the medium for data transfer claim that the system is almost impossible to hack as multiple copies of the data can be used to identify malicious tampering. Healthcare workers can have access to local ledgers within the blockchain network ensuring access and consistency even when connectivity is problematic. A prime example is the case of rural diagnostics in sub-Saharan Africa [1]. Changes to the network are verified by consensus. However, protection of the individual's privacy in this case happens by anonymisation of data entries. Another example which has quickly become has been the utilisation of blockchain in privacy preservation during geospatial tracking [16]. Blockchain has historically attracted interest in the domain of financial transitions but more recently it has been increasingly investigated in relation to the energy sector and IoT. These benefits can improve credibility of the distributed IoMT systems but bring interesting challenges in terms of technological integration in resource constrained devices. However, it is worth mentioning that under very specific circumstances the blockchain network can be tampered and further research is required in this direction as identified in [17].

Even though early research has demonstrated possible integration mechanisms in IoT [4] transferable to IoMT, these still leave parts of the system out of the blockchain network. This is evident in Fig. 11.1 where the bottom layer is outside the blockchain network in both the architectures. The data management strand can benefit from the decentralised distributed ledger architecture. This can support verified changes to the data, further auditing and retrieval while moving away from the single point of failure architectures. However, due to the resource constraints of the IoT devices the blockchain network cannot be deployed on the devices themselves. Thus, an intermediary approach is taken, utilising the edge computing system architecture. As a result, data transmissions from IoT to the blockchain network happen outside the network's secure enclosure. Also, this approach introduces new problems related to optimised use of edge servers and resource allocation for the support of the blockchain network.

On the other hand, the privacy protection challenges remain with or without the use of blockchain. Similarly, security challenges remain for system components outside the blockchain network. Especially in the IoMT domain where data is stored and processed on third-party Cloud servers these issues are heightened [12]. As a result, security and privacy must be considered at design stage and across the system

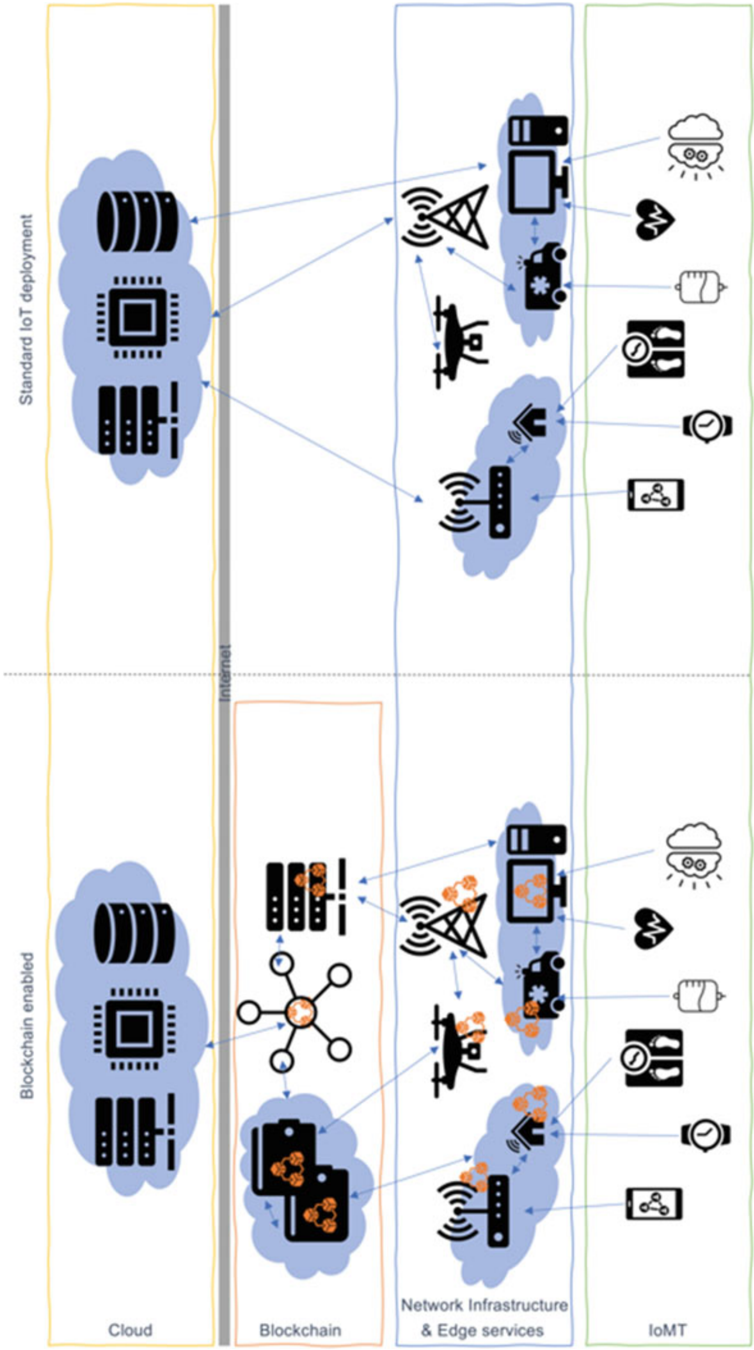


Fig. 11.1 The architectures most prevalent in digital healthcare state of the art applications. Comparison between blockchain and non-blockchain system architectures

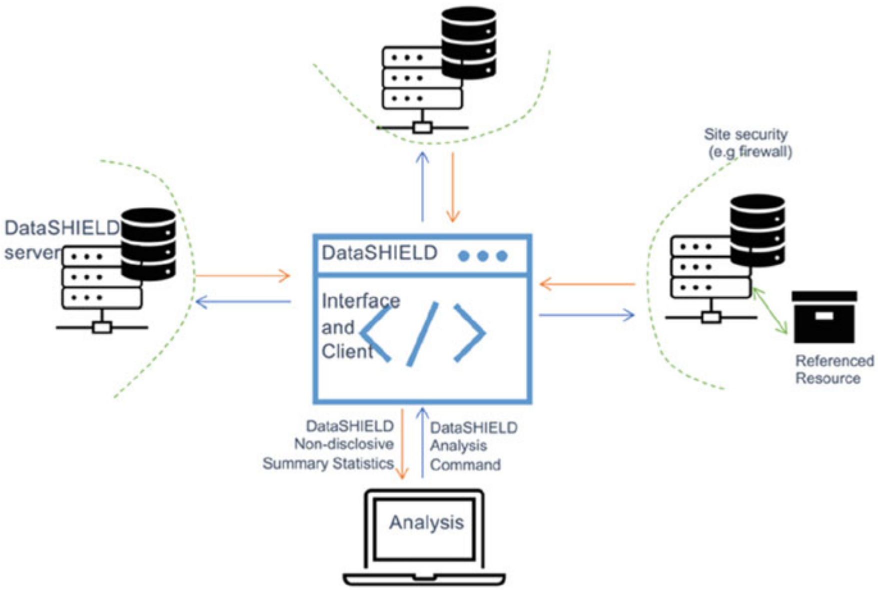


Fig. 11.2 The distribution of both storage and processing for higher privacy protection may be a solution for edge service provisioning but not suitable for IoMT devices

stack. Following from the analysis presented in [12], the design time considerations for privacy and security are:

- cryptosystems suitable for IoMT devices,
- data anonymisation balanced with identity preservation,
- efficient use of edge servers to minimise exposure,
- data access policies and appropriate access control methods.

In this direction, research has made significant advancement in other domains which could be transferable to IoMT if resource constraints are respected. These domains include research in encryption, access control, anonymisation, and edge computing [12]. In the direction of moving privacy protection closer to the generation of data several researchers have investigated providing access based on conditions. For example, DataSHIELD allows data to be distributed in local computers and distributes data processing algorithms across those locations to enable collaborative research [18]. The architecture of a DataSHIELD enabled system is presented in Fig. 11.2.

In this setting privacy preservation is achieved by distributing the database and the processing of data. However, this assumes that enough resources exist for long term data storage and analytics to be executed at the remote locations. Thus, it is not optimised for IoMT scenarios where the device has limited processing and storage local access.

11.3 Challenges and Opportunities

Following from the above analysis, this section will elaborate on open challenges in IoMT resulting from the integration of new technologies in already large and dynamic digital healthcare systems. We categorise the challenges in Security, Privacy and Network Infrastructure related. Further to address these challenges we discuss Edge Computing and Federated Learning as opportunities which also introduce new challenges in turn.

11.3.1 Security

A number of recent surveys investigate security in IoT systems with a special focus on industrial applications (Table 11.1). Many of those are transferable to the IoMT application domain which similarly suffers from retrofitting security approaches.

The lack of security on IoT is generally recognised. However, adapting current approaches to the IoT domain is not trivial. Research proposes interesting optimisation trade-offs between securing the network edge and sacrificing more power or storage or computation. However, there is no consensus towards a preferred approach. Lightweight Public Key Encryption as well as other cryptographic approaches have been investigated for the transmission of information across a variety of networks. However, more advanced methods are required to enable searching over encrypted data at low resource cost to enable more authentication and access control at all levels of the stack.

Another interesting problem arises from the introduction of multiple stakeholders in an IoMT system scenario. In such a system a doctor may require a different level of clearance to access IoMT data and/or metadata. While an insurance company might have quite a different level of access to protect the patient's interests while

Table 11.1 Summary of open security challenges in IoMT identified in IoT literature

Source	Challenge
Bader et al. [12]	Lightweight public key encryption with keyword search (PEKS) for IoMT.
	Combining PEKS with authentication and access control mechanisms.
	Distributing security mechanisms over an edge/fog architecture.
	Increasing security within power, computation, storage, and timing constraints.
Dan Chia et al. [19]	Dynamic system and security adaptation.
Xiong et al. [4]	Incomplete system information (e.g. ongoing attacks).
Sengupta et al. [15]	Varied nature of possible attacks; physical, network, software, data.
	Data integrity preservation in transit and in centralised storage.
	Standardisation and interoperability of security solutions in IoMT.

meeting their corporate goals. In this situation authentication and access control protocols will be required to enable specific access to authorised users on demand. This might be via the Cloud or through an Edge service infrastructure. As a result, it is no longer sufficient to entrust all of the access control rights to just the server and warehousing end. The full stack needs to have a notion of the various access levels and activities must be checked at various points in the system stack. Thus interesting challenges are introduced in terms of distributing such methods across a dynamic network of devices and servers while meeting their heterogeneous needs in terms or resources. Methods must be investigated in terms of their performance overhead for deployment in the various system components and appropriate architectures proposed. These may differ between IoMT applications depending on the targeted use and devices involved. For example in a diagnostics scenario a mobile phone camera may be the only required device while in another case a reader may be necessary (e.g. malaria diagnostics [1]).

An open challenge is the implementation of security mechanisms that adapt well to the distributed nature of the IoMT and account for the constant change of geolocation and network infrastructure. Such systems have been investigated for use in the case of mobile phones where the network infrastructure is widely delivered via telecommunications networks such as 3G and 4G. However, this work is not directly transferable to IoMT devices which are commonly a few orders of magnitude smaller than the mobile phone platforms in battery, storage and processing capabilities. Similarly to [19], static assessment of risks ahead of deployment time may not be sufficient to ensure security and privacy so we need to evaluate more dynamic risk assessment methods that take into account the deployment environment and continuously assess the security and privacy threats. Edge servers can provide the ideal platform for such evaluation in the future smart health and care environments.

Further, it is recognised that standard web security approaches have vulnerabilities over wireless networks and are often not sufficient for safety-critical applications (e.g. medical) [20]. Even when all current security measures are in place, these systems are added on. This means they require specialised equipment and trained personnel to provide data provenance and management over and above their main security purpose. Both of these requirements are particularly restrictive in situations where resources are scares, such as LMICs. On the other hand, blockchain has proven to improve security and privacy preservation with limited overhead when there are sufficient resources such as battery, computational capacity, connectivity [21–23]. Light-weight and low-power versions of blockchain are emerging to bring those benefits to resource limited applications such as IoMT. Additionally, block chain can reduce cost of maintenance, improve compliance with regulation for governed processes, and enable interoperability to other healthcare systems already in deployment. Further if blockchain is used as a ledger it supports higher privacy and security during storage of the data and is an access control mechanism for trusted and endorsed users.

11.3.2 Privacy

The medical field is one of the first to have introduced protection of personal information long before GDPR even existed. As a result, it is only expected that the privacy protection challenge is only larger within the IoMT domain. A medical app running on a mobile phone platform is not only able to expose protected information (e.g., age, gender) but also much more sensitive information that could have a detrimental effect on a person's life. To the extreme of this spectrum an app that controls insulin intake could become a lethal weapon. According to [12] and [24] the design time considerations for privacy and security are:

- *Enforcing privacy policies through the use of cryptographic mechanisms.* However, to support this on IoMT devices (e.g. smart watch) new lightweight designs are required. These new approaches must be both privacy-preserving and suitable for the IoMT target devices and their limited resources. Thus, it is crucial to prevent heavy computations.
- *Data anonymization combined with cryptosystem approaches.* Here data anonymization may require obscuring exact geolocation while preserving a level of location accuracy. Also, it may require using the healthcare system's patient ID through some kind of commissioning phase, instead of storing private information on the IoMT device. New lightweight data anonymisation cryptosystem methods are an open challenge in this domain.
- *Advanced data analytic tools to process anonymised data and preserve privacy.* As the purpose of IoMT is to feed data to analytics, it becomes self-evident that we must ensure that no processing is performed to reveal identities. However, this is a sensitive balance between being able to identify patients to provide individualised care and being able to protect the same patient's identity from being reverse engineered from big data for malicious purposes.
- *Consuming data on the Edge.* The Edge may refer to the IoMT device or an Edge server. Moving the data consumption closer to production will inherently improve privacy as the data is not exposed to other devices or parties. This entails improving the learning capacity of the edge so that information is derived from the data before the latter is discarded. Thus, the overall IoMT system will expose the minimum data and information required for each system component to operate efficiently.
- *Enforcing standardisation across the IoMT stack.* New protocols, standards and access policies are required to provide IoMT developers with the appropriate tools to protect privacy. The current landscape is fragmented and gives a considerable amount of freedom to vendors and developers who apply privacy protection as a matter of afterthought or as a matter of company ethics. Technical committees and policy makers need to devise appropriate guidance for the industry to ensure wide adoption and compliance. In the case of IoMT we argue that access control will be of paramount importance given the variable nature of the stakeholders involved in any IoMT application (e.g., patient, primary and secondary care, insurance). Similarly, data trust models that

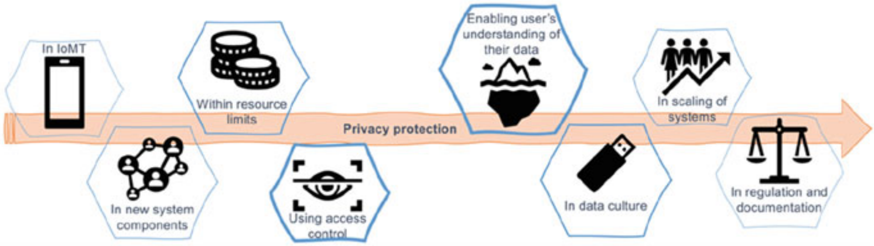


Fig. 11.3 Challenges in introducing privacy protection to the IoMT system stack beyond technology including the human and regulatory aspects

incentivise privacy protection and data sharing policies specifically developed for IoMT are in high demand.

- *Changing corporate and user culture*. One of the most difficult and non-technical challenges in establishing privacy is changing cultures [25]. This challenge requires a multidisciplinary community of experts, policy makers and stakeholders to collectively address the issue. This challenge is closely linked to the issues of standardisation, but it goes beyond them as presented in Fig. 11.3.

11.3.3 Network Infrastructure

As discussed in the introduction, the infrastructure is a major enabler for the wider adoption of IoMT. However, unreliable/unavailable communications is a significant concern affecting latency in many IoT applications [26]. Installing networked infrastructure in rural areas is a challenge even for developed countries such as the UK where much of northern Scotland remails off the network. At the same time new methodologies are actively investigated to support big data transfer over the infrastructure such as the one presented in [27]. In LMICs the issue is aggravated further. As a result latency tolerant measures are often used to enable access to the network when and if it becomes reachable, but also support operations when offline; e.g. the delay tolerant work presented in [1]. Porting intelligence to the edge of the network is one possible direction for research to overcome this challenge. On the other end of the spectrum research is focusing on providing connectivity to rural areas. A prime example is the introduction of LoRa technology to enable connectivity coverage in large un-obstructed areas (e.g., farmland) but at the cost of bandwidth.

In urban settings where connectivity is not an issue, the availability of bandwidth and the latency is a larger concern for IoMT applications such as a smart ambulance. In this case research challenges are identified in sustainably transmitting information. Reducing the power transmission introduces issues in transmission error rates. At this front, new methods such as the Network Coding (NC) technique provide several algorithms to reduce the transmission power and improve the Bit Error Rate

(BER) and Packet Error Rate (PER) [27–32]. Similarly methods such as Multi-Service Streams Network [33] and the Orthogonal Frequency-Division Multiplexing (OFDM) [34] could divert IoMT traffic away from the Internet thus protecting sensitive data from exposure to general cyber-threats. OFDM could be applied to various wireless communication standards and compensate for the lack of time-invariant multi-path channel effects while improving the doppler shift. However, it remains an open challenge to standardise approaches suitable for medical applications such as IoMT particularly in the event of streaming large files (e.g., video).

11.3.4 Edge Computing

As briefly discussed above, edge computing can be an opportunity to address several aspects of security, privacy and network infrastructure availability. However, it introduces new challenges. As IoT devices become more capable, it is a natural selection to move computation to the edge [35]. Resource allocation in edge servers is another possible solution [36]. Edge processing has been demonstrated in safety critical applications such as operational condition monitoring of rotating machinery [37–45]. In medical applications where trust is paramount existing IoT solutions fail to address resilience [46] which introduces challenges in trusting the data generated. The authors in [46] propose resilient authentication and authorisation for IoT using edge computing. According to the authors the edge computing architecture is ideally situated to improve availability of service as well as resilience. This is maintained even when grater Interment connectivity is not available and when the network is suffering a denial-of-service attack. Exploring further the issues of availability under attack, the authors propose a method for secure migration to ensure continued authentication and authorisation. One could argue that their approach could further develop to support secure migration of access control in the case of IoMT in the future. Most importantly the authors propose a formalised migration policy construction based on integer linear programming and protocols for preparing and executing the secure migration. More research in this direction could pave the way for better standards in both security and privacy within IoMT applications and Edge service provisioning.

With all its merits, edge computing introduces interesting problems of distributed resource allocation, service provisioning, opportunistic resource reuse as well as privacy and security. Many of these concepts have been explored in the sense of the cloud or large datacentres. But those systems tend to rely on uncapped power, common network infrastructure from/to all the server nodes and access to vast storage both in memory and in permanent storage space. On the other hand, the edge is a new and not yet fully charted territory.

11.3.5 Federated Learning

Taking the opportunity of Edge computing one step further, the natural development for IoMT is to introduce intelligence. However, well documented issues exist in relation to the limitation of data available to any one IoMT device at a time. We could call this "IoMT tunnel vision". In this sense you could train a model in advance and deploy it on a number of IoMT devices. However, this does not allow the IoMT to learn from the dynamic environment around it. It is quite the missed opportunity. To explore the benefits of this opportunity, research has focused on exploring federated learning as a promising direction for IoMT. Early examples of ML libraries have emerged. Net IoT [47] demonstrates that ML inference on IoT devices is feasible in terms of computational and power budgets. To an extent training has also proven to be plausible though further research is required to adapt algorithms for the heterogeneous target IoMT. The future however is going to require accurate and trustworthy edge inference to enable federated and distributed IoT ML directly interfacing to the user. Thus, ML algorithms must be reconfigured to execute on local IoT devices stand-alone or federated and an orchestration method must be designed to enable wider learning and inference.

11.4 Advances in Secure Data Transfer and Provenance for Distributed Healthcare

As hinted through the earlier sections in this chapter edge computing and blockchain are some of the most prominent and disruptive technologies in the IoMT domain. In our view federated learning will be the next disruptive technology to emerge in this space once standards and policies have solidified for the first two. In this section we present an advanced IoMT system that uses edge computing and blockchain for management of healthcare data in aided remote diagnosis.

11.4.1 Exemplar State-of-the-Art IoMT

This IoMT system was presented in [1] and the system's architecture is presented in Fig. 11.4. The diagnostics IoMT utilised blockchain for the transmission of information between the different components of the system in a similar manner as Fig. 11.1. However, in this case the device (heater) does not generate or collect any data. As a result, there is no security or privacy threat introduced to the system by not including the device in the blockchain network. From the mobile phone layer and all the way to the cloud information is transferred through the blockchain network. The application relies on the characteristics of blockchain (immutability, consistency, high level of trust, endorsement) to ensure secure transfer but also provenance. These features are consistent with the requirements for trustworthy AI

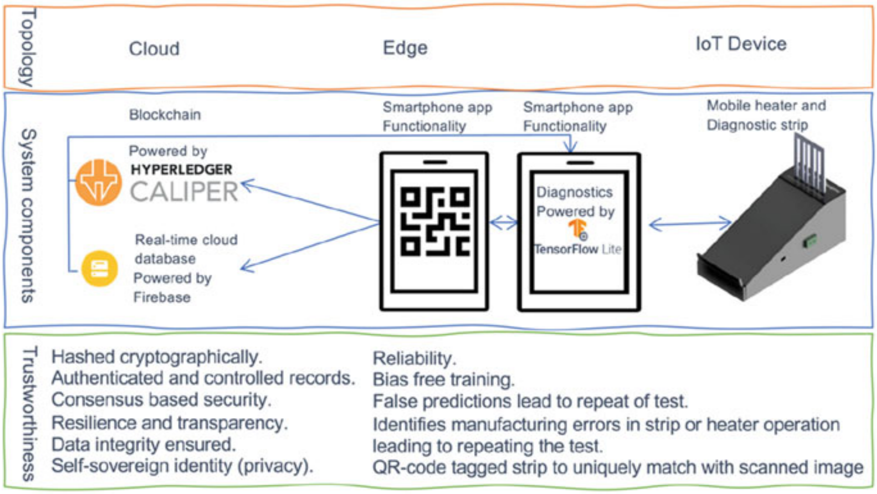


Fig. 11.4 Use of blockchain to improve security in both transmission, verification, and provenance of data for health and care applications. The system components presented here are based on a smartphone application for malaria diagnostics published in Ref. [1]

and *trustworthy* IoMT as analysed in Sect. 11.2. Also, it addresses several *Security challenges* as identified in Sect. 11.3.1.

Further through the use of anonymised patient identifiers the privacy preservation is achieved when data is in transit and when it resides in the database (*Privacy Challenges*, Sect. 11.3.2). The use of blockchain enables a delay tolerant networking approach where information is updated in the ledger as and when network access is possible (*Network Infrastructure Challenges*, Sect. 11.3.3). To achieve this, it deploys a trained deep neural network on the mobile phone application layer (*Edge Computing Challenges*, Sect. 11.3.4). The system is suitable for use in rural areas with low connectivity and low human-resource. As analysed in Fig. 11.4 the system meets several of the trustworthy AI principles by design.

A side effect of the improved data provenance is that this system can improve the record keeping as well as privacy preservation which previously used to be a manual process between the rural districts and the urban centres. The result is a highly accurate and reliable tool that improves the collection, interpretation, and reporting of diagnostic results for malaria. Further research could elaborate on the use of federated learning to dynamically retrain the deep neural network with new diagnostic images collected in the field. However, this remains future work.

11.4.2 Analysis on Security

The exemplar system is currently connected to a generic rea-time database for long term storage and data warehousing. A more advanced option would be a disturbed platform specifically designed for medical data such as DHIS2 [48]. Such a platform could bring additional benefits to the overall system. Firstly, it is a well-accepted platform for the permanent storage of medical data and comes with a variety of analytical tools for health and care management at the level of county wide planning. The platform is currently adopted by 73 countries (LMICs mostly) and reaches up to 30% of the world's population in terms of governmental healthcare system data management. The added security benefits are sandboxing and sandboxing and break-glass options for accessing records, security based on identification, separation of attributes, as well as encryption both in transit and in storage [49]. These are all well-established security practices in web-based systems.

However, using standard web platform technologies comes with several drawbacks [50–52]. Firstly, there is a risk of exposure to all known attacks and particularly integrity related vulnerabilities. In the simplest form the DHIS2 but also the database used by the exemplar system suffer from single point of failure. Being cloud based also introduces data ownership and privacy issues. This issue is avoided by removing private information from the data that resides in the exemplar system. However, this is not always possible in a state-wide application of generic IoMT. Another issue is the lack of safety around medical image records leading to privacy threats. Other approaches such stenography could be used to secure such data in the future; an example of such an application suitably developed for IoMT is presented in [53]. Also, such systems are design with a directional flow of information in mind. This makes it difficult for downstream sharing of information leading to repeated diagnostic tests in our exemplar IoMT scenario. Most importantly though, data integrity is subject to human error or power cuts (e.g., changes to records, no consensus on accepting this change, single point of entry). Finally, network infrastructure challenges are still a barrier in the use of platforms such as DHIS2.

Combining DHIS2 with blockchain could provide added security and privacy benefits along with extended data provenance. The benefits include data being hashed cryptographically, authenticated, and controlled over a distributed network of nodes. Consensus based security can address integrity challenges. The network has no single point of failure, introducing resilience, and transparency to protect against malware or manipulative actions. Self-sovereign identity for privacy protection is possible. Secure sharing of records between healthcare systems thus becomes much easier. However, blockchain introduces challenges in terms of power consumption and bandwidth consumption. Furthermore, it is not designed to be a permanent data warehousing system component. Peer to peer file sharing could address bandwidth issues and improve security against distributed denial of service attacks. However further research is required in this area.

The exemplar IoMT approach improves the security of collecting and propagating information related to diagnostics, improves image data security, and can be easily interfaced with DHIS2. This interfacing action will make the data vulnerable to all known DHIS2 threats once the data is stored in the DHIS2 database. However, integrity could be dynamically checked with the blockchain network and corrective actions could be taken to maintain integrity even after a security breach on DHIS2. Additionally a watermarking approach could be used to verify the integrity of data such as the one presented in [54]. On the other hand, the exemplar IoMT system's images were kept on traditional cloud storage while blockchain only keeps the URLs to the images. This introduces the same security and privacy threats for images which may be used to reveal patient information. The Interplanetary File System (IPFS) could potentially provide a solution for better protection to the image data [50].

11.4.3 Analysis on Provenance

Traditional databases (e.g. SQL) do not inherently provide mechanisms for managing provenance data (or metadata) [55]. Blockchain on the other hand inherently enriches data with provenance metadata to track changes and attest those against authorised and endorsed user access privileges. This information relates to the source of the data, any changes that happened in the data pipeline when the data was transferred over the network and any processing related to the use of this data. This is ensured as recorded transactions on the ledger are signed by the device/entity generating the data and/or interacting with the data [15]. Furthermore, data provenance can be instrumental in understanding cyber-attacks, gathering information on ongoing attacks and performing forensic analytics [56].

Particularly for IoMT applications there are several challenges in implementing complete data provenance. Firstly there is a need for continuous compliance with regulation for data privacy and secondly there is the potential for large meta-data being generated for every piece of patient generated data [56]. There is a balance to be gained from combining provenance auditing and machine learning to reduce the amount of information recorded. Provenance auditing could be instrumental in keeping abreast with policy and regulation as it evolves. On the other hand, edge computing could support machine learning applications for the optimisation of provenance metadata storage required for the compliance needed in each application.

11.5 Discussion

This chapter examined the state of secure data transfer and provenance in state-of-the-art distributed healthcare. Within this context the chapter specifically analysed the state of IoMT as the most promising research domain in distributed healthcare. The introduction of IoMT is demonstrating significant benefits for health and care particularly in LMICs and rural areas. With a low cost and high availability of latency tolerant networking methods, IoMT is expected to become highly proliferate in High and LMICs alike.

However, existing approaches lack in trustworthiness. This is evident in the extended governance, industrial and academic effort in establishing policies and guidelines for trust and ethics in the context of AI. The chapter discussed the significant research needed to address those same issues in the vastly distributed and fragment IoMT offering. Particularly the open challenges in security and privacy were analysed in respect to the application domain. Then the implications of network infrastructure were discussed. Finally, edge computing and federated learning were proposed as opportunities for advancing IoMT while improving security, privacy, and network tolerance. At the same time blockchain was presented as an opportunity to improve security and data provenance beyond the capabilities of conventional methods.

State-of-the-art still suffers from potential issues such as the security of the IoT plane and the drawbacks of the blockchain integration in IoMT systems. The exemplar system reviewed paves the way for more secure and privacy preserving IoMT. However, there are several open challenges in the direction of federated learning and data provenance as well as optimising blockchain for IoMT applications. Research should focus on improving security and integration of IoMT systems particularly when discussing vastly connected systems involving several software parts and communication methods. Work is required in the direction of federated learning and provenance for those vast systems as information travels through a variety of networks processed by various users.

11.6 Conclusion and Future Work

To demonstrate the effect of edge computing, intelligence at the edge and blockchain a state-of-the-art system was reviewed. The system met several of the trustworthiness goals through the appropriate design of AI models, the use of blockchain and the appropriate data anonymisation approaches. This example demonstrates how the adherence to AI design ethics and principles can improve trustworthiness while the use of appropriate data transfer and provenance methods can establish trust across the data pipeline. This example demonstrates how appropriate design methods can be successfully used in the development of IoMT systems that support trust and ethics by design. In future developments for IoMT these methods should be used as a starting point. Further research is required in the areas of improving security and integration of IoMT in existing systems but also in the direction of federated learning and provenance to support trustworthy and reliable distributed healthcare.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Guo, X., Khalid, M. A., Domingos, I., Michala, A. L., Adriko, M., Rowell, C., Ajambo, D., Garrett, A., Kar, S., Yan, X., Reboud, J., Tukahebwa, E. M., & Cooper, J. M. (2021). Smartphone-based DNA diagnostics for malaria diagnostics using deep learning for local decision support and blockchain technology for security. *Nature Electronics, 4*, 615–624.
2. The "World malaria report 2019" at a glance. Retrieved July 8, 2021, from https://www.who.int/news-room/feature-stories/detail/world-malaria-report-2019.
3. Holst, C., Sukums, F., Radovanovic, D., Ngowi, B., Noll, J., & Winkler, A. S. (2020). Sub-Saharan Africa—The new breeding ground for global digital health. *The Lancet Digital Health, 2*, e160–e162. https://doi.org/10.1016/S2589-7500(20)30027-3
4. Xiong, Z., Zhang, Y., Luong, N. C., Niyato, D., Wang, P., & Guizani, N. (2020). The best of both worlds: A general architecture for data Management in Blockchain-enabled Internet-of-Things. *IEEE Network, 34*, 166–173. https://doi.org/10.1109/MNET.001.1900095
5. *Ethics and governance of artificial intelligence for health*. Retrieved July 12, 2021, from https://www.who.int/publications-detail-redirect/9789240029200.
6. *Ethics guidelines for trustworthy AI | Shaping Europe's digital future*. Retrieved July 20, 2021, from https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai.
7. Responsible AI principles from Microsoft. Retrieved July 20, 2021, from https://www.microsoft.com/en-gb/ai/responsible-ai.
8. Vourganas, I., Stankovic, V., Stankovic, L., & Michala, A. L. (2020). Evaluation of home-based rehabilitation sensing systems with respect to standardised clinical tests. *Sensors, 20*, 26. https://doi.org/10.3390/s20010026
9. Vourganas, I., Stankovic, V., Stankovic, L., & Kerr, A. (2019). Factors that contribute to the use of stroke self-rehabilitation technologies: A review. *JMIR Biomedical Engineering, 4*, e13732. https://doi.org/10.2196/13732
10. Vourganas, I., Stankovic, V., & Stankovic, L. (2021). Individualised Responsible artificial intelligence for home-based rehabilitation. *Sensors, 21*, 2. https://doi.org/10.3390/s21010002
11. Data protection. In: *GOV.UK*. Retrieved July 12, 2021, from https://www.gov.uk/data-protection.
12. Bader, J., & Michala, A. L. (2021). Searchable encryption with access control in industrial Internet of Things (IIoT). *Wireless Communications and Mobile Computing, 2021*, e5555362. https://doi.org/10.1155/2021/5555362
13. Gebremichael, T., Ledwaba, L. P. I., Eldefrawy, M. H., Hancke, G. P., Pereira, N., Gidlund, M., & Akerberg, J. (2020). Security and privacy in the industrial Internet of Things: Current standards and future challenges. *IEEE Access, 8*, 152351–152366. https://doi.org/10.1109/ACCESS.2020.3016937
14. Alcaraz, C. (2019). *Security and privacy trends in the industrial Internet of Things*. Springer.
15. Sengupta, J., Ruj, S., & Das Bit, S. (2020). A comprehensive survey on attacks, security issues and Blockchain solutions for IoT and IIoT. *Journal of Network and Computer Applications, 149*, 102481. https://doi.org/10.1016/j.jnca.2019.102481
16. Xu, H., Zhang, L., Onireti, O., Fang, Y., Buchanan, W. B., & Imran, M. A. (2020). *BeepTrace: Blockchain-enabled privacy-preserving contact tracing for COVID-19 pandemic and beyond*. IEEE.
17. Kumar, A., Abhishek, K., Bhushan, B., & Chakraborty, C. (2021). Secure access control for manufacturing sector with application of ethereum blockchain. *Peer-to-Peer Networking and Applications, 14*, 3058–3074. https://doi.org/10.1007/s12083-021-01108-3
18. Home. In: *DataSHIELD*. Retrieved July 13, 2021, from https://www.datashield.org/.
19. Dan Chia, W. M., Loong Keoh, S., Michala, A. L., & Goh, C. (2021). Real-time recursive risk assessment framework for autonomous vehicle operations. In *2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring)* (pp. 1–7). IEEE.

20. Blockchain: A panacea for healthcare cloud-based data security and privacy? | *IEEE Journals & Magazine* | IEEE Xplore. Retrieved July 21, 2021, from https://ieeexplore.ieee.org/abstract/document/8327543.
21. Farouk, A., Alahmadi, A., Ghose, S., & Mashatan, A. (2020). Blockchain platform for industrial healthcare: Vision and future opportunities. *Computer Communications, 154*, 223–235. https://doi.org/10.1016/j.comcom.2020.02.058
22. Vazirani, A. A., O'Donoghue, O., Brindley, D., & Meinert, E. (2020). Blockchain vehicles for efficient medical record management. *npj Digital Medicine, 3*, 1–5. https://doi.org/10.1038/s41746-019-0211-0
23. Cheng, X., Chen, F., Xie, D., Sun, H., & Huang, C. (2020). Design of a secure medical data sharing scheme based on blockchain. *Journal of Medical Systems, 44*, 52. https://doi.org/10.1007/s10916-019-1468-1
24. PETRAS. (2019). *Cybersecurity of the INTERNET of THINGS*.
25. *CloverDX The 8 most challenging data privacy issues (and How to Solve Them)*. Retrieved July 20, 2021, from https://www.cloverdx.com/blog/data-privacy-issues-and-how-to-solve-them.
26. Liu, X., Yu, J., Wang, J., & Gao, Y. (2020). Resource allocation with edge computing in IoT networks via machine learning. *IEEE Internet of Things Journal, 7*, 3415–3426. https://doi.org/10.1109/JIOT.2020.2970110
27. Attar, H., Stankovic, L., Alhihi, M., & Ameen, A. (2014). Deterministic network coding over long term evaluation advance communication system. In *2014 Fourth International Conference on Digital Information and Communication Technology and its Applications (DICTAP)* (pp. 56–61). IEEE.
28. Attar, H. H., Solyman, A. A. A., Khosravi, M. R., Qi, L., Alhihi, M., & Tavallali, P. (2021). Bit and packet error rate evaluations for half-cycle stage cooperation on 6G wireless networks. *Physical Communication, 44*, 101249. https://doi.org/10.1016/j.phycom.2020.101249
29. Attar, H., Alhihi, M., Zhao, B., & Stankovic, L. (2018). Network coding hard and soft decision behavior over the physical payer using PUMTC. In *2018 International Conference on Advances in Computing and Communication Engineering (ICACCE)* (pp. 471–474). IEEE.
30. Attar, H. (2017). Data combination over physical layer using network coding with PUM turbo codes. *Journal of Computer and Communications, 5*, 32–44. https://doi.org/10.4236/jcc.2017.56002
31. El-Hihi, M., Attar, H., Solyman, A., & Stankovic, L. (2016). Network coding cooperation performance analysis in wireless network over a lossy channel, M users and a destination scenario. *Communications and Network, 8*, 257–280. https://doi.org/10.4236/cn.2016.84023
32. Attar, H. (2016). Physical layer deterministic network coding using PUM turbo codes over AWGN Channel, N nodes through a Base Station scenario. *Communications and Network, 08*, 241. https://doi.org/10.4236/cn.2016.84022
33. Attar, H., Khosravi, M., Igorovich, S., Georgievna, K., & Alhihi, M. (2021). E-health communication system with multiservice data traffic evaluation based on a G/G/1 analysis method. *Current Signal Transduction Therapy, 16*(2), 115–121. https://doi.org/10.2174/1574362415666200224094706
34. Attar, H. H., Solyman, A. A. A., Mohamed, A.-E. F., Khosravi, M. R., Menon, V. G., Bashir, A. K., & Tavallali, P. (2020). Efficient equalisers for OFDM and DFrFT-OCDM multicarrier systems in mobile E-health video broadcasting with machine learning perspectives. *Physical Communication, 42*, 101173. https://doi.org/10.1016/j.phycom.2020.101173
35. Alhaizaey, Y., Singer, J., & Michala, A. L. (2021). Optimizing task allocation for edge micro-clusters in smart cities. In *2021 IEEE 22nd International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)* (pp. 341–347). IEEE.
36. Cano, J., White, D. R., Bordallo, A., McCreesh, C., Michala, A. L., Singer, J., & Nagarajan, V. (2018). Solving the task variant allocation problem in distributed robotics. *Autonomous Robots, 42*, 1477–1495. https://doi.org/10.1007/s10514-018-9742-5
37. Michala, A. L. (2018). *An edge processing solution development for vessel condition monitoring*. Ph.D., University of Strathclyde.

38. Michala, A. L., & Vourganas, I. (2017). A smart modular wireless system for condition monitoring data acquisition. In V. Bertram (Ed.), Hamburg, p. 14 p. Research output: Chapter in Book/Report/Conference proceeding › Conference contribution *Compit'17* (pp. 212–225). Volker Bertram.
39. Lazakis, I., Dikis, K., Michala, A. L., & Theotokatos, G. (2017). Advanced ship systems condition monitoring for enhanced inspection, maintenance and decision making in ship operations. *Transportation Research Procedia, 14*, 1679–1688.
40. Michala, A. L., & Lazakis, I. (2016). *Ship machinery and equipment wireless condition monitoring system* (pp. 63–69). University of Strathclyde Publishing, GBR.
41. Michala, A. L., Barltrop, N., Amirafshari, P., Lazakis, I., & Theotokatos, G. (2016). *An intelligent system for vessels structural reliability evaluation* (pp. 171–179). University of Strathclyde, GBR.
42. Dikis, K., Lazakis, I., Michala, A. L., Raptodimos, Y., & Theotokatos, G. (2016). In L. Walls, M. Revie, & T. Bedford (Eds.), *Dynamic risk and reliability assessment for ship machinery decision making* (pp. 685–692). CRC/Taylor & Francis Group, GBR.
43. Lazakis, I., Dikis, K., & Michala, A. L. (2016). *Condition monitoring for enhanced inspection, maintenance and decision making in ship operations*. University of Denmark (DTU).
44. Michala, A. L., Lazakis, I., Theotokatos, G., & Varelas, T. (2016). *Wireless condition monitoring for ship applications* (pp. 59–66). The Royal Institution of Naval Architects.
45. Michala, A. L., Lazakis, I., & Theotokatos, G. (2015). *Predictive maintenance decision support system for enhanced energy efficiency of ship machinery* (pp. 195–205). International Conference on Shipping in Changing Climates. GBR.
46. Kim, H., Kang, E., Broman, D., & Lee, E. A. (2020). Resilient authentication and authorization for the Internet of Things (IoT) using edge computing. *ACM Trans Internet Things, 1*, 4.1–4.27. https://doi.org/10.1145/3375837
47. *CamSoper. NET IoT Libraries documentation*. Retrieved July 12, 2021, from https://docs.microsoft.com/en-us/dotnet/iot/.
48. Home. In: *DHIS2*. Retrieved July 21, 2021, from https://dhis2.org/.
49. Almås, K. (2020). *Information security management of a DHIS2 implementation - exploring what is appropriate in a developing country*. Master thesis, University of Oslo
50. Kombe, C., Sam, A., Dida, M., & Finne, A. (2019). Blockchain technology in Sub-Saharan Africa: where does it fit in healthcare systems: A case of Tanzania. *Health Informatics Journal, 13*, 2.
51. Braa, J., & Sahay, S. (2017). The DHIS2 open source software platform: Evolution over time and space. In L. F. Celi (Ed.), *Global health informatics* (p. 451). The MIT Press.
52. Dehnavieh, R., Haghdoost, A., Khosravi, A., Hoseinabadi, F., Rahimi, H., Poursheikhali, A., Khajehpour, N., Khajeh, Z., Mirshekari, N., Hasani, M., Radmerikhi, S., Haghighi, H., Mehrolhassani, M. H., Kazemi, E., & Aghamohamadi, S. (2019). The district health information system (DHIS2): A literature review and meta-synthesis of its strengths and operational challenges based on the experiences of 11 countries. *The HIM Journal, 48*, 62–75. https://doi.org/10.1177/1833358318777713
53. Dhawan, S., Chakraborty, C., Frnda, J., Gupta, R., Rana, A. K., & Pani, S. K. (2021). SSII: Secured and high-quality steganography using intelligent hybrid optimization algorithms for IoT. *IEEE Access, 9*, 87563–87578. https://doi.org/10.1109/ACCESS.2021.3089357
54. Gupta, A. K., Chakraborty, C., & Gupta, B. (2021). Secure transmission of EEG data using watermarking algorithm for the detection of Epileptical seizures. *TS, 38*, 473–479. https://doi.org/10.18280/ts.380227
55. Gupta, A. (2009). Data provenance. In L. Liu & M. T. Özsu (Eds.), *Encyclopedia of database systems* (pp. 608–608). Springer US.
56. Alam, M. M., & Wang, W. (2021). A comprehensive survey on the state-of-the-art data provenance approaches for security enforcement. *JCS, 29*, 423–446. https://doi.org/10.3233/JCS-200108

Chapter 12
Blockchain Technology in Healthcare: Use Cases Study

Halima Mhamdi, Soufiene Ben Othman, Ahmed Zouinkhi, and Hedi Sakli

Abstract Blockchain technology is now regarded as one of the most interesting and possibly innovative technologies. It enables information to be stored and exchanged securely and transparently without the need for a centralized authority to regulate it. A few of the primary benefits of this technology is the atomicity of the stored data. Given its features, this technology has the potential to give answers to challenges encountered in a very sensitive sector, notably healthcare. The medical field is dealing with several issues that some are attempting to address today. The most important are the administration of medical records and the claims process, the acceleration of clinical and biomedical research, and the advancement of the biomedical and health data registry. The major challenge is the processing and analysis of patient records due to the large amount of data collected. The security of this data is another challenge to consider. Due to the high connectivity, these systems are prone to malicious attacks. In addition, it is difficult to ensure confidentiality due to the exchange of sensitive data. This chapter discusses the use of blockchain technology in healthcare sector. The purpose of this survey was to provide an overview of the features and concepts related to security requirements of blockchain in a healthcare system. It shows that this technology has a major role in terms of security of patient's medical data.

H. Mhamdi · A. Zouinkhi
MACS Research Laboratory, National Engineering School of Gabes, Gabes University, Gabes, Tunisia
e-mail: ahmed.zouinkhi@enig.rnu.tn

S. B. Othman
PRINCE Laboratory Research, ISITcom, Hammam Sousse, University of Sousse, Sousse, Tunisia

H. Sakli (✉)
MACS Research Laboratory, National Engineering School of Gabes, Gabes University, Gabes, Tunisia

EITA Consulting, Montesson, France
e-mail: hedi.s@eitaconsulting.fr

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_12

Keywords Blockchain · Smart healthcare · Secure data management · Internet of medical things · Electronic healthcare record · Drug supply chain · Clinical trials · Security · Privacy

12.1 Introduction

The Internet of Things (IoT) is described as a network of identifiable and unique components that interact even without human assistance via Internet connectivity [1]. This new idea encompasses numerous areas: energy [2], smart home [3], agriculture [4], healthcare [5–7], industry [8] and etc.

The incorporation of IoT in the healthcare field is fostering a new approach known as the Internet of Medical Things (IoMT). This term refers to a connected infrastructure of devices and software applications that can communicate with various IT systems to provide health-related services [9]. Telemonitoring for patients with chronic or long-term diseases is one instance of IoMT. This sort of therapy eliminates the need for patients to visit the hospital or doctor's office every time they have a medical concern or a change in their health, as well as inpatient wearable mHealth devices that can communicate data to nurses. Another example, in the pharmaceutical sector, is drug tracking. However, it is important to note that the healthcare sector faces many challenges. The major challenge is the processing and analysis of patient records due to the large amount of data collected. The security of this data is another challenge to consider. These systems are vulnerable to malicious assaults due of their high connection. Furthermore, due to the sharing of sensitive data, it is difficult to maintain privacy.

Healthcare sector faces many challenges. The first one is Patient records management. Currently, information is not shared between doctors, and the patient must carry over the reports of his previous consultations to each new specialist. This mission is more difficult for an uninformed patient who does not master the medical discussion and does not have a precise idea of the content of his file. With the rise of telemedicine, visits to the doctor are made through multiple channels, making it more difficult for healthcare professionals to update patients' medical records. Therefore, it will be vital for this industry to create a way to record and update medical records for both in-person and virtual visits. This means digitizing these records and sharing them, after patient consent, with healthcare professionals to be updated in real time. Clinical trial certification is another one. Clinical trials involving drugs are intended to establish or verify a certain amount of data. The sharing of this data including confidentiality, integrity, record keeping, and patient enrollment is often used by researchers in a secure manner. Sharing research between different scientists and organizations could lead to better and more rapid progress on specific topics. Also, the lack of drug traceability is another issue to which a distributed and public database could provide a start. Securing access to health data is a major issue in network-to-network data transmission. The dependence of IoMT applications and platforms on a centralized cloud puts security at risk.

Blockchain is a new technology that is gaining traction in a variety of industries and offers several benefits and prospects. Blockchain technology is characterized by the immutability of stored data, decentralization, and privacy. Integrated in the health sector, it helps to overcome the problems encountered in the latter.

The purpose of this chapter is to review the current literature on the challenges and approaches to security and privacy in Blockchain Healthcare applications. To provide the reader with the Blockchain necessary background for a better understanding of this area, we outline the various aspects of Blockchain technology, including basic concepts, features, smart contracts, and blockchain types. We also examine current academic chapters that make advantage of Blockchain in various fields. The study of the bibliography is in relation with security from 2018 to 2021. Then, an interest is devoted to the integration of blockchain technology in healthcare. We present existing applications around blockchain to increase healthcare security. Also, we give an overview of the solutions offered by researchers to secure patients' medical data.

The remainder of this chapter is organized as follows. In the second section we discuss the blockchain technology, its function mode, its characteristics as well as the smart contracts. Section 12.3 presents the application of this technology in the healthcare field. In Sect. 12.4, we present the solutions proposed by the researchers in this axis. Finally, we conclude the chapter in Sect. 12.5.

12.2 Fundamentals of Blockchain Technology

Machines and devices connect with each other without the use of intermediaries in a peer-to-peer network, resulting in a decentralized network known as Blockchain. It is in fact a set of connected nodes that share and record transactions. Each node in the network keeps a copy to avoid having a single point of failure. The data shared through the blockchain is structured in blocks that are linked together forming a distributed ledger (DLT). The security and immutability of this data is ensured through cryptographic functions. The concept of blockchain is introduced by Satoshi Nakamoto in 2008 [10].

Blockchain technology is mainly characterized by major elements: decentralized, transparent, autonomous, secure, and immutable [11, 12]. Blockchain is decentralized. It is a distributed database where data is stored in all nodes of the network. All nodes can manipulate access and update transactions simultaneously and without intermediary via a well-defined protocol. This data is not all held on a central intermediary's server, but instead is "distributed", i.e. hosted by each participant. Since their creation, the transactions in the blockchain are accessible by all users. But they are extended by cryptographic functions so that they cannot be modified. That is to say that the addition of transactions is allowed and not their modification or deletion. As in the Bitcoin network, all transactions are public and verifiable by everyone through a consensus mechanism, which will allow everyone to ensure that each participant owns the Bitcoins they are spending and that they are spending them only once. The transparent nature of blockchain could certainly prevent the modification or theft of this data. The blockchain corresponds to a history of transactions on which everyone agrees. This consensus on the sequencing of transactions solves the so-called "double spending" problem: A Bitcoin spent in one transaction cannot be spent a second time in a transaction that would later be broadcast on the network. The second transaction would be rejected by the network. Once recorded in the blockchain, it is impossible to delete or modify a transaction since there are several copies in different nodes of the network. Therefore, the blocks can be extended and not modified. This gives the blockchain a high level of security and makes it more complicated to attack the blocks of information. In the blockchain network, the handling of transactions is no longer concentrated in a central organization but is spread over all participants of the network. Transactions can be consulted and stored by each node and even transferred and updated. In this way, the blockchain functions autonomously without the intervention of a trusted third party and keeping the identity of the node anonymous and secure.

12.2.1 Blockchain Operations and Classifications

Once we begin the blockchain operating procedure, we must specify a transaction. This is the process by which Blockchain nodes exchange and share information. Transactions are really data exchanges between network members that are saved in files called blocks. These data are encrypted before being linked to the previous block to form a chain. Each time a transaction is added to the blockchain, it develops. Transactions must be checked and validated ahead of time.

The function process of blockchain transactions begins when someone B requests a transaction from A. The data requested by the other party B will form a new block and will be distributed on the different nodes of the blockchain network. In order to be transferred, the new block is verified and validated by the network nodes using cryptographic techniques. After being validated, it is added to the previous blocks in chronological order. The added block is chained in such a way that it cannot be modified or deleted. At the final stage, user B receives the transaction from A which ends successfully.

According to its characteristics and functionalities, the blockchain is classified into three categories: public blockchain, private blockchain and consortium blockchain [13]. In the public blockchain network, transactions are managed by all participants without central control organs. They have the right to consult and even modify the exchanged data. The use of consensus mechanism guarantees the security and immutability of this type of network. The most famous example of public blockchain is Ethereum and Bitcoin. In the private blockchain network only authorized participants can access it. The access is done by invitation from the entities controlling the network. Therefore, in order to carry out transactions, participants must request permission from third parties. This type of network is usually applied between companies of the same type. Hyperledger Fabric is an example of a private blockchain. The consortium blockchain is the fusion between the public and private blockchain. The reading and writing of transactions in this type is both allowed for some nodes and restricted for others. The consensus is the most noticeable distinction between the two systems. Instead of an open system in which anybody may validate blocks or a closed system in which only one entity appoints block producers, a consortium chain includes a number of equally powerful parties that serve as validators and producers at the same time. BigchainD B is an example of a consortium blockchain.

12.2.2 Smart Contracts and Ethereum Platform

The use of smart contracts and decentralized applications (DApp) is one of blockchain's most valuable assets. Their primary function is to facilitate the exchange of goods and services, as well as monetary transactions, without the need of a third-party authority.

Nick Szabo defines smart contracts in 1994 as "a computerized transaction protocol that performs the provisions of a contract" [14]. The smart contract performs transactions automatically, with no human intervention required. The information handled by the smart contract is transmitted via linked items and other measurement equipment. Miners in the blockchain examine the transactions [15, 16] and update them in order for them to be stored in the blockchain. Blockchain systems such as Ethereum are used to create smart contracts. This is the most promising blockchain platform. It can handle sophisticated bespoke smart contracts written in Turing-complete code. Solidity, a high-level programming language, is used to create smart contract code, which is subsequently translated into Ethereum Virtual Machine (EVM) byte code. In the EVM, the quantity of gas is the cost or execution fee for each transaction. This fee is calculated as follows:

$$Fee = gasPrice \times \min(gasLimit, gasUsed) \tag{12.1}$$

where *gasPrice* is the amount of Gwei, as a form of remuneration, received by the miners, *gasLimit* is the maximum gas amount to complete a transaction and *gasUsed* is defined depending on the storage and processing quantity for each transaction.

A decentralized application is an application deployed on blockchain and is generally based on smart contracts. It aims to improve the transparency and traceability of the collected information. Given the number of researchers and developers who are attracted to DApp, various sites gather statistics on the different DApp applications.

12.2.3 Blockchain Applications

Blockchain technology attracts the interest of several researchers in different fields. B. Bhushan et al. [17, 18] and Saxena et al. [19] presented an in-depth study on the combination of blockchain technology and IoT. They focused on IoT applications by ensuring security, confidentiality, and privacy in IoT systems. They also investigated the future challenges in this sector. Authors in their article [20], with the same aim guarantee security and confidentiality, have exposed the contribution of this technology in the design and development of smart city. Other researchers have exploited the use of blockchain in the supply chain [21, 22]. This use aims to solve the problem of reliability and access to manufacturer information. The proposed solution is based on the use of the Ethereum blockchain and the ERC20 interface. It guarantees data security and traceability as well as interoperability by reducing the cost and making exchanges automatic in the supply chain and manufacturing. Authors in [23] addressed the security and privacy issue in Internet of vehicle using blockchain. In addition, Halima et al. [24] exploited the decentralized feature to ensure communication between vehicles and service providers. To protect and secure the flow of financial data on mobile banking platforms, the authors in Ref. [25] propose architecture based on a multilevel authentication mechanism that produces a unique time-based password. This solution ensures the security and confidentiality of banking transactions.

To study the impact of blockchain technology in various sectors: Healthcare, smart cities, Internet of Vehicles, agriculture, ... in terms of security, statistics concerning articles published in this context are made. The queries used are “blockchain and security”, “blockchain and security and Healthcare”, “Blockchain and security and smart cities”, “Blockchain and security and Internet of Vehicles”... The data is collected from IEEE explore, Springer, Science Direct and MDPI, etc. databases from 2018 to 2021. Figure 12.1 depicts the number of articles by year

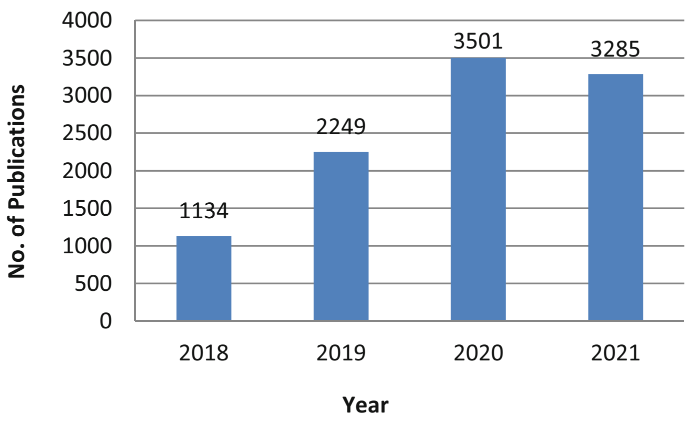


Fig. 12.1 Number of publications from 2018 to 2021

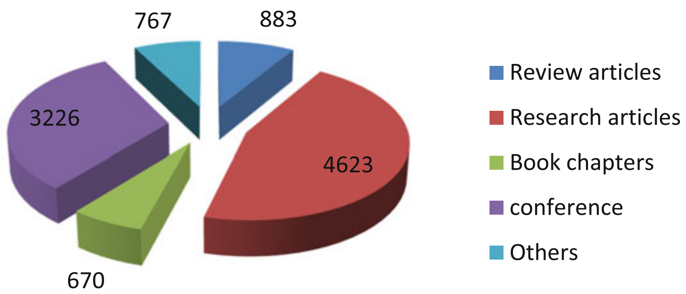
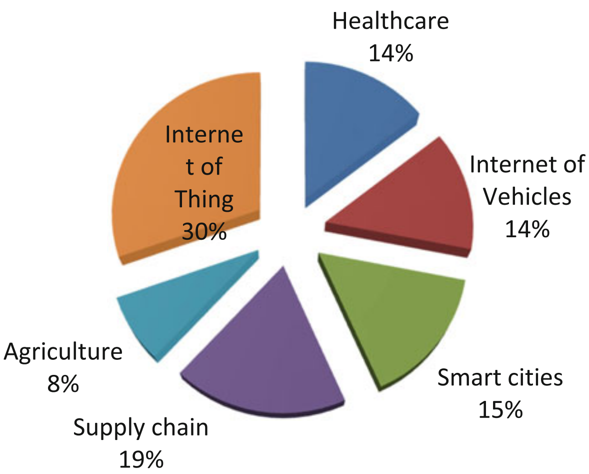


Fig. 12.2 Number of publications according to article type

Fig. 12.3 Distribution of publications according to application sector



during the last 4 years. We discovered about 10,169 publications in total. This number is growing more and more, which shows the interest of this technology in improving security in various sectors. As shown in Fig. 12.2, analyses made on the number of articles according to the type of publication show that research articles exceed 45% of the publications followed by conference papers of 31%.

We have reported the data from the evaluated publications regarding the implication of blockchain technology in the different sectors in Fig. 12.3. This graph reveals that the highest percentages of research articles were obtained in Internet of things, while the second-highest percentages of publications were obtained in supply chain then Healthcare and internet of Vehicles.

Figure 12.4 illustrates the numbers of published studies based on applicable disciplines and Blockchain roles in various applications, where the majority of articles are from Blockchain IoT and the second-highest number of articles cover supply chain applications. Healthcare sector the field of health is ranked as the third most important. These statistics are for articles published in 2021.

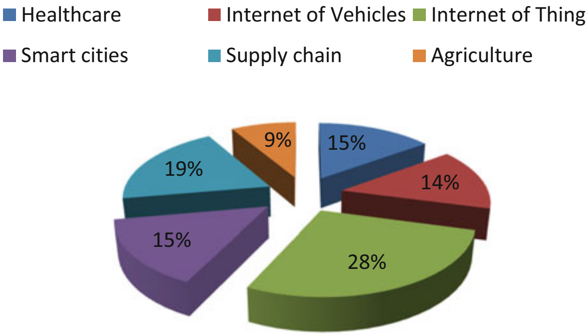


Fig. 12.4 Distribution publications according to application sector in 2021

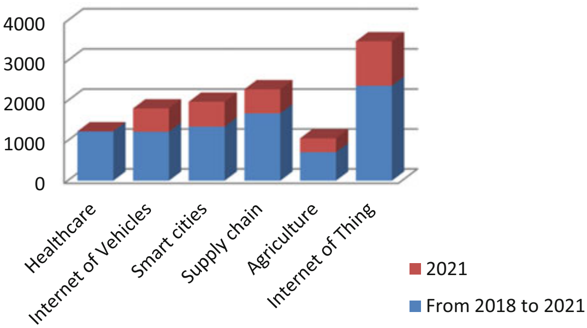


Fig. 12.5 Distribution Journal articles according to application sector

While Fig. 12.5 shows the number of publications by type of domain during the last 4 years compared to the year 2021. Taking the list of research publications, we can see that the Internet of Things still occupies the first place since it groups the other domains.

In the rest of this chapter, we will focus on the exploitation of blockchain technology in the health care sector. More precisely, how to use this new concept to secure medical data. We will expose the existing works in this context.

12.3 Blockchain for Smart Healthcare

Because of blockchain's potential and features, this technology is seen as a critical answer to challenges encountered in the Healthcare sector. It piques the curiosity of many healthcare experts. 7 out of 10 anticipate blockchain's major benefits to apply to clinical trials and medical records, and 6 out of 10 believe blockchain will enable them access new markets and new reliable and secure information [26]. The application of blockchain in the healthcare sector can be classified into many axes. The most relevant one is patient data management which includes electronic healthcare record sharing and access. Counterfeit drugs and pharmaceutical supply chain are the second axes in drug supply chain. Clinical trials are another use cases that need security and privacy manipulation. Table 12.1 presents a summary of the integration of blockchain technology in the healthcare field. It groups different use cases with various types of blockchain with the use of smart contracts.

Bakhtawar et al. [27] suggested a method to protect individuals from the Corona virus. The created architecture is built on blockchain technology and ANFIS (Adaptive Neuro-Fuzzy Interference System). The connection between these two ideas and the KNN (K Nearest Neighbor) method ensures patient privacy while increasing the detection probability of those infected with Covid19. The mobile application ensures the traceability of patient interactions through bluetooth, and the data acquired is kept on the cloud.

In Ref. [28], the authors proposed a platform named BiiMed. This solution aims at sharing the patient's electronic health record between different stakeholders. It ensures data integrity and interoperability thanks to the blockchain. The proposed architecture is composed of two parts: Health Information System and BiiMed blockchain. HIS consists in gathering, saving, and sharing medical data while the BiiMed platform manages the shared data. It is based on the Ethereum blockchain and the smart contract.

MedChain [29] is another platform that works on the same principle of sharing data by storing them immutably in the blockchain. In their work [30], test scenarios are designed and implemented. They are based on HyperLedger Fabric to examine various identification criteria in the health sector. The authors have exploited blockchain technology to ensure security, privacy and confidentiality of data. The health sector is a very sensitive area and therefore these criteria must be present in any application in this sector. Analyses made show that blockchain technology ensures authenticity by avoiding attacks through its encryption capacity. Moreover, and most importantly, access to patient medical data is controlled. Only authorized persons are able to consult this data. However, the private blockchain, HyperLedger Fabric, ensures the security, confidentiality and transparency of data for healthcare. These criteria can be extended to other blockchain platforms with performance evaluation as well as energy consumption while ensuring security.

The authors of Ref. [31] have proposed a system called MeDShare. This system allows the exchange of medical data and keeps electronic medical records secure. The participants in this system are hospitals, service providers and health research. They use medical data shared by MeDshare. Data confidentiality is ensured by a customized audit control. In the same sense of sharing medical information, the authors have developed the Medblock prototype [32] based on the blockchain. This prototype allows secure access to electronic medical records.

H. S. Z. Kazmi et al. [33] have exploited smart contracts to design a system for remote patient monitoring and alerting health specialists in case of emergency. This remote monitoring system guarantees the security and privacy of the patient through blockchain.

To solve the interoperability problem, authors [34] implemented a blockchain-based system. It allows patients to share their clinical data with healthcare providers. The patient has the right to choose the person with whom he shares his data. Access

Table 12.1 Summarized literature review

Problem addressed					
Uses Cases	Ref	Year	Framework	Smart contract	Contribution
Patient data management	[27]	2021	NM	No	- Share the patient's electronic health record between different stakeholders. - Ensures integrity, confidentiality and interoperability of the data shared - Resolved the problem of large-scale data management and sharing in an EHR system. - Remote monitoring system guarantees the security and privacy of the patient.
	[28]	2020	NM	Yes	
	[29]	2019	Ethereum		
	[30]	2021	Ethereum		
	[31]	2018	NM	No	
	[32]	2018	NM		
	[33]	2020	Proprietary		
	[34]	2019	NM		
Security and privacy in blockchain-healthcare	[35]	2018	NM	NM	- Allows the sharing of patient data by controlling the access to these sensitive data. - Ensure the security of private data. - Ensure the confidentiality of messages on the blockchain. - Provides access at different levels of granularity without the need for a public key infrastructure (PKI). - Ensures the integrity, security, and confidentiality of private patient data.
	[36]	2018	NM	NM	
	[37]	2017	NM	NM	
	[38]	2018	NM	NM	
	[39]	2018	NM	NM	
	[40]	2021	NM	Yes	
	[41]	2021	NM	NM	
Drug/pharmaceutical supply chain management	[42]	2020	NM	NM	- Product identification and tracking in pharmaceutical supply chains. - Maintain security, traceability, and visibility in the pharmaceutical supply chain. - Tracking of pharmaceutical products during distribution. - Monitor drug files to ensure the confidentiality, security and transparency of the management process and the sharing of the drug life cycle.
	[43]	2010	NM	Yes	
	[44]	2019	NM		
	[45]	2019	NM		
	[46]	2019	NM		
Clinical trial certification	[47, 48]	2019, 2018	Bitcoin	NM	- Avoid undesirable consequences of drug use. - Development of platforms and systems for collecting and sharing patient data in clinical trials. - Support the transparency of the data and documents retrieved during clinical research. - Ensure traceability of clinical data.
	[49]	2018	NM	NM	
	[50]	2017	NM	NM	
	[51]	2019	NM	NM	
	[52]	2021	Ethereum	Yes	

to the data in a secure way is ensured by the identification and authentication of the user. Once identified, they can access and update the patients' data.

The authors of [35] tackled the problem of security and patient privacy. They proposed a system based on the immutability and autonomy of the blockchain. This system allows the sharing of patient data by controlling the access to these sensitive data. Discrete wavelets transform and genetic algorithm are the basis of the proposed scheme.

To ensure the security of private data, the authors of Refs. [36, 37] proposed a key management scheme to ensure the confidentiality of messages on the blockchain. In the same context, Zhang and Poslad [38] suggest an access authorization model and scheme called Granular Access Authorization supporting Flexible Queries (GAA-FQ) using encryption and decryption algorithms. This scheme provides access at different levels of granularity without the need for a public key infrastructure (PKI).

The signature scheme proposed in Ref. [39] is a solution ensuring security and trust. Thanks to the attribute with multiple authorities, which is the backbone of this solution, the patient's public/private keys are not generated and shared.

The solution proposed by the authors [40] deals with contract automation in the healthcare supply chain. It brings together all parties involved in the purchasing process of medical products. The manufacturer, the distributor as well as the Group Purchasing Organization (GPO) and the healthcare provider interact with each other using smart contracts. For storage of large amounts of information, transactions and data exchange are stored in a distributed storage system such as Interplanetary File System (IPFS) or Filecoin. Then a link between Ethereum blockchain and the storage system is established in order to keep the data secure via cryptographic functions. Therefore, the result is a more secure, feasible and cost-minimizing automatic health supply chain management system.

The authors proposed [41] a system named "Internet-of-Healthcare Systems" (IoHCS). This system saves patient medical data on the distributed blockchain system. In this way, all participants: doctor, nurse or a member of the medical staff, can access the patient's electronic records in real time and securely. As illustrated in the following figure, the developed model is composed by six elements: Hospital Information system HIS, The Central Server, Web / Software Agents, Message Queuing Telemetry Transport (MQTT) Broker, Mobile Device Systems and blockchain. The components of the system work together to ensure the proper functioning of the process of access to the electronic medical record in a way that guarantees the security, confidentiality, and integrity of data.

The traceability of drugs and the fight against counterfeiting is another concrete case of blockchain and IoMT. According to the World Health Organization, 1 in 10 pharmaceutical products are counterfeit. This figure reaches 30% of medicines in developing countries, which represents a market of 200 billion dollars. Moreover 25 million counterfeit drugs are distributed on the Internet with a value of 43 million Euros [42].

Drug traceability is a very sensitive area that needs an urgent solution as it affects the lives of individuals. The use of blockchain technology brings advantages in this context especially in the tracking of pharmaceutical products during distribution. For this use case, the different supply chain actors are identified in the blockchain network. Pharmaceutical companies register their products with a unique identifier. Stores reselling the drugs or pharmacists could check upon receipt of stocks of drugs that they come from valid laboratories; the information related to each drug is updated in the blockchain each time.

Clauson et al. [43] present a detailed study on the application of blockchain technology in pharmaceutical supply chains. This study includes product identification and tracking as well as validity verification.

To manage medical data, the authors [44] proposed a decentralized application (Dapp) based on blockchain technology in particular Ethereum blockchain and smart contracts. The developed solution handles various medical cases including patient, doctor, pharmacies, laboratory and any other service provider. The application includes the management of medical prescriptions, tests and analysis results from the laboratory. The communication between the different actors of the system and the reimbursement of health care are also covered. The authors did not forget the cases of clinical trials and surgical procedure in their study. They used different smart contracts for each study case based on the consensus mechanism and a distributed file system (DFS). The cost of deploying smart contracts varies between the developed services. It depends on the number of actors in the platform and the complexity of the process required such as surgery and pediatrics.

In their article [45], authors exploit the notion of smart contracts and multi-agents ‘system. They propose a platform allowing the storage of transactions between the different actors of the system in the blockchain. The smart contracts ensure the management of these transactions.

To maintain security, traceability and visibility in the pharmaceutical supply chain, the authors [46] designed a private blockchain platform to fight drug counterfeiting. Similarly, a proof-of-concept application has been developed by Jamil et al. [47]. This platform consists of a web application whose role is to monitor drug files between doctors, patients, pharmacists, etc. in a decentralized manner. The smart contracts guarantee the confidentiality, security and transparency of the management process and the sharing of the drug life cycle.

In order to develop medical and biological insights, biomedical research called a clinical trial is done on humans. The objective of these clinical trials is to develop and verify a series of data. They allow, but are not limited to, demonstrating the efficacy, relevance and safety of a drug in relation to a disease. Indeed, the objective of these studies is to demonstrate causality between the favorable evolution of a disease and the taking of a specific treatment.

Several studies have exploited blockchain in clinical research to avoid undesirable consequences of drug use [48]. The characteristics of blockchain, notably its immutability, transparency, and decentralization, encourage the development of platforms and systems for collecting and sharing patient data in clinical trials [49].

The authors of [50] use the Ethereum Blockchain platform and smart contracts. The results found support the transparency of the data and documents retrieved during clinical research. In the same context, use of smart contracts and blockchain, Zhuang et al. [51, 52] presented an automatic and secure validation system for unmediated clinical trials via distributed databases.

12.4 Discussion and Solutions

Healthcare is not like any other field, and it must adhere to extremely stringent confidentiality regulations. To work in the healthcare sector, a blockchain must first and foremost provide data confidentiality and patient data privacy.

While handling health records, the patient, the physicians, the hospital, the pharmacists, or the medical analysis laboratories all seem to be sources of data that must be seen and shared in a straightforward manner. This is a common issue when a patient is admitted to the hospital. Health practitioners do not always have access to the patient's past and do not have comprehensive insight into the therapies he/she is receiving, the history of his/her disease, or the history of his/her family. The optimal solution would be to have a list of all the locations where a patient's medical data may be found so that it can be accessed promptly. With the patient's permission, this list would be available to any health practitioner who requested it. As a result, rather than having access just to the database of the establishment where one is, one might have access to all of the sources of information spread across the network's databases. Blockchain technology, in the form of a distributed and secure registry, presents precisely such a solution, allowing patients to not only see their data, but also manage access to it. As a result, we assure the interoperability of the platform utilized by the various health players using blockchain technology. Similarly, the emergency service can have access to patient data without requiring a request from the patient.

The MyHealthMyDataproject in Europe creates a health blockchain model that is consistent with medical privacy since no information is kept directly on the blockchain: only links to its information are saved. MyHealthMyData, a Siemens partner, strives to improve access to and exchange of health data in clinical studies. If a person wishes to delete his or her data from the blockchain, he or she will be able to break the links to his or her information, without having to break the chain. The different blocks will remain in place in the chain but will be permanently deactivated.

The characteristics of blockchain technology allow it to play a prominent role in the certification of clinical trials. Indeed, blockchain could be used to ensure that data is collected and exchanged, when necessary, while respecting patient privacy or proprietary information. The use of this technology allows saving the results found as well as the data and reports from the clinical research in an immutable way. This property overcomes the problems of changing results, thus reducing the incidence of fraud and error in clinical trial records. Blockchain brings transparency to clinical trials. Also, the pharmaceutical industry could use blockchain to authenticate clinical trial results.

Table 12.2 Security solutions in IoT smart healthcare systems

Reference	Problem addressed	Technology used	Solution
[53–56]	Patient data security and privacy	Multi-agents system and Blockchain	Use of patient agent-assisted end-to-end, patient centric agent, smart contracts and consensus algorithm.
[57–59]	Respect patients' privacy	Artificial intelligence	Develop protocol and deep learning-based algorithm to ensure patient privacy that authenticate
[60–63]	Data integrity and privacy of the patient	Lightweight cryptography	Propose an EPPDA scheme: An efficient and privacy-preserving data aggregation scheme with authentication for IoT-based healthcare applications.
[64–66]	Control and management of IoT data	Software defined networking	Combine SDN with data generated by smart healthcare applications to improve the flexibility and intelligence of IoT supervision and control.

To overcome gaps in secure patients' healthcare data, many solutions are proposed in the literature. Table 12.2 summarizes this several works.

Authors in [53–56] suggest the use of Multi-agents system with blockchain. In this solution, autonomous agents can execute action in place of users. For constructing secure intelligent healthcare systems, Smart agents are used with smart contracts to combine Blockchain technology with Body Area Sensor Networks (BASN). Smart contracts implemented on the Blockchain may automatically analyze health data based on threshold levels and store transaction logs in the Blockchain's immutable ledger to provide direction regarding for nurses or doctors. Nevertheless, nothing is known about the archival management of medical records, the security and privacy of the patient end-devices, and processing organization for the Blockchain in present IoT eHealth and Blockchain research. Authors in [54] suggested a Patient Agent-assisted End-to-End decentralized Blockchain-enabled eHealth architecture. By combining Blockchain, machine learning, and artificial intelligence technologies. The agent can handle the issues highlighted by combining wireless body sensors with Blockchain. Other solutions [55] consist of developing Patient Centric Agent (PCA) based on consensus algorithm. It maintains the patient's safety and privacy. It also identifies the streaming data storage and security requirements.

Other researchers are using artificial intelligence (AI), in particular machine learning (ML), to ensure security and privacy in the smart healthcare. In their article [57], the authors have gone over the key applications and systems where AI and IoT are being advocated for a safer, more accurate, and predictive healthcare system. The protocol defined by Gope et al. [58] allows to respect patients' privacy by authenticating IoT devices. Security is provided against machine learning or modeling attacks. Using a deep learning-based algorithm, authors [59] create an IoT-based automated noninvasive patient pain detection/monitoring system. To monitor patient pain, the proposed system does not require any wearable bothersome sensing devices, line-of-sight cameras, or any specialized/constrained surroundings.

Many approaches based on Cryptography were built to detect and block attacks in the healthcare application using IoT. Several security schemes to protect healthcare systems based-IoT using Cryptographic solutions are available in the literature [60–63].

In the literature, there are several security approaches for IoT-based healthcare systems that use Software Defined Networking (SDN) [64–66]. SDN allows healthcare businesses to benefit from virtualization, resulting in greater network agility and lower total cost of ownership. SDN delivers security benefits as a result of its architecture. Because the SDN controller can view all network data at the same time, it's simpler to identify unusual behavior in intruder-generated network traffic. Rather of waiting for an operating system or application software update for manufacturer-proprietary equipment, once a new threat has been detected, operators can quickly build new software to analyze and mitigate the risk.

12.5 Conclusion

This chapter presents a state of the art on the impact of blockchain technology in the healthcare sector. The most relevant applications in this area are electronic patient record sharing, and pharmaceutical tracking, clinical trial, and security in healthcare. Blockchain brings security, integrity, and transparency to the healthcare field. Despite the promising offers of blockchain in terms of confidentiality and efficiency, there is a lack of realization of solutions proposed by researchers. It is therefore necessary to carry out an important upstream work of data digitization, process automation, staff education and regulatory supervision.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Farooq, M., Waseem, M., Mazhar, S., et al. (2015). A review on internet of things (IoT). *International Journal of Computers and Applications, 113*(1), 36–54.
2. Zouinkhi, A., Ayadi, H., Val, T., Boussaid, B., & Abdelkrim, M. N. (2020). Auto-management of energy in IoT networks. *International Journal of Communication System, 33*(1), e4168.

3. Malcheand, T., & Maheshwary, P. (2017). Internet of things (IoT) for building smart home system. In *Proceedings of the 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, India* (pp. 65–70). IEEE.
4. Minbo, L., Zhu, Z., & Guangyu, C. (2013). Informat ion service system of agriculture IoT. *Automatika, 54*(4), 415–426.
5. George, G., & Thampi, S. M. (2019). Securing smart healthcare systems from vulnerability exploitation. In G. Wang, A. El Saddik, X. Lai, G. MartInez Perez, & K. K. Choo (Eds.), *Smart city and informatization. iSCI* (Communications in computer and information science) (Vol. 1122). Springer.
6. Almalki, F. A., Othman, S. B., Almalki, F. A., & Sakli, H. (2021). EERP-DPM: Energy efficient routing protocol using dual prediction model for healthcare using IoT. *Journal of Healthcare Engineering, 15*, 9988038.
7. Almalki, F. A., & Othman, S. B. (2021). EPPDA: An efficient and privacy-preserving data aggregation scheme with authentication and authorization for IoT-based healthcare applications. *Wireless Communications and Mobile Computing, 2021*, 5594159.
8. Trab, S., Bajic, E., Zouinkhi, A., Abdelkrim, M. N., & Chekir, H. (2018). RFID IoT-enabled warehouse for safety management using product class-based storage and potential fields methods. *International Journal of Embedded Systems, 10*(1), 71–88.
9. Mohd Aman, A. H., Hassan, W. H., Sameen, S., et al. (2021). IoMT amid COVID-19 pandemic: Application, architecture, technology, and security. *Journal of Network and Computer Applications, 174*, 102886.
10. Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. Retrieved from https://bitcoin.org/bitcoin.pdf.
11. Tasca, P., & Tessone, C. J. *A taxonomy of blockchain technologies: Principles of identification and classification* (p. 4). Ledger. https://doi.org/10.5195/ledger.2019.140
12. Manpreet, K., Mohammad, Z. K., Shikha, G., Abdulfattah, N., Chinmay, C., & Subhendu, K. P. (2021). MBCP: Performance analysis of large scale mainstream Blockchain consensus protocols. *IEEE Access, 9*, 1–14. https://doi.org/10.1109/ACCESS.2021.3085187
13. Hong-Ning, D., Zibin, Z., & Zhang, Y. (2019). Blockchain for Internet of Things: A survey. *IEEE Internet of Things Journal, 6*(5), 8076–8094.
14. Szabo, N. (1997). Smart contracts: Formalizing and securing relationships on public networks. *First Monday, 2*, 9–1.
15. Wang, S., Yuan, Y., Wang, X., Li, J., & Qin, R. (2018). *An overview of smart contract: Architecture, applications, and future trends* (pp. 108–113). IEEE.
16. Riabi, I., Ayed, H. K. B., & Saidane, L. A. (2019). A survey on Blockchain based access control for internet of things. In *15th International Wireless Communications & Mobile Computing Conference (IWCMC)* (pp. 502–507). Tangier.
17. Bhushan, B., Sahoo, C., Sinha, P., & Khamparia, A. (2020). *Unification of Blockchain and Internet of Things (BIoT): Requirements, working model, challenges and future directions*. Wireless Networks. https://doi.org/10.1007/s11276-020-02445-6
18. Bhushan, B., Sinha, P., Sagayam, K. M., & J, A. (2021). Untangling blockchain technology: A survey on state of the art, security threats, privacy services, applications and future research directions. *Computers & Electrical Engineering, 90*, 106897. https://doi.org/10.1016/j.compeleceng.2020.106897
19. Saxena, S., Bhushan, B., & Ahad, M. A. (2021). Blockchain based solutions to secure IoT: Background, integration trends and a way forward. *Journal of Network and Computer Applications, 181*(5), 103050. https://doi.org/10.1016/j.jnca.2021.10305
20. Haque, A. K., Bhushan, B., & Dhiman, G. (2021). *Conceptualizing smart city applications: Requirements, architecture, security issues, and emerging trends*. Expert Systems. https://doi.org/10.1111/exsy.12753
21. Ajay, K., Kumar, A., Bharat, B., & Chinmay, C. (2021., [SCI, IF 2.79]). Secure access control for manufacturing sector with application of Ethereum blockchain. *Peer-to-Peer Networking and Applications, 14*, 3058–3074. https://doi.org/10.1007/s12083-021-01108-3

22. Hong-Ning, D., Zibin, Z., & Zhang, Y. (2019). Blockchain for Internet of Things: A survey. *IEEE Internet of Things Journal, 6*(5), 8076–8094.
23. Ramaguru, R., Sindhu, M., & Sethumadhavan, M. (2019). Blockchain for the internet of vehicles. In M. Singh, P. Gupta, V. Tyagi, J. Flusser, T. Ören, & R. Kashyap (Eds.), *Advances in computing and data sciences. ICACDS* (Communications in computer and information science) (Vol. 1045). Springer.
24. Mhamdi, H., Zouinkhi, A., & Sakli, H. (2020). Multi-agents system of vehicle services based on Blockchain. In *20th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA)* (pp. 291–296). Monastir.
25. Joseph, B. A., Chinmay, C., & Sakinat, O. F. (2021). A secured transaction based on Blockchain architecture in Mobile banking platform. *International Journal of Internet Technology and Secured Transactions, 2021*, 1–12. https://doi.org/10.1504/IJITST.2021.10039177
26. IBM Institute for Business Value. In *Healthcare rallies for blockchains*. IBM. https://www.ibm.com/downloads/cas/BBRQK3WY
27. Bakhtawar, A., Abdul, R. J., Chinmay, C., Jamel, N., Saira, R., & Muhammad, R. (2021). Blockchain and ANFIS empowered IoMT application for privacy preserved contact tracing in COVID-19 pandemic. *Personal and Ubiquitous Computing, 2021*, 1–17. https://doi.org/10.1007/s00779-021-01596-3
28. Jabbar, R., Fetais, N., Krichen, M., & Barkaoui, K. (2020). Blockchain technology for healthcare: Enhancing shared electronic health record interoperability and integrity. In *2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT)* (pp. 310–317). IEEE.
29. Bingqing, S., Guo, J., & Yang, Y. (2019). MedChain: Efficient healthcare data sharing via Blockchain. *Applied Sciences, 9*(6), 1207.
30. Antwi, M. S., Adnane, A., Ahmad, F., Hussain, R., Rehman, M. H. u., & Kerrache, C. A. (2021). The case of HyperLedger fabric as a blockchain solution for healthcare applications. *Blockchain: Research and Applications, 2*(1), 100012. https://doi.org/10.1016/j.bcra.2021.100012
31. Yang, Y., et al. (2018). Medshare: A novel hybrid cloud for medical resource sharing among autonomous healthcare providers. *IEEE Access, 6*, 46949–46961.
32. Fan, K., et al. (2018). Medblock: Efficient and secure medical data sharing via blockchain. *Journal of Medical Systems, 42*(8), 136.
33. Syeda, K., Faiza, N., Sahrish, M., et al. (2020). In L. Barolli et al. (Eds.), *Trusted remote patient monitoring using blockchain-based smart contracts* (BWCCA 2019, LNNS) (Vol. 97, pp. 765–776). Springer Nature.
34. Ullah Khan, A., Shahid, A., Tariq, F., et al. (2020). In L. Barolli et al. (Eds.), *Enhanced decentralized management of patient-driven interoperability based on blockchain* (BWCCA 2019, LNNS) (Vol. 97, pp. 815–827). Springer Nature.
35. Hussein, A. F., Kumar, N. A., Ramirez-Gonzalez, G., Abdulhay, E., Tavares, J. M. R. S., & de Albuquerque, V. H. C. (2018). A medical records managing and securing blockchain based system supported by a genetic algorithm and discrete wavelet transform. *Cognitive Systems Research, 52*, 1–11.
36. Zhao, H., Bai, P., Peng, Y., & Xu, R. (2018). Efficient key management scheme for health blockchain. *CAAI Transactions on Intelligence Technology, 3*, 114–118.
37. Zhao, H., Zhang, Y., Peng, Y., & Xu, R. (2017, March 22–24). Lightweight backup and efficient recovery scheme for health blockchain keys. In *Proceedings of the 2017 IEEE 13th International Symposium on Autonomous Decentralized System (ISADS), Bangkok, Thailand* (pp. 229–234). IEEE.
38. Zhang, X., & Poslad, S. (2018, May 20–24). Blockchain support for flexible queries with granular access control to Electronic Medical Records (EMR). In *Proceedings of the 2018 IEEE International Conference on Communications (ICC), Kansas City, MO, USA*.

39. Guo, R., Shi, H., Zhao, Q., & Zheng, D. (2018). Secure attribute-based signature scheme with multiple authorities for Blockchain in electronic health records systems. *IEEE Access, 6*, 11676–11686. https://doi.org/10.1109/ACCESS.2018.2801266
40. Omar, I. A., Jayaraman, R., Debe, M. S., Salah, K., Yaqoob, I., & Omar, M. (2021). Automating procurement contracts in the healthcare supply chain using Blockchain smart contracts. *IEEE Access, 9*, 37397–37409. https://doi.org/10.1109/ACCESS.2021.3062471
41. Yongjoh, S., So-In, C., Kompunt, P., Muneesawang, P., & Morien, R. I. *Development of an internet-of-healthcare system using blockchain*. IEEE Access. https://doi.org/10.1109/ACCESS.2021.3103443
42. du LEEM, R. (2017). *Contrefaçon de médicaments, une atteinte à la santépublique*. Leem, juin. http://www.leem.org/sites/default/files/DP-contrefacon-06-07-2017.pdf
43. Clauson, A., Breeden, A., Davidson, C., & Mackey, K. *Leveraging blockchain technology to enhance supply chain management in healthcare: An exploration of challenges and opportunities in the health supply chain*. Blockchain in Healthcare Today™. ISSN 2573-8240. https://doi.org/10.30953/bhty.v1.20
44. Khatoon, A. (2020). A Blockchain-based smart contract system for healthcare management. *Electronics, 9*(1), 94. https://doi.org/10.3390/electronics9010094
45. Casado-Vara, R., González Briones, A., Prieto, J., & Corchado Rodríguez, J. (2019, June). Smart contract for monitoring and control of logistics activities: Pharmaceutical utilities case study. In *Advances in intelligent systems and computing*. IEEE.
46. Raj, R., Rai, N., & Agarwal, S. (2019). Anticounterfeiting in pharmaceutical supply chain by establishing proof of ownership. In *TENCON 2019–2019 IEEE Region 10 Conference (TENCON)* (pp. 1572–1577). IEEE.
47. Jamil, F., Hang, L., Kim, K., & Kim, D. (2019). A novel medical blockchain model for drug supply chain integrity management in a smart hospital. *Electronics, 8*(5), 505.
48. Radanović, I., & Likić, R. (2018). Opportunities for use of blockchain technology in medicine. *Applied Health Economics and Health Policy, 16*, 583–590. https://doi.org/10.1007/s40258-018-0412-8
49. Roman-Belmonte, J. M., De la Corte-Rodriguez, H., Rodriguez-Merchan, E. C. C., la Corte-Rodriguez, H., & Carlos Rodriguez-Merchan, E. (2018). How Blockchain technology can change medicine. *Postgraduate Medicine, 130*, 420–427.
50. Mytis-Gkometh, P., Efraimidis, P. S., Kaldoudi, E., & Drosatos, G. (2017). Notarization of knowledge retrieval from biomedical repositories using Blockchain technology. In *IFMBE Proceedings* (Vol. 66, pp. 69–73). Springer Nature.
51. Zhuang, Y., Sheets, L. R., Shae, Z., Chen, Y. W., Tsai, J. J. P., & Shyu, C. R. (2019). Applying Blockchain technology to enhance clinical trial recruitment. *AMIA Annual Symposium Proceedings AMIA Symposium., 2019*, 1276–1285.
52. Zhuang, Y., Sheets, L., Gao, X., Shen, Y., Shae, Z. Y., Tsai, J. J. P., & Shyu, C. R. (2021 January 25). Development of A blockchain framework for virtual clinical trials. *AMIA Annual Symposium Proceedings, 2020*, 1412–1420.
53. Cha, S.-C., Chen, J.-F., Chunhua, S., & Yeh, K.-H. (2018). A blockchain connected gateway for ble-based devices in the internet of things. *IEEE Access, 6*, 24639–24649.
54. Uddin, M. A., Stranieri, A., Gondal, I., & Balasubramanian, V. (2020). Blockchain leveraged decentralized iot ehealth framework. *Internet of Things, 9*, 100159.
55. Uddin, M. A., Stranieri, A., Gondal, I., & Balasubramanian, V. (2019). Blockchain leveraged task migration in body area sensor networks. In *25th Asia-Pacific Conference on Communications (APCC)* (Vol. 2019, pp. 177–184). IEEE.
56. Uddin, M. A., Stranieri, A., Gondal, I., & Balasubramanian, V. (2020). Dynamically recommending repositories for health data: A machine learning model. In *Proceedings of the Australasian Computer Science Week Multiconference* (pp. 1–10). IEEE.
57. Bharadwaj, H. K., et al. (2021). A review on the role of machine learning in enabling IoT based healthcare applications. *IEEE Access, 9*, 38859–38890. https://doi.org/10.1109/ACCESS.2021.3059858

58. Gope, P., Sikdar, B., & Millwood, O. A scalable protocol level approach to prevent machine learning attacks on PUF-based authentication mechanisms for internet-of-medical-things. In *IEEE Transactions on Industrial Informatics*. IEEE. https://doi.org/10.1109/TII.2021.3096048
59. I. Ahmed, G. Jeon and F. Piccialli, "A deep-learning-based smart healthcare system for patient's discomfort detection at the edge of internet of things," in *IEEE Internet of Things Journal*, vol. 8, 13, pp. 10318–10326, 2021, doi: https://doi.org/10.1109/JIOT.2021.3052067.
60. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). *BIFM: Big-data driven intelligent forecasting model for COVID-19* (pp. 1–13). IEEE Access. https://doi.org/10.1109/ACCESS.2021.3094658
61. Almalki, F. A., & Soufiene, B. O. (2021). EPPDA: An efficient and privacy-preserving data aggregation scheme with authentication and authorization for IoT-based healthcare applications. *Wireless Communications and Mobile Computing, 2021*, 5594159., 18 pages. https://doi.org/10.1155/2021/5594159
62. Almalki, F. A., Othman, S. B., Almalki, F. A., & Sakli, H. (2021). EERP-DPM: Energy efficient routing protocol using dual prediction model for healthcare using IoT. *Journal of Healthcare Engineering, 2021*, 9988038., 15 pages. https://doi.org/10.1155/2021/9988038
63. Soufiene, B. O., Bahattab, A. A., Trad, A., & Youssef, H. (2020). PEERP: An priority-based energy-efficient routing protocol for reliable data transmission in healthcare using the IoT. *Procedia Computer Science, 175*, 373–378. https://doi.org/10.1016/j.procs.2020.07.053
64. Wang, T., & Chen, H. (2021). A lightweight SDN fingerprint attack defense mechanism based on probabilistic scrambling and controller dynamic scheduling strategies. *Security and Communication Networks, 2021*, 6688489., 23 pages. https://doi.org/10.1155/2021/6688489
65. Ahvar, E., Ahvar, S., Raza, S. M., Manuel Sanchez Vilchez, J., & Lee, G. M. (2021). Next generation of SDN in cloud-fog for 5G and beyond-enabled applications: Opportunities and challenges. *Network, 1*, 28–49. https://doi.org/10.3390/network1010004
66. Li, Y., Su, X., Ding, A. Y., Lindgren, A., Liu, X., Prehofer, C., Riekki, J., Rahmani, R., Tarkoma, S., & Hui, P. (2020). Enhancing the internet of things with knowledge-driven software-defined networking technology: Future perspectives. *Sensors, 20*, 3459. https://doi.org/10.3390/s20123459

Chapter 13
Integrating Artificial Intelligence and Blockchain for Enabling a Trusted Ecosystem for Healthcare Sector

V. S. Anoop and S. Asharaf

Abstract The advances in the information technology and communication technologies have fueled the digitization process in almost all sectors. Healthcare is one of such sectors where we could witness a rapid paradigm shift for the last couple of years. The major share of medical data that are generated from sources such as patient health records, clinical trials, patient-generated data such as forum posts, and social network data. There are several advantages due to this digitization but at the same time, it poses several challenges as well. One major challenge is on the storage and efficient retrieval of the digital healthcare data and another one is to capture the data in such a way that the sensitive medical data will not be tampered with. Thus, building a credible and trustworthy ecosystem for efficiently capturing and storing sensitive healthcare data is the need of the hour in the healthcare sector. Exponential technologies such as Artificial Intelligence (AI) and Blockchain are being used to develop innovative healthcare applications and solutions to tackle the issues mentioned. The credible data capturing infrastructure that is introduced with the famous currency, Bitcoin, now changing the way various industries and business function. The tamper-proof nature of blockchain can store the data that no one can erase but with the consent of the patient and a machine learning model trained on this data may have several potential applications in healthcare. This chapter proposes a new framework for building a trusted data management platform for the healthcare domain using blockchain that can be integrated with artificial intelligence techniques to build machine learning models. The authors believe that such a model will be useful to build several semantic knowledge discovery applications in the healthcare sector. This chapter will also discuss the future research dimensions combining AI and blockchain for enabling a trusted healthcare ecosystem.

V. S. Anoop (✉)
Kerala Blockchain Academy, Kerala University of Digital Sciences, Innovation and Technology, Thiruvananthapuram, India
e-mail: anoop.vs@iiitmk.ac.in

S. Asharaf
Kerala University of Digital Sciences, Innovation and Technology, Thiruvananthapuram, India
e-mail: asharaf.s@duk.ac.in

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_13

Keywords Healthcare · Artificial intelligence · Blockchain technology · Technological innovations · Decentralized data management · Trusted artificial intelligence · Machine learning · Transparency

13.1 Introduction

The current healthcare sector is undergoing a rapid paradigm shift for the last couple of years with the adoption of digitization techniques. The major share of medical data that are generated from sources such as patient health records, clinical trials, and also, patient-generated data such as discussion forum posts and social medical data. There are several advantages due to digitization but at the same time, it poses several challenges as well. One of the major challenges is the efficient storage and retrieval of the digital healthcare data and another challenge is to capture and process the data in such a way that the sensitive medical data will not be tampered with. Thus, building a credible and trustworthy ecosystem that efficiently captures and storing sensitive healthcare data is the need of the hour in the healthcare sector. Exponential technologies such as Artificial Intelligence (AI) and Blockchain are being used to develop innovative healthcare applications and solutions to tackle the issues mentioned.

The credible data capturing infrastructure that is introduced with the famous cryptocurrency, Bitcoin, is now changing the way various industries and businesses function. Healthcare is one of the sectors that find several use cases that can be developed using Blockchain but the benefits are multifold when combining with other technologies such as artificial intelligence and the internet of things. The tamper-proof nature of blockchain makes it an ideal technology for healthcare, where the data recorded once cannot be erased. Such invaluable data that are captured in the system can be used to train machine learning models that can have several potential applications in the healthcare sector. The benefits will be more when combined with AI and IoT, for example, the sensor data from wearable devices may be captured in a blockchain, and the same data can be used for monitoring and predicting patient health status. The Healthcare domain is one of the most critical sectors where prompt decision-making is required and that should be backed by relevant but trustworthy data. While blockchain technology provides security and privacy on sensitive patient data, artificial intelligence technologies can leverage useful insights and build prediction models on it. According to a recent study, 55–65% of healthcare applications will have blockchain components by 2025 and the same trend may be followed in the coming years as well. It is estimated that blockchain will bring disruptions in several areas in healthcare such as the medical supply chain, health record maintenance, clinical trial management, and data security on the internet of medical things. Smart contracts that are self-executing digital codes can enable patient anonymity and can also record the data in a decentralized ledger in an unbiased manner. Combining artificial intelligence and blockchain would bring innovative solutions for solving many pain problems that are prevalent in the healthcare industry. The proposed chapter is an attempt to combine the best of both the world for enabling the notion of trust in the healthcare sector. This chapter proposes a new framework for building a trusted data management platform for the healthcare domain using blockchain that can be integrated with artificial intelligence techniques to build credible and unbiased machine learning models. The authors strongly believe that such models will be highly useful to build several semantic knowledge discovery applications in the healthcare sector. This chapter will also discuss the future research dimensions combining AI and blockchain for enabling a trusted healthcare ecosystem. The major contributions of this chapter are outlined below:

(a) This chapter discusses the potential of artificial intelligence and blockchain technologies for the healthcare domain
(b) This chapter shows how blockchain and artificial intelligence can be combined for enabling the notion of trust in a decentralized manner.
(c) A thorough literature analysis has been provided that critically examined the use of AI and Blockchain in the healthcare sector.
(d) A new framework for establishing a trusted ecosystem for the healthcare sector is proposed in this chapter.
(e) Some future research dimensions on the applications of AI and Blockchain for building innovative applications in the healthcare sector are also discussed in this chapter.

The remainder of this chapter is organized as follows: In Sect. 13.2, some of the very recent and prominent approaches that use blockchain and artificial intelligence in healthcare data are discussed. Section 13.3 discusses the proposed framework that combines blockchain and artificial intelligence for building a trusted ecosystem for healthcare. In Sect. 13.4, the authors discuss the details of the experiment conducted along with the challenges faced for the implementation of the system. In Sect. 13.5, the authors conclude the chapter and discuss some of the future research dimensions.

13.2 Background and Related Literature

There are several approaches reported in the recent past on using exponential technologies to improve the processes in the healthcare sector and many of them are on integrating artificial intelligence and blockchain technology. While the former will be used for better prediction of diseases and timely intervention on many challenges faced by the healthcare professionals, the latter can record the data in a tamper-proof and credible manner. This will bring in the notion of trust and anonymity in the medical data but still can be used for leveraging machine learning models for better healthcare services. This section discusses the basics of blockchain technology and also details some of the recent but prominent approaches reported in the literature on using artificial intelligence and blockchain in the healthcare domain.

Blockchain is a distributed ledger technology with added capabilities such as anonymity, security, and tamper-proof nature, that was introduced first as a data

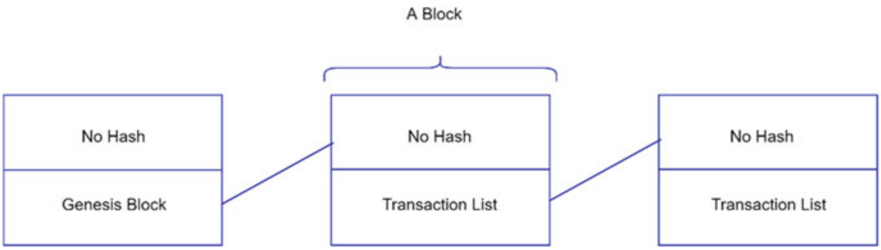


Fig. 13.1 Structural organization of a Blockchain

capturing mechanism of the famous cryptocurrency - Bitcoin [1]. This decentralized ledger can bring in the notion of trust to the mathematically verifiable platform from the organizations where the centrality was the enabler for trust in the past. This forms a transparent infrastructure where multiple parties can collaborate and perform transactions without the intervention of a trusted third party. Each participant (node) in this network infrastructure will have their updated copies of the ledger and the transactions are updated in the same near-real-time manner.

The activities such as ledger keeping, record replication, and transaction commit are managed by well-developed consensus algorithms. The first application of such an immutable and tamper-proof ledger was Bitcoin, which was proposed by Satoshi Nakamoto, where anonymous transactions of the cryptocurrency were possible. The immutability here was enabled by an efficient hashing technique and consensus mechanism that makes sure that every participant in the network will have a single version of the truth and the same state of the network. A high-level structure of a Blockchain is shown in Fig. 13.1.

A block in a blockchain is a collection of transactions, the hash of the previous block, and optionally the nonce of the validating peer. A nonce is nothing but a uniquely identifying piece of information pointing to each transaction. In the case of public blockchains such as Bitcoin and Ethereum, the nonce can simply be understood as a guessing number to solve the cryptographic puzzle and this will be done by miners. Every finalized block of transactions holds the hash of the previous block and this will be the underlying principle for enabling immutability in the blockchain. If any of the members in a blockchain network attempts to tamper with the data, the hash generated from the malicious node will be different from other peers in the network and this can be tracked. Having said the basic properties of blockchain technology, based on the way it functions, the networks can be mainly classified into public blockchains, private blockchains, and consortium blockchains. Public blockchains are open to anyone and membership services are not required for joining the network. Anyone who has a computer or even a mobile device can be a part of this network and does not require any personal details to be a part of the blockchain. Any node (the participating element in the network) can see the transaction details and also take part in the consensus mechanism to determine which transactions get added to the Blockchain. There are many public blockchain platforms out of which Bitcoin and Ethereum are widely popular. On the other hand, private blockchains are managed and administered by an individual or an organization and the entry is restricted. Only registered members or those who have gone through an authentication check such as know your customer (KYC) can gain access to the private blockchain.

There are specially privileged nodes such as transaction endorsers and validators who will have rights for consensus and other network administration activities. Ethereum private networks are examples of private blockchains. On the other hand, Consortium blockchains are blockchains managed by a group of institutions that own a pre-selected number of nodes. These blockchains are partially decentralized [2] and one of the major examples is Corda decentralized ledger technology. For an enterprise application, to manage the privacy and confidentiality of the data and transaction, industries prefer customizable, access permissions, resource-effective Blockchain implementation. This led to the development of permissioned Blockchain [2–7] e.g.: Hyperledger Fabric, Hyperledger Sawtooth, etc.

13.2.1 Artificial Intelligence in Healthcare

Artificial intelligence plays a crucial role in redefining the healthcare sector as many challenges can be addressed by AI. There are several approaches and techniques reported in the HealthTech literature with varying degrees of success. Some of those notable and prominent approaches are discussed in this section. The chances and challenges of artificial intelligence in healthcare have been presented in a recent article by Manne et al. [8]. The authors have conducted a study on analyzing the implications of artificial intelligence on managing the healthcare sector. They have conducted a literature review on AI models in different sectors of healthcare like Dermatology, Radiology, Drug design, etc. The conflicting roles for humans in learning health systems and artificial intelligence-enabled healthcare is reported in an article by Kasperbauer [9]. The author pointed out that the goals of learning health systems and artificial intelligence in medicine overlap in many ways. At the same time, they diverge as well, for example, the learning health system focuses on enhancing physician-patient relationships but artificial intelligence is trying to enable a physician-less ecosystem in healthcare. The core idea of this chapter is that points of conflict may require a reconsideration of the role of humans in medical decision-making as it is unclear to what extent artificial intelligence helps in the clinical decision-making process [9]. An interesting article that discusses machine learning and artificial intelligence safety, the effectiveness and explainability of the same in healthcare was reported very recently [10]. While the machine learning and AI models are treated as a “black box”, the explainability of the models is very important in healthcare. This facilitates the need for regulatory frameworks to enable the explainability in models that use healthcare data. The opportunities and challenges of artificial intelligence-based technologies in the healthcare industry were discussed in an article published by DonHee Lee and Seong No Yoon [11]. This study analyzed the applications of artificial intelligence in healthcare and highlighted that major hospitals are heavily using AI-powered systems to augment medical staff and also for providing personalized healthcare services to patients. At the same time, the study also pointed out that the full-fledged implementation needs careful planning and more regulatory frameworks that involve multiple stakeholder buying.

Healthcare communication plays a significant role in tactfully translating and disseminating information to support and educate patients and the public. Siddique et al. [12] highlighted some of the prominent applications of artificial intelligence and machine learning in healthcare communications such as health education to the patients, cancer therapy, and medical imaging. They have concluded that artificial intelligence can significantly reduce the cost for healthcare operations and the same trend will continue to grow in the coming years as well. When we discuss artificial intelligence-based systems in healthcare systems, safety plays a crucial role. Since we are dealing with the highly sensitive data of the patients, this needs to be given utmost care. A safety controlling framework that attempts to reduce the risk of potential healthcare-related incidents is developed by Devahli et al. [13]. The proposed framework may act as a checklist for those organizations where AI-based models are being developed or implemented to assist healthcare activities.

Artificial intelligence and machine learning will have a high positive impact in the healthcare sector but the risks associated with the same will also be noted. The major risk factor in implementing artificial intelligence in healthcare is ethics and bias. Sunarti et al. highlighted the applications of artificial intelligence in the healthcare sector and also many of the risks and challenges associated with the implementation of the same [14]. There are numerous applications and use cases for AI and ML that can bring in multifold disruptions in the healthcare sector, but the privacy concerns of the patients and anonymity of the data are holding us back from many implementations. This has led to the exploration of explainable artificial intelligence [15] to address the challenge of treating machine learning models as a "black box" and attempts to bring in the notion of accountability in the process. Gerke et al. [16] have discussed the ethical and legal issues and challenges of artificial intelligence-driven healthcare and also suggestions to deal with the same.

Priyanka et al. proposed various technological aspects and solutions using supervised and unsupervised machine learning techniques that enable continuous health monitoring with physiological parameters [17]. The authors have demonstrated their COVID-19 detection with the Gaussian mixture model-universal background model (GMM-UBM) technique using the voice signal. Their proposed system achieved performance in terms of areas under receiver operating characteristic (ROC) curves in the range of 60–67%. A chapter that explored various studies reported in the literature that uses big data analytics in the healthcare domain along with the big data tools and techniques was reported by Chinmay et al. [18]. This chapter is highly useful for healthcare enthusiasts and professionals and can be well-utilized by health practitioners and researchers to explore the area of big data analytics in medical science in the direction of disease prediction, drug suggestion, treatment effectiveness, and online health monitoring, to name a few [18]. From the recent articles and methods reported in the HealthTech literature, it is highly evident that artificial intelligence and machine learning techniques continue to play a vital role in assisting clinical decision-making processes. At the same time, several concerns are connected with the ethical considerations for the implementation of such systems. With the support of well-defined legal frameworks and regulations, many of these challenges can be eliminated.

13.2.2 Blockchain in Healthcare

Introduced as a credible data capturing mechanism for the most celebrated cryptocurrency, Bitcoin, this immutable and tamper-proof decentralized technology redefines the way businesses and organizations work. The Healthcare sector is no exception as such a decentralized ledger can solve many challenges faced by healthcare. The recent years witnessed the development of several blockchain proofs-of-concept to tackle many use-cases in the healthcare domain. In this section, we outline some of the recent approaches reported in the literature on using blockchain technology for healthcare. Hussien et al. [19] addressed the gap between the healthcare industry and blockchain technology by evaluating the state-of-the-art. This comprehensive review not only discussed the previous approaches but also highlighted the security and privacy aspect of blockchain by taking telecare medicine information systems and E-health as case studies. Implementing a technology that is still treated to be in its infancy stage may raise several questions on the application side. Blockchain technology may not work in isolation but can enable the notion of trust in several scenarios when integrated with technologies such as artificial intelligence and the internet of things. Balasubramanian et al. proposed a readiness assessment framework for blockchain adoption taking healthcare as a case study [20]. The framework applied to the healthcare sector in the United Arab Emirates shows the multifaceted significance of government readiness in driving blockchain initiatives.

Privacy preservation is highly important when dealing with sensitive medical data as any tampering with the data may lead to the violation of the privacy of a patient. A privacy-preserving blockchain framework for healthcare data that leverages both on-chain and off-chain capabilities is proposed by Miyachi et al. [21]. The proposed framework is patient-centric and priority is given to preserving patient data to liberate healthcare data. Identity management is one of the use-cases that has several applications in many domains such as government, education, and other citizen services. Healthcare is one such area where the identity of the patient is very important. Creating a single identity and mapping all the associated data about a patient to the same identity has several advantages. Such a patient-centric mechanism gives the data sharing consent management privileges to the patient and the patient can choose which data needs to be shared with whom. Shuaib et al. proposed a self-sovereign identity management mechanism for healthcare that is powered by blockchain technology [22]. If properly implemented, such a self-sovereign identity-linked health record may eliminate several challenges associated with a patient's identity.

Like other technologies, blockchain may not exist in isolation. The full potential of the technology can be leveraged when combined with technologies such as artificial intelligence and the internet of things. The need for securely capturing data from sensors that are part of patient wearables is highly necessary. Specially designed blockchain solutions can perform this where patient data can be captured in a tamper-proof manner. Banotra et al. discussed the use of blockchain and the internet of things for securing data in healthcare systems [23]. In such cases, appropriate access control mechanisms need to be implemented where the interference of third-party services needs to be eliminated. Randhir Kumar et al. proposed a scalable and secure access control policy for healthcare systems using blockchain and enhanced Bell–LaPadula model [24]. The authors have implemented the proposed model using Hyperledger Fabric and showed the potential of the proposed approach for a scalable access control mechanism. Electronic health record management system is one of the crucial components of the healthcare sector and now the same is digitized in the majority of the countries. Blockchain-based electronic health record systems solve many challenges associated with the current centralized way of processing. In this connection, a blockchain-based electronic health record management system was proposed by Chelladurai et al. [25]. Another notable work in this direction to use blockchain for EHR management was reported by Tanwar et al. [26]. The authors stated that improved and credible healthcare records management will solve many issues in the multi-party environment where various stakeholders such as insurance agencies and governments.

The benefits of implementing blockchain technology in the healthcare sector are multifold but at the same time, it poses several challenges and risks associated with it. A scoping review on the benefits and threats of using blockchain technology in the healthcare sector is highlighted by Israa Abu-elezz et al. [27]. The authors highlighted that the challenges related to security, privacy, scalability, and interoperability are still obvious vulnerabilities of blockchain in healthcare and we may need to investigate the social acceptance of blockchain implementations in healthcare [27]. Recently, several approaches have been introduced that attempt to integrate artificial intelligence and blockchain for building systems and solutions for healthcare. Mashamba-Thompson et al. proposed an approach that combines blockchain and artificial intelligence for COVID-19 self-testing [28]. The authors claim that the overburdened healthcare system can use the proposed approach for better tracing and testing of the patients, but there need to be several ethical and legal considerations before implementing the same. There are other related approaches like combining artificial neural networks and blockchain [29] for better managing healthcare applications.

An Internet of Things (IoT) model that may be used for contract tracing, that preserves anonymity was proposed by Lalit et al. [30]. The authors highlighted that the current measures for infection control and tracing do not include animals and other moving objects. In this context, they have designed and presented a privacy anonymous IoT model powered by Blockchain technology. The authors have claimed that their model will make it easy to identify the clusters of infection contacts that may help for mass isolation while preserving individual privacy [30]. Another notable recent work that discussed an approach for privacy-preserved contact tracing Internet of Medical Things (IoMT) application using Blockchain and ANFIS was reported by Aslam et al. [31]. The authors have developed a mobile application that will work on Bluetooth-enabled smartphones that preserves the anonymity of the patients while tracing their contacts. Their smartphone application backed by an Adaptive Neuro-Fuzzy Interference System (ANFIS) was capable enough to check the COVID-19 status after analyzing the symptoms quickly [31].

From the careful and systematic analysis of the state-of-the-art, it is highly evident that artificial intelligence and blockchain technology plays a crucial role in healthcare and preferably towards building a resilient healthcare ecosystem. But several ethical and legal factors need to be considered for reaping the full benefits for the same. In the next section, the authors propose a framework that combines artificial intelligence and blockchain technology for establishing trust in the healthcare sector.

13.3 Artificial Intelligence and Blockchain for Building a Trusted Ecosystem for Healthcare

Enabling trust is highly inevitable in the healthcare sector. The traditional centralized systems use the credibility of the organizations to build trust but that poses several risks on quantifying the level of trust. Blockchain technology, which was introduced as a credible data capturing and management platform as the backend infrastructure of Bitcoin, has the potential to demolish the notion of centrality. This platform can bring the notion of trust from the organization to the platform, which can be easily quantified using well-defined mathematical and cryptographic techniques. The healthcare sector generates a humongous amount of sensitive data and it is highly necessary to capture, manage, and share in a credible and trustworthy manner. In the current healthcare ecosystem, the processes are organization-centric and the patient data is captured and consumed by the organization without the consent of patients. While the agreement stands between the patient and the healthcare providers, there is no surety that this data will be manipulated and shared with any third parties. This poses several risks as the data contain personally identifiable information that can be a threat to any individual.

Building a trusted, decentralized artificial intelligence ecosystem is highly necessary for a sensitive sector such as healthcare. Such an ecosystem, while capturing the data can record the consent of the patients and the same can be recorded in a tamper-proof, immutable ledger. The various stakeholders of the ecosystem can access the patient data only with consent from the patient in a highly informed manner. The organizations can build machine learning models with the data that are shared by an individual (patient) for the purpose explicitly stated in the consent that

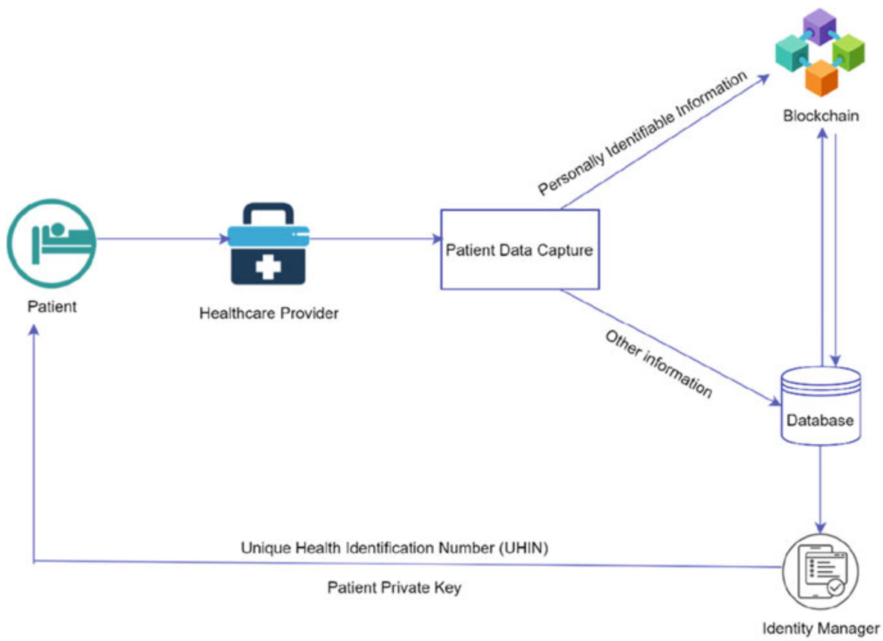


Fig. 13.2 Proposed blockchain-enabled framework for secure patient data management

is digitally signed and executed using smart contracts. This will smoothen the transition from a healthcare provider-centric mechanism to a patient-centric mechanism and can implement better data management and sharing strategies. Also, data protection and regulation rules that are in place (for example, GDPR of European Union) or in the process of framing can use such a framework for capturing the citizen data in a most trusted and efficient fashion. The proposed framework in this chapter is a contribution towards building such an ecosystem.

The proposed framework for secure data capture and management is shown in Fig. 13.2. When the patient approaches a healthcare provider, there will be a data capturing mechanism in which all required information about the patient will be recorded. This may contain both personally identifiable information (PII) and Non-personally Identifiable Information (Non-PII). While the PII is very sensitive, this needs to be captured and recorded in a tamper-proof manner. Once the data segregation process is completed, the PII information will be stored in a blockchain and the non-sensitive information will be sent to a secure database. At the same time, the identity manager module attached with this framework will generate a Unique Health Identification Number (UHIN) along with a private key, and both this information will be communicated with the patient. On the high-level process flow diagram shown in Fig. 13.2, the blockchain module can capture the consent from the patient while registering the details and the same can be stored in the blockchain with the help of self-executing digital code called smart contracts.

As the treatment procedures are going on, several data can be accumulated for an individual patient such as treatment records, prescriptions, and discharge summaries. The records and data can be mapped against the same UHIN and for these individual medical data, the patient can check or uncheck the corresponding consent. For example, if the patient does not wish to disclose their lab results, they have the freedom to do that. If they do so, no one else will have the privilege to view the same, unless the view request raised by the other party (such as doctors or caregivers) is granted by the patient. Once this request is approved and granted by the patient, the details along with the timestamp can be captured by the blockchain network. This will bring in the notion of trust for all the stakeholders in the healthcare ecosystem such as patients and healthcare providers.

The decentralized identity management module is used in this context for creating a unique health identification number for each patient to smoothen the interoperability aspect of the healthcare applications. For example, the Unique Health Identification Number (UHIN) will be generated for a patient for the first time an individual visits a healthcare provider. This process will create a pair of keys (private and public keys) where the private key will be stored in a mobile wallet and the public key is fused with the UHIN. When the patient visits a different healthcare provider for the next time, the UHIN number will be keyed in the system and with the consent of the patient, his or her data can be accessed by the healthcare provider. Such a mechanism will enable interoperability and provide the patients with transparent and seamless healthcare services. This framework for enabling the trusted ecosystem will be an enabler for trusted artificial intelligence as well. The data captured with the consent of the patient can be used for training machine learning models that can leverage meaningful insights from patient records, for example, prediction models. This process also asks for consent from the patient and can only be used if the patient wishes to sell their data to third parties. Data monetization pipelines can also be fused with this framework for giving rewards in terms of tokens for every data point shared by the patient for building machine learning models. Blockchain technology will not only build trust among the healthcare stakeholders, but this will create a decentralized artificial intelligence model where the explainability and ethical considerations are considered effective.

13.4 Experiments and Discussions

The framework discussed in Sect. 13.3 has been implemented to check the feasibility of implementing a hybrid approach that incorporates artificial intelligence and blockchain for building a trusted ecosystem for the healthcare sector. The details of implementation and results along with a short discussion are given in this section. The experimental testbed for the framework given in Sect. 13.3 has been implemented using Hyperledger Fabric which is available at https://github.com/hyperledger/fabric. We have simulated a private blockchain network locally and added different validators such as patients, healthcare providers, and certifying authorities. For this work, we have used Fabric SDK written in Python which is publicly available at https://github.com/hyperledger/fabric-sdk-py. For this framework, we have evaluated the operational efficiency of the proposed approach by setting up an equivalent centralized application using MySQL database. However, the centralized database-based approach is prone to data manipulation and data forging by malicious agents. Normally, for typical blockchain implementation, the data could be stored off-chain and the metadata will be stored in blockchain. For this blockchain implementation, we have stored the data and metadata in blockchain and the permissions to the data are managed by chaincode deployed in the Fabric network.

One of the major challenges faced by the researchers in the medical domain is the availability of public datasets, especially datasets containing patient's personally identifiable data. As the proposed framework requires data points with patient's personally identifiable data, many of the publicly available datasets will not be suitable for our requirement. Thus, for this experiment, we have used the MIMIC-III dataset which is available at https://physionet.org/content/mimiciii-demo/, and then manually added some personally identifiable information with the deidentified patient records. Even though the dataset contains a total of 40,000 records, for this experiment we have used only 1500 records due to scalability issues. We have developed a web application that captures both personally identifiable and personally non-identifiable information while onboarding the patient at a healthcare provider. The selected records from the MIMIC-III dataset were taken and added to the blockchain with all the default permissions or consents for all the records. Since we need to compare the performance of the framework shown in Fig. 13.1, we have also implemented a database project where MySQL was used as the backend. To compare the operation, we have simulated an attacker trying to get access to the patient records that are stored in the Blockchain application. Technically, this has been done by amending the default permissions set for the patient data that is recorded while a patient is first on boarded in the system. As blockchain stores the data in an immutable and tamper-proof ledger, these attempts were recorded during the consensus process.

In this work, we could evaluate and compare the advantages of a blockchain-based system with the traditional database-based application in terms of tamper-proof and secure record keeping. The proposed framework was implemented in a very controlled environment with a very limited set of users. One of the limitations of the current implementation is the scalability aspects. In the real scenario, there could be thousands of transactions that need to be committed in parallel and that require significant efforts. Some of the challenges we have faced are outlined here:

(a) One of the major challenges is interoperability. The blockchain-based application needs to interfere with cloud environments, other legacy systems, and mobile devices. There should be a serious effort involved in developing systems that are interoperable with blockchain-based systems.
(b) Governmental regulations related to healthcare data storage and management are another concern for such applications. The data protection law that is already

developed in several countries prohibits organizations from storing data in cloud-based environments.

(c) Implementation and maintenance cost for blockchain-based systems is another concern. The infrastructure facilities required and the maintenance cost involved are holding the organizations back from such implementations.

We hope that in the coming years, there will be serious efforts from various stakeholders in the healthcare sector such as governments, healthcare providers, and hospitals to build such a trusted ecosystem. This effort will supplement various proofs-of-concept to be taken to production-level implementations that may enable the complete digital transformation process across organizations.

13.5 Conclusions and Future Work

This chapter proposed a framework that integrates artificial intelligence and blockchain technologies for building a trusted ecosystem for the healthcare domain. With the help of a tamper-proof and immutable data capturing mechanism, the highly sensitive data in healthcare can be easily captured and managed. This will enable the notion of trust with healthcare providers to the mathematical infrastructure that eliminates middlemen activities. Even though this conceptual framework better captures and enables trust, there are several challenges associated with it in the implementation. The first and foremost one is to associate various stakeholders associated with the healthcare domain such as patients, healthcare providers, governments, and other law-enforcing bodies. This will be a difficult task. The absence or incomplete legal frameworks for the healthcare sector is another challenge in implementing such frameworks. However, with more interventions from the government and other public-facing bodies, the blockchain and artificial intelligence-based systems will come to mainstream adoptions and that will initiate the process of a complete paradigm shift in the healthcare sector.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. Decentralized Business Review, 21260.

2. Benhamouda, F., Halevi, S., & Halevi, T. (2019). Supporting private data on hyperledger fabric with secure multiparty computation. *IBM Journal of Research and Development, 63*(2/3), 3.1–3.8.
3. Cachin, C. (2016, July). Architecture of the hyperledger blockchain fabric. In *In Workshop on distributed cryptocurrencies and consensus ledgers* (Vol. 310, p. 4). IBM Research.
4. Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., Caro, A. D., Enyeart, D., Ferris, C., Laventman, G., Manevich, Y., Muralidharan, S., Murthy, C., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolić, M., . . . Yellick, J. (2018). Hyperledger fabric. In *Proceedings of the Thirteenth EuroSys Conference*. ACM Digital Library.
5. V. Dhillon, D. Metcalf, and M. Hooper, "The Hyperledger project," Blockchain enabled applications, pp. 139–149, 2017. M. Swan (2015). Blockchain: Blueprint for a new economy. " O'Reilly Media, Inc.
6. Gorenflo, C., Lee, S., Golab, L., & Keshav, S. (2019). Fastfabric: Scaling hyperledger fabric to 20,000 transactions per second. In *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)* (pp. 455–463). IEEE.
7. Olson, K., Bowman, M., Mitchell, J., Amundson, S., Middleton, D., & Montgomery, C. (2018). *Sawtooth: An introduction*. The Linux Foundation.
8. Manne, R., & Kantheti, S. C. (2021). Application of artificial intelligence in healthcare: Chances and challenges. *Current Journal of Applied Science and Technology, 40*(6), 78–89.
9. Kasperbauer, T. J. (2021). Conflicting roles for humans in learning health systems and AI-enabled healthcare. *Journal of Evaluation in Clinical Practice, 27*(3), 537–542.
10. Benrimoh, D., Israel, S., Fratila, R., Armstrong, C., Perlman, K., Rosenfeld, A., & Kapelner, A. (2021). ML and AI safety, effectiveness and explainability in healthcare. *Frontiers in Big Data, 4*, 727856.
11. Lee, D., & Yoon, S. N. (2021). Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. *International Journal of Environmental Research and Public Health, 18*(1), 271.
12. Siddique, S., & Chow, J. C. (2021). Machine learning in healthcare communication. *Encyclopedia, 1*(1), 220–239.
13. Davahli, M. R., Karwowski, W., Fiok, K., Wan, T., & Parsaei, H. R. (2021). Controlling safety of artificial intelligence-based systems in healthcare. *Symmetry, 13*(1), 102.
14. Sunarti, S., Rahman, F. F., Naufal, M., Risky, M., Febriyanto, K., & Masnina, R. (2021). Artificial intelligence in healthcare: Opportunities and risk for future. *Gaceta Sanitaria, 35*, S67–S70.
15. Pawar, U., O'Shea, D., Rea, S., & O'Reilly, R. (2020, June). Explainable AI in healthcare. In *2020 International Conference on Cyber Situational Awareness, Data Analytics and Assessment (CyberSA)* (pp. 1–2). IEEE.
16. Gerke, S., Minssen, T., & Cohen, G. (2020). Ethical and legal challenges of artificial intelligence-driven healthcare. *Artificial Intelligence in Healthcare, 2020*, 295–336. Academic Press.
17. Priyanka, D., & Chinmay, C. (2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence*, 1–24, https://doi.org/10.1080/0952813X.2021.1958063
18. Chinmay, C., & Megha, R. (2021). Smart healthcare systems using big data. *Elsevier: Demystifying Big data, Machine learning and Deep learning for Healthcare Analytics, 2*, 1–16. https://doi.org/10.1016/B978-0-12-821633-0.00002-7
19. Hussien, H. M., Yasin, S. M., Udzir, N. I., Ninggal, M. I. H., & Salman, S. (2021). Blockchain technology in the healthcare industry: Trends and opportunities. *Journal of Industrial Information Integration, 22*, 100217.
20. Balasubramanian, S., Shukla, V., Sethi, J. S., Islam, N., & Saloum, R. (2021). A readiness assessment framework for Blockchain adoption: A healthcare case study. *Technological Forecasting and Social Change, 165*, 120536.

21. Miyachi, K., & Mackey, T. K. (2021). hOCBS: A privacy-preserving blockchain framework for healthcare data leveraging an on-chain and off-chain system design. *Information Processing & Management, 58*(3), 102535.
22. Shuaib, M., Alam, S., Alam, M. S., & Nasir, M. S. (2021). Self-sovereign identity for healthcare using blockchain. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2021.03.083
23. Banotra, A., Sharma, J. S., Gupta, S., Gupta, S. K., & Rashid, M. (2021). *Use of blockchain and internet of things for securing data in healthcare systems* (Multimedia security) (pp. 255–267). Springer.
24. Kumar, R., & Tripathi, R. (2021). Scalable and secure access control policy for healthcare system using blockchain and enhanced Bell–LaPadula model. *Journal of Ambient Intelligence and Humanized Computing, 12*(2), 2321–2338.
25. Chelladurai, U., & Pandian, S. (2021). A novel blockchain based electronic health record automation system for healthcare. *Journal of Ambient Intelligence and Humanized Computing*, 1–11.
26. Tanwar, S., Parekh, K., & Evans, R. (2020). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. *Journal of Information Security and Applications, 50*, 102407.
27. Abu-Elezz, I., Hassan, A., Nazeemudeen, A., Househ, M., & Abd-Alrazaq, A. (2020). The benefits and threats of blockchain technology in healthcare: A scoping review. *International Journal of Medical Informatics, 142*, 104246.
28. Mashamba-Thompson, T. P., & Crayton, E. D. (2020). Blockchain and artificial intelligence technology for novel coronavirus disease 2019 self-testing. *Diagnostics (Basel), 10*(4), 198.
29. Kim, S. K., & Huh, J. H. (2020). Artificial neural network Blockchain techniques for healthcare system: Focusing on the personal health records. *Electronics, 9*(5), 763.
30. Lalit, G., Emeka, C., Nasser, N., Chinmay, C., & Garg, G. (2020). Anonymity preserving IoT-based COVID-19 and other infectious disease contact tracing model. *IEEE Access, 8*, 159402–159414. https://doi.org/10.1109/ACCESS.2020.3020513. ISSN: 2169-3536.
31. Bakhtawar, A., Abdul, R. J., Chinmay, C., Jamel, N., Saira, R., & Muhammad, R. (2021). Blockchain and ANFIS empowered IoMT application for privacy preserved contact tracing in COVID-19 pandemic, *Personal and Ubiquitous Computing*, 1–17, https://doi.org/10.1007/s00779-021-01596-3

Part IV
Intelligent Healthcare Infrastructures

Chapter 14
Internet of Medical Things (IoMT): Applications, Challenges, and Prospects in a Data-Driven Technology

Sunday Adeola Ajagbe, Joseph Bamidele Awotunde, Ademola Olusola Adesina, Philip Achimugu, and T. Ananth Kumar

Abstract Internet of Things technology (IoT) is a fast-growing area of computing, and it is applicable to almost all human endeavor. The introduction of IoT into medicine brought about the Internet of Medical Things (IoMT) that has really redefined the smart healthcare systems globally, though its apprehension to security threats and risk especially in the field of medicine is second to none. Though it is very challenging to provide a secured expansion using the sensor in the medical domain but the impart of the IoMT-based system can never be denied and was greatly deployed in various countries accordant with available facilities to curb the spread of Covid-19 pandemic. But because of the sensitivity of data and critical information in the IoMT-based systems, it continues posing several perilous challenges and these keep growing. Therefore, this chapter discussed inherent opportunities and challenges facing data-driven solutions for a secured IoMT. This will broaden the research and reassure the users of IoMT for data-driven solutions in healthcare delivery.

S. A. Ajagbe (✉)
Computer Engineering Department, Ladoke Akintola University of Technology LAUTECH, Ogbomoso, Nigeria
e-mail: saajagbe@pgschool.lautech.edu.ng

J. B. Awotunde
Computer Science Department, University of Ilorin, Ilorin, Nigeria
e-mail: awotunde.jb@unilorin.edu.ng

A. O. Adesina
Mathematical Sciences Department, Olabisi Onabanjo University, OOU, Ago-Iwoye, Nigeria
e-mail: ademola.adesina@oouagoiwoye.edu.ng

P. Achimugu
Computer Science Department, Air Force Institute of Technology Kaduna, Kaduna, Nigeria
e-mail: p.achimugu@afit.edu.ng

T. A. Kumar
Computer Science & Engineering, IFET College of Engineering, Villupuram, India
e-mail: tananthkumar@ifet.ac.in

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_14

Keywords Challenges · Data-driven · Healthcare system · Intelligence system · IoMT application · Internet of things · Privacy and security · Prospects

14.1 Introduction

Internet of Medical Things (IoMT) is an innovative means of connecting healthcare systems, medical devices, and applications using networking technologies. It originated from Internet of Things (IoT) that is been used by most companies for device connections, and site monitoring. Healthcare industries are using IoT devices for monitoring patients' well-being and maintain their medical records and acquiring medical related data for improved medical deliveries [1]. Monitoring of patients takes the largest percentage of IoT usage application, it is up to 64%. Keeping healthcare data in a safe and secured manner is important, meanwhile medical industries not a concern with delivering healthcare remotely and tamper-proof and therefore it will take some adaptive measure of IoT to perform effectively, hence, the IoMT was informed. The IoMT is making its place in the world today with about 60% of global healthcare institutions making use of it and the record is expected to increase with the advent of the COVID-19 pandemic. Although, many healthcare organizations are still maintaining the conventional methods of medical treatments and moving towards technologically advanced digital systems that connect the patients to physicians remotely is yet to be implemented in most developing countries.

The development of smart solutions in the field of medicine is inevitable. Smart solutions such as sophisticated lightweight communication protocols, smart sensors, and smart devices using IoT are playing an important role in quality healthcare delivery at the moment. It has made it possible to interconnect medical apparatus and equipment to monitor biomedical signals and effect diagnose of patients' diseases without serious human intervention and this is referred to as IoMT, and this operation is the heart of the healthcare intelligence system [2]. The IoMT advances IoT that deals with internet connectivity to address the problems in healthcare industries, it allows medical equipment to gather, analyze, and transmit data through the Internet and other media with the help of internet solutions. Digital devices like non-digital gadgets such as patient beds and heart monitors are connected to the internet for effective health monitoring purposes. On some occasions, it requires wearable devices for IoMT facilities to work effectively, in a way that the devices facilitate patient monitoring from a remote location that leads to a reduction in the visitation by the physician who regularly visits the patients, this will in turn, save a lot of money spent on transportation, ensure risk of the life of physician during transportation and protect physicians against infectious diseases. This provides a good medium for physicians to keep track of the physical condition of their patients and send alerts on medical cares appropriately [3].

Accuracy, reliability and productivity of electronic devices in medical field improves with the help of IoMT. This is as a result of the contributions of researchers that make IoMT a reality and improving as a digitized healthcare system for interconnectivity of the available medical resources and medical services. The IoT converges different fields of human endeavor but IoMT pays much attention medical related contributions of IoT in medical field. Joyia et al. [1] application and challenges of IoT in healthcare were studied with a view to point out where practitioners and researchers should focus for quality healthcare with internet facilities [1]. The ongoing COVID-19 pandemic confronting the world was explored by IoMT implementation to offer treatment to orthopaedic patients [4]. The data sharing, patients tracking, medical hygiene, gathering of information as well as analyzing, were connected using various cloud systems connecting network-based services of IoMT has been reported to protect many lives most importantly, the health workers' security, and other frontliners. The introduction of IoMT has changed the workflow of medical facilities completely and the provision of exceptional care and satisfaction to orthopaedic patients, especially during the COVID-19 pandemic lockdown, with the proposed IoMT technique, remote location healthcare is also possible [4].

Infectious disease outbreaks introduce technologies to combat them. For instance, the centers for disease control around the world introduces some portable, and cost-effective systems for point-of-care diagnostics and the earlier stage of COVID-19 pandemic, which could also use global network to create IoMT but IoMT based functionality was not active in POC instrument [5]. The study then implemented a fast, user-friendly IoMT based system using a miniaturized polymerase chain reaction device and amplified complementary deoxyribonucleic acid of the dengue fever virus to demonstrate the system capacity. The data was automatically uploaded to an Android-based smartphone and disseminated to a global network via a Bluetooth interface. This made the test results instantly available anywhere in the world and it was a novel intelligence healthcare system because of the introduction of IoT, and it has been listed among the essential tool for the control of infectious disease outbreaks [5].

The latest advancement and trends in ICT have been playing a vital role in the healthcare sector by advancing traditional healthcare delivery to the intelligence healthcare system stir by IoMT that provide a continuous, remote and real-time of patients' monitoring. Advent of IoMT that defined healthcare intelligence system came with security solutions and issues that is posing a perilous problem in the growth of IoMT. The data sensitivity, vital information, and a lack of a secure environment are all factors to consider were highlighted by Ref. [2]. Future research directions and ways of solving uncharted research problems were provided [6]. For clarity's sake, the IoMT in this chapter is internet of medical things not internet of multimedia things that has to do with multimedia in smart agriculture, security, homes and traffic monitoring [7].

14.1.1 Chapter Contribution

In this chapter, we reveal the opportunity, application and challenges of IoMT. This study novelty is the highlight of important areas where both information technology and medial experts and researchers connects to provide an intelligence healthcare systems, the trend of IoMT application and the needs to improve it for effective healthcare delivery with the aid of internet facility.

14.1.2 Chapter Organization

The chapter was organized as follows: Sect. 14.1 introduces IoT, and the advancement of research on IoT to address healthcare issues that lead to the internet of medical things (IoMT). Section 14.2 data-driven for IoMT deployment. Section 14.3 enumerates the opportunities and prospects of IoMT, Sect. 14.4 discusses the applications of IoMT for efficient and effective healthcare delivery. Section 14.5 explains the challenges of IoMT and the prospects of IoMT. Finally, Sect. 14.6 concludes the chapter and highlighted the directions of future work.

14.2 Data-Driven for Internet of Medical Things Technology

Ghubaish et al. [8] proposed a state-of-the-art technique for IoMT data collection, and transmission. Critical attention was paid to physical and network layers' attack, the study proposed a security framework that combined both cryptographic and non-cryptographic security techniques to mitigate data security problems in intelligence healthcare systems and IoMT in particular but other OSI layers and other devices used for IoMT data sharing were not considered. One of the important characteristics of IoT and IoMT is the data-driven characteristics [9]. These characteristics are considering to monitor energy consumption, tolerance of faulty, balancing of load, and time delay when deploying an IoT solutions for healthcare delivery [10]. Table 14.1 compared data-driven characteristics of IoMT Data and Multimedia Data.

Many technologies today are data-driver and this is one of the ways promoting some fields of computer science such as data science and big data in other fields. Intelligence healthcare systems are also a data-driven technology, many data-driven

Table 14.1 IoMT data and multimedia data comparison

Serial number	IoMT data	Multimedia data
1.	Liner data	Bulky data
2.	Low processing	Excessive processing
3.	Low bandwidth	High bandwidth
4.	Low storage	High storage
5.	Tolerance delay	Sensitive delay
6.	Consume low amount of energy	Consume a high amount of energy

solutions were provided in the healthcare system by some scholars. Table 14.2 provides data-driven technologies with their respective solutions.

14.3 The Internet of Medical Things Applications

The deployment of IoMT has in existence before the advent of COVID-19 pandemic, but since the beginning of the present pandemic ravaging the whole world, the deployment of IoMT has taken a new dimension characterized by data regardless of data sharing and privacy issues [35]. The IoMT evolved from IoT to focus on the applications of IoT that can be properly annes and maximized in the healthcare sector. One of the recent innovation applications of IoMT was presented in IoMT model by [36, 37]. It has embedded chips / nano sensors to monitor blood pressure, pulse, and ECG of the patient, the model used the cellphone as the gateway to connect the internet and the desktop at the healthcare provider end. The novelty in the application includes placement of the sensors to monitor the important organs as shown in Fig. 14.1.

Table 14.3 reveals the studies on IoMT applications that make it refers to as intelligence healthcare systems, the areas as well as their uses.

An overview of the healthcare system current operations was the review by Ref. [46] and examines how the technology is helping the healthcare sector. A review of intelligence healthcare applications was provided in Table 14.4, attention was paid to the technologies and goals of the research. The first column is the research reference, followed type of technologies applied to aid healthcare system and the third column was the research goals.

14.4 Challenges of Internet of Medical Things

Vishnu et al. [2] reviewed studies on IoMT based remote healthcare delivery, tracking sensors, mobile health, smart hospitals, improved chronic illness treatment and methods are some of the topics being discussed. The study presented an overview of the poor internet infrastructures, security, and privacy as areas of concern that are limiting the usage level of IoMT. The growth of IoMT was also posted to be threatened by security risks. It is challenging to fully provide with the expansion when using sensor objects, especially in healthcare. Many researchers including [1] listed some challenges of IoMT. They are; The IoT generally is emerging in computing and IoMT is expanding very rapidly. This fast-growing field of computer science in the healthcare domain does not come with some inherent challenges meant to be overcome, believing that overcoming these inherent challenges will improve IoT in general and the IOMT in particular. IoMT provides reliable and better services in the medical field and this is due to the revolutionary changes of IoT and internet communication that is contributing to the field of IoMT.

Table 14.2 Healthcare data-driven technologies and solution

Author (s) year	Data-Driven technologies	Solutions provided
Khan et al. [11]	Glucose sensor	Glucose monitoring using IoT and ANN
Geetha et al. [12]	Urine testing	Self-monitoring, reliable, and effective glucose monitoring system
Valenzuela et al. [13]	Glucose sensor	IoT-based glucose monitoring to prevent diabetes complications in elderly persons
Al-Odat [14]	Alaris-8100 infusion pump	Implementation of an insulin pump for diabetic patients' control and monitoring Cloud-based health data sharing
Schwartz et al. [15]	Smartwatches and fitness trackers	Continuous glucose monitoring
Chatterjee et al. [16]	Persuasive wireless sensing	Analytic models for predicting blood glucose levels are being developed.
Francia et al. [17]	Sensor for continuous movement tracking	Monitoring daily activity and blood glucose levels that prevent diabetic foot ulcers.
Lucisano et al. [18]	Spontaneous glucose excursions and glucose clamping	Long-term sensor/telemetry system implanted for glucose monitoring, control, and management
Edge et al. [19]	Glucose monitoring device FreeStyle libre flash	The accuracy, safety, and usability of a glucose monitoring system in children are discussed.
Facchinetti [20]	Spontaneous glucose excursions and glucose clamping	Methods for attenuating basal insulin levels automatically
Rodbard [21]	Spontaneous glucose excursions and glucose clamping	Glucose level and rate of change, as well as alerts and alarms, are displayed in real time scenario. These featured IoMT-based devices that are small, comfy, and user-friendly
Toschi et al. [22]	Blood glucose sensor with self-monitoring	Diabetes monitoring, control and management
Bellazzi et al. [23]	Data from home surveillance (genomics data repositories)	Management of type 2 diabetes (T2D) To manage and control diabetes, big data technologies and IoMT are being used.
Cichosz et al. [24]	Sensor for continuous glucose monitoring	Management of type 2 diabetes (T2D) Big data analytics and ML techniques are used to create predictive T2D models.
Devarajan et al. [25]	ECG sensors and continuous glucose monitoring	Patients with diabetes who live in remote areas can benefit from a fog-assisted method. Personalized healthcare system aided by fog Tracking glucose levels with physical activity and ECG.
Longva & Haddara [26]	Glucose monitoring sensor that is always on	IoMT improves the quality of life for diabetes people.

(continued)

Table 14.2 (continued)

Author (s) year	Data-Driven technologies	Solutions provided
		IoMT allows for continuous glucose monitoring, and tracking.
Fernández-Caramés et al. [27]	Sensor for continuous glucose monitoring	A diabetes continuous glucose monitoring system based on the internet of mobile crowdsourcing health things has been developed. Diabetes is managed and controlled remotely and continually using mobile fog computing, blockchain, and IoT.
Gupta et al. (2020) [28]	Sensor for flexi-force	Diabetic foot ulcer detection
Puri et al. [29]	Sensor for measuring blood glucose levels	A blood glucose monitoring system based on the IoT An IoT-based glucose testing meter prototype
Charles et al. [30]	A photo-acoustic signal is a signal that consists of light and sound.	IoT-based glycemic control Intelligent blood glucose level monitoring technology that is non-invasive IoT-based alert signals are provided.
Fernández-Caramés et al. [31]	Sensor for measuring blood glucose levels	Glucose monitoring system that is always on monitoring system based on fog computing, blockchain, and IoT. mHealth system that is quick, adaptable, scalable, and low-cost
Kharbouch et al. [32]	Glucose levels, activity, and dietary habits	Hypoglycemia detection with the IoT Platform for IoT and large data analytics
Ara & Ara, [33]	Injectable defibrillators, activity trackers, and continuous glucose monitoring	IoT based intelligent diabetes management system Machine learning diabetes management application Smart, and cost-effective
Sujaritha et al. [34]	ECG, blood pressure sensor, and foot pressure sensor	Diabetes treatment software based on machine learning Automated IoT-based diabetes risk assessment system.

Singh et al. [4] carefully selected challenges of IoMT basis on the contribution of researchers in the field of IoT from different resources. Selected articles were chosen based on selection and rejection criteriawhere the majority of the articles were selected from ACM, IEEE, Elsevier and few others [4]. Patients whose treatment and prescriptions are now in progress and are being impacted by the current scenario have been distressed by the COVID-19 pandemic's lockdown. Patients were required to communicate with their doctors on a regular basis for follow-ups [66, 67]. The patients with orthopaedic disorders have special hurdles because their mobility is restricted by their illness or previous surgeries such as fractures,

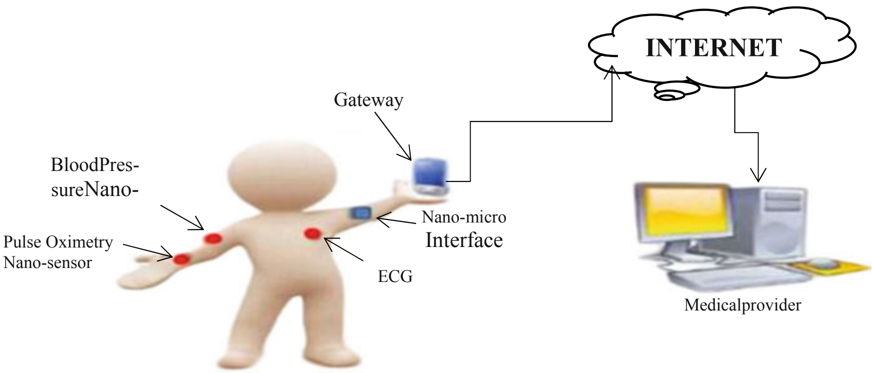


Fig. 14.1 The internet of medical things (IoMT) model

joint replacements, arthroscopic and spinal surgery, among others. It may not be able to avoid exposure and infection by the Coronavirus by meeting with their doctors face-to-face [68, 69].

The IoMT architectures must deal with issues such as bandwidth, communication protocols, big data and data volume, flexibility, reliability, data management, data acquisition, data processing and analytics availability, cost effectiveness, data security and privacy, and energy efficiency [70]. AlShorman et al. [66] sought practical solutions for improving healthcare systems. In addition, the use of IoMT and Remote health monitoring (RHM) to improve preventive, prognosis, diagnosis, and treatment abilities is discussed. A case study of real-time data processing and IoMT to monitor the vital signs of diabetes patients is also presented. The IoMT's excellent expansion and real-time adaptation quality in resolving medical issues has been significant. Without a doubt, IoMT applications are numerous in nature, with multimedia sensors and devices being one of the most prominent areas of use. Smart traffic monitoring to smart hospitals are among the real-time implementation possibilities. Since a result, timely delivery of IoMT datasets and decision-making is crucial, as it affects human life safety [71]. Management of device diverse scales, data volume [72], data privacy requirement, performance flexibility and evolution of applications, medical expertise. Interoperability, Real time processing, System predictability [73, 74]. The pain that these orthopaedic patients go through can be excruciating; as a result, advanced cloud-based services are necessary to support and treat orthopaedic patients during this epidemic [75]. The Implementation of IoMT come with numerous challenges, few of the challenges of IoMT are considered in this section.

Table 14.3 Application areas and uses of internet of medical things

S/N	Authors and year	Area of application	Uses
1.	Matheny et al., [38]	Hospital	IoMT applications are used to connect patients to doctors for monitoring, laboratory and scan equipment such as X-ray scan, CT scans, MRI) and smart apps are connected from laboratory to doctors' office for laboratory report access and medical care.
2.	Polu [39]	Home	Connection of medical devices beyond hospital environment, patients are been treated at homes. This prevents patients that are severing from serious diseases infection other patients (at the hospitals) and medical workers. This is called 'telemedicine'. A typical example is remote patient monitoring system (RPMS/RTM). This application is IoMT based application. This devicesis commonly used for heart and diabetic patients to monitor heartbeat and glucose level and send an automatic alert to the doctor.
3.	Pateraki M. et al., Ajami & Teimouri [40, 41]	Human body	Another IoMT innovation is biosensors, it is used in the design and development of wearable devices for patient monitoring. They can be embedded in apparel (skin attached) or implanted under the skin, providing freedom for the patient and keep a watch on their health.
4.	National Academy of Sciences [42]	Health insurance	Stakeholders (caregivers, clinicians and patients) in healthcare are connected together with the helpt IoMT ensuring seamless monitoring and diagnosis operations and increase overall efficiency.
5.	Alotaibi & Federico [43]	Remote clinic	Patients are far away from the physicians location, possibly the patient is in another clinic different from where (medical) specialist. IoMT solutions are used as a medium to connect them together for medical care. This adds comfort to the healthcare delivery process and reduces the cost.
6.	Sharma et al. [44]	Rural area	Digital solution are taken the benefits of IoMT to provide healthcare services in villages where the medical services are rearlly accessible, IoMT proves to be a great tool to provide treatment in rural areas, although such treatments may like first aid treatment and the patient will have to go to the hospital later, unlike remote clinic or home where facilities that will complete the treatment can be setup. With we can create a better world.
7.	Dash [45]		Advancement in technologies on medical by the manufacturer has made detection

(continued)

Table 14.3 (continued)

S/N	Authors and year	Area of application	Uses
		Healthcare equipment manufacturer	functionality issues (if any) of medical equipment possible with the use of IoMT. Manufacturers like Sienens and Philips have manufactured medical image processing machines that will alert manufacturers if there is any fault on medical equipment during diagnosis before the hospital staff can detect it.
8.	Haque & Hasan [35]	Hospital	It has enbeded chips / nano sensors to monitor blood pressure, pulse and ECG of the patient, the model used the cellphone as the gateway to connect the internet and the desktop at the healthcare provider end.

Table 14.4 Intelligence technologies used for IoMT applications

Author(s) Year	Intelligence technologies applied	Research goals
Lalmuanawma et al. [47]	Artificial intelligence/machine learning	Medical diagnosis and analysis.
Sedik et al. [48]	AI/ML	Accurate screening
Turabieh et al. [49]	Artificial intelligence/recurrent neural network	Missing data
Khan et al. [50]	AI/ML	Brain tumor detection (precision)
Kilic [51]	AI/ML	Accurate cardiovascular detection
Song et al. [52]	AI	Spectrum sharing and selection
Rachakonda et al. [53]	AI/ML and Blockchain	Accuracy and security respectively
Fotopoulos et al. [54]	Blockchain	Authentication
Esposito et al. [55]	Blockchain	Security and privacy
Girardi et al. [56]	Blockchain	Security
Noura [57]	Cryptography	Security
Yanambaka & Abdelgawad [58]	Physically unclonable functions (PUF)	Privacy and host tracing
Ma et al. [59]	PUF	Secured sensing
Masud et al. [60]	PUF	Telemedicine authentication
Liaqat et al. [61]	Software-defined networking (SDN) and AI	Security
Cecil et al. [62]	Software-defined networking (SDN)	Surgical operation
Askari et al. [63]	SDN scheduling	Healthcare monitoring performance
Badotra et al. [64]	SDN	Traffic flow
AlShorman et al. [66]	Wearable sensors	Inertial, location, image, phycological and brain activity sensing

14.4.1 Issues of Standardization

The majority IoMT devices manufacturer is looking after gains, scalability, devices with low time and consumption, and cost-effectiveness. In this scenario, the standardization of IoMT devices is traded off. At present, about 51% of medical manufacturing devices and 44% of healthcare organizations follow the food and drugs administration (FDA) lay down rules that affect the overall efficiency of IoMT and consequently disturb medical delivery [76].

14.4.2 Challenges of Regulation

New medical devices or an upgrade need clearance from the FDA before entering market. Typical example is the data collection and storage data for patient by Health Insurance Portability and Accountability Act of 1996 (HIPAA) [77]. These laws and regulation are too rigid and a new flexible that will have seamless administrative passage are needed for intelligence and smart based solutions in medical field.

14.4.3 Cost of Infrastructures

There is high cost of implementing IoMT, although it will reduce overall medical cost at the long run but the infrastructure implementation at the beginning is costly. This cost includes the acquisition of hardware equipment, building an app, maintenance and storage require a high initial investment challenging the implementation IoMT at the preliminary stage [78].

14.4.4 Security Vulnerabilities Issue

The security issue is one of the major challenges of any cyber related solutions, data of patient are prone to cyber-attacks and various data breaches since IoMT relies on the internet for its effectiveness. Out of about 340% security issues in the healthcare industry reported about 200% are data theft susceptible [79]. Vaiyapuri et al., Ajagbe et al. [80, 81] raised the problem of data intrusion on the patient sensitive health data, bridging the security and privacy that can expose the lives of patients or worsen the health condition and finally terminate the lives of the patients.

14.4.5 Existing Networks Strain

The existing healthcare infrastructures that connects with IoMT devices into hospitals are using Wi-Fi and similar technologies. While healthcare organizations lack the necessary network infrastructure to integrate and utilize IoMT devices. To take advantage of it, they must first emerge.

14.5 Prospects of Internet of Medical Things

The appearance of IoMT is supporting the intelligent healthcare system is very promising. Although, it is currently in its early stages but it has a lot of potentials and applications to transform the healthcare system. With time, it will become a valuable tool in the healthcare profession, comparable to thermometers and stethoscopes as a result of innovation from its deliverables. People will notice a shift toward IoMT solutions as it saves time, cost and increases efficiency. This will happen because of the inherent opportunities of IoT that IoMT is annexing and maximizing in the medical field. This section reveals the prospect and opportunities of IoMT that make it prefer than traditional healthcare delivery means. The ongoing COVID-19 pandemic ravaging the world is a typical example, where there is variance of the disease, and available vaccines appear to be ineffective in curbing the virus. The use of IoMT offers many advanced cloud-based services and has many opportunities to serve both orthopedic and non-orthopedic patents effectually are to explore more.

The IoMT offers a number of critical applications for combating the devastating effects of epidemics and pandemics [82]. The capacity to give medical services in a remote location, online and onscreen checks, report analysis, database sharing, information processing, and overall patient tracking and monitoring are only a few of the key applications of IoMT [83]. Some of the specially developed features from IoMT services for older patients and patients with chronic diseases. This includes remembering feature devices to keep them reminded about certain things such as medication, medicine time, sleep monitoring, and many more services [84, 85].

The fast adoption of IoT in the healthcare sector has resulted in the emergence of numerous security concerns and risks. With the increased use of sensor objects in the healthcare sector, it has become increasingly difficult to provide complete protection. As a result, the IoMT definition was created. The security component of IoMT poses a perilous problem that continues to grow, due to the sensitivity of data and critical information. Mawgoud et al. [86] observed patients' privacy is jeopardized due to a lack of a secure environment in IoMT, which not only jeopardizes patient data privacy but also puts patients' lives in jeopardy. To improve security, the researchers presented a novel authentication method based on machine learning [87, 88]. Both trust management and authentication were used to construct the authentication and at the gateway, machine learning is used to recognize device

Table 14.5 Prospective areas and applications classes of IoMT

S/N	Prospective areas	Class of IoMT Applications
1.	Users health wearable clinical/medial wearable	On body
2.	Remote monitoring, telemedicine based healthcare, emergency response system,	In home
3.	Mobility, emergency response intelligence, kiosks, logistics	Community
4.	Innovative device, patient flow system	In hospital
5.	Point-of-care, tele-health model or telemedicine	In clinic

frequencies and access timing that are resource constrained as an advantage in IoMT [89, 90]. This is a promising technology to promote healthcare intelligence system. The major goal is to investigate the medical field's dynamic environment and implement adaptive access control. Gradually, security improvements would be made to IoMT systems in order to reduce communication latency, take proactive security measures, and ensure data privacy for both patients and physicians in a healthcare system [91, 92].

Furthermore, various upcoming technologies like AI, and SDN are envisioned as critical solutions for overcoming several electronic healthcare concerns such as security, privacy, accuracy, and performance. Other prospective application areas to confront pandemics such as COVID-19, Ebola, SARS by IoMT device and their area of applications are summarized in Table 14.5 [93].

The Internet of medical things has numerous prospects that result in many advantages in the medical field. Some of the prospective advantages of IoMT that hope to benefit human being in the healthcare sector has information technology and medical experts collaborate to improve healthcare delivery in the nearest future are highlighted.

The Benefits of the IoMT include:

1. Improves Efficiency: using digital solutions improves accuracy and reduce operation time and these improve efficiency.
2. Reduce cost: it allows physicians and patients to connect remotely without having physical meetings that reduce consultation or transportation costs and visiting time.
3. Fast response time: Fitness sensing devices integrated as intelligence healthcare systems allow quick response time on patients' medical status monitoring.
4. Improve communication: One of the major reasons of IoMT invention was to improve communications between healthcare provider, patient and healthcare providers
5. Ease of use: it is a flexible means of communication between the doctors, hospital staff and patients. This makes medical services to be more precisely and actively using minimal effort and intelligence.
6. It provides simplicity, flexibility and affordability service delivery in the healthcare sector.

7. Orthopaedic treatment that is proactive It allows for an interruption in health supervision and proactive orthopaedic care.
8. Medical Assistance in an Emergency IoMT establishes an advanced culture in the treatment process through the use of analytics and current digital gadgets, allowing any potential emergency to be predicted and studied from afar.
9. Monitoring and tracking of one's health IoMT provides innovative wearable devices for efficient patient monitoring.
10. The use of cloud-based data analysis and report testing can be used to track the health of orthopaedic patients.
11. It allows doctors to keep track of their patients in real time. In the current COVID-19 circumstance, where the pandemic is still much around.
12. The provided analysis results assist doctors in deciding on additional treatment procedures that may be required.
13. Allows medical personnel to provide immediate assistance to patients. A culture of real-time monitoring allows for more effective patient care.
14. It allows for quick disease identification. Because the data is well maintained on a cloud foundation, the real-time database helps in diagnosing the condition at the early stage.
15. It aids in the monitoring of patients on health insurance policies in order to avoid possible fraud and guarantees that claims are processed in a transparent manner

14.6 Conclusion and Future Direction

Emerging technology around the world relies on internet connectivity to function optimally, and it is data-driven. The interaction of the internet with data has come out with an intelligence system, providing the solution to many problems with less human interactions. Healthcare industries have taken the advantage of intelligence system, providing the solution to prevailing challenges in the healthcare sector. The remote medical care facility is more needed in such a critical time of lockdown and non-lockdown period to monitor the infected patient and contact tracing respectively. The effective systems interconnecting devices, applications, internet, database, and so on avail the users (medical workers and patient) of smartly IoMT services. The IoMT also has many applications that promote its services and applications. It can even be referring to as 'game-changer' that may change completely the practices in the medical field globally. The quality of monitoring and contact tracing services at this time make the approach more fruitful and worthwhile, for the elderly, patients in rural locations, and those with special healthcare needs. It is believed that traditional healthcare services may witness a paradigm shift in the near future, as the transformation in the computing world would advance technology and its connected products will improve patients' well-been and healthcare delivery at remote locations and access to quality healthcare facilities. This chapter has also highlighted challenges of IoMT in a data-driven environment, and this is crucial as future researchers in intelligence healthcare systems are expected to be intended towards IoMT technological advancement and address Challenges of Regulation, Issues of Standardization, cost of infrastructure, existing networks strain, security and privacy issues healthcare sector. This will aid the users of IoMT infrastructure to adapt to needed changes in an effective way. As researchers and practitioners proffer solutions to these identified challenges of IoMT will promote intelligence healthcare systems and the healthcare providers, as well as patients, benefit from the evolving technologies.

14.6.1 Future Direction

The future direction in the area of intelligence healthcare system is to apply AI (Deep learning or Machine Learning) algorithms that has provided paradm shift in data-driven environment, to provide secutiry and address the vulnerability problems in intelligence healthcare systems. Adoption of 5G network to enhance intenet facility and relif the existing network strain should be consider.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Adeniyi, E. A., Ogundokun, R. O., & Awotunde, J. B. (2021). *IoMT-based wearable body sensors network healthcare monitoring system* (IoT in healthcare and ambient assisted living) (pp. 103–121). Springer.
2. Vishnu, S., Ramson, S. R., & Jegan, R. (2020). Internet of medical things (IoMT) - an overview. In *5th International Conference on Devices, Circuits and Systems (ICDCS)* (pp. 101–104). IEEE. https://doi.org/10.1109/ICDCS48716.2020.243558
3. Awotunde, J. B., Folorunso, S. O., Bhoi, A. K., Adebayo, P. O., & Ijaz, M. F. (2021). Disease diagnosis system for IoT-based wearable body sensors with machine learning algorithm. *Intelligent Systems Reference Library, 2021*(209), 201–222.
4. Singh, R. P., Javaid, M., Haleem, A., Vaishya, R., & Ali, S. (2020). Internet of medical things (IoMT) for orthopaedic in COVID-19 pandemic: Roles, challenges, and applications. *Journal of Clinical Orthopaedics and Trauma, 11*, 713–717. https://doi.org/10.1016/j.jcot.2020.05.011
5. Zhu, H., Podesva, P., Liu, X., Zhang, H., Teply, T., Xu, Y., . . . Neuzil, P. (2020). IoT PCR for pandemic disease detection and its spread monitoring. *Sensors and Actuators. B, Chemical, 303*, 127098. https://doi.org/10.1016/j.snb.2019.127098
6. Gatouillat, A., Badr, Y., Massot, B., & Sejdi'c, E. (2018). Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine. In *IEEE Internet of Things Journal*. IEEE. https://doi.org/10.1109/JIOT.2018.2849014

7. Bamimore, I., & Ajagbe, S. A. (2020). Design and implementation of smart home for security using radio frequency modules. *International Journal of Digital Signals and Smart Systems (Inderscience Journal), 4*(4), 286–303. https://doi.org/10.1504/IJDSSS.2020.111009
8. Ghubaish, A., Salman, T., Zolanvari, M., Unal, D., Al-Ali, A. K., & Jain, R. (2020). Recent advances in the Internet of Medical Things (IoMT) systems security. In *IEEE Internet of Things Journal Special Issue on Internet of Things for Smart Health and Emotion Care*. IEEE. https://doi.org/10.1109/JIOT.2020.3045653
9. Abdul, R. J., Chinmay, C., & Celestine, W. (2021). Exploratory data analysis, classification, comparative analysis, case severity detection, and internet of things in COVID-19 Telemonitoring for smart hospitals. *Journal of Experimental & Theoretical Artificial Intelligence, 8*, 1–8. https://doi.org/10.1080/0952813X.2021.1960634
10. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). *BIFM: Big-data driven intelligent forecasting model for COVID-19* (Vol. 9). IEEE Access. https://doi.org/10.1109/ACCESS.2021.3094658
11. Folorunso, S. O., Awotunde, J. B., Ayo, F. E., & Abdullah, K. K. A. (2021). RADIoT: The unifying framework for IoT, Radiomics and deep learning modeling. *Intelligent Systems Reference Library, 2021*(209), 109–128.
12. Geetha, S., Ramachandran, V., Gomathy, V., Vasuki, R., & Geetha, S. (2019). Non invasive technique for measuring blood glucose based on IOT. *Indian journal of Public Health Research & Development, 10*(5), 1456–1458. https://doi.org/10.37506/ijphrd.v10i5.6842
13. Valenzuela, F., García, A., Ruiz, E., Vázquez, M., Cortez, J., & Espinoza, A. (2020). An IoT-based glucose monitoring algorithm to prevent diabetes complications. *Applied Sciences, 10*(3), 921.
14. Al-Odat, Z. A., Srinivasan, S., Al-qtiemat, E., & Shuja, S. (2019). A reliable IoT-based embedded health care system for diabetic patients. *International Journal on Advances in Internet Technology, ArXiv*, abs/1908.06086.
15. Schwartz, F. L., Marling, C. R., & Bunescu, R. C. (2018). The promise and perils of wearable physiological sensors for diabetes management. *Journal of Diabetes Science and Technology, 12*(3), 587–591. https://doi.org/10.1177/1932296818763228
16. Chatterjee, S., Byun, J., Dutta, K., Pedersen, R. U., Pottathil, A., & Qi Xie, H. (2018). Designing an Internet-of-Things (IoT) and sensor-based in-home monitoring system for assisting diabetes patients: Iterative learning from two case studies. *European Journal of Information Systems, 27*(6), 670–685. https://doi.org/10.1080/0960085X.2018.1485619
17. Francia, P., De Bellis, A., Seghieri, G., Tedeschi, A., Iannone, G., Anichini, R., & Gulisano, M. (2019). Continuous movement monitoring of daily living activities for prevention of diabetic foot ulcer: A review of literature. *International Journal of Preventive Medicine, 10*, 22. https://doi.org/10.4103/ijpvm.IJPVM_410_17
18. Lucisano, J. Y., Routh, T. L., Lin, J. T., & Gough, D. A. (2017). Glucose monitoring in individuals with diabetes using a long-term implanted sensor/telemetry system and model. *IEEE Transactions on Biomedical Engineering, 64*(9), 1982–1993.
19. Edge, J., Acerini, C., Campbell, F., Hamilton-Shield, J., Moudiotis, C., Rahman, S., Randell, T., Smith, A., & Trevelyan, N. (2017). An alternative sensor-based method for glucose monitoring in children and young people with diabetes. *Archives of Disease in Childhood, 102*(6), 543–549. https://doi.org/10.1136/archdischild-2016-311530
20. Facchinetti, A. (2016). Continuous glucose monitoring sensors: Past, present and future algorithmic challenges. *Sensors, 16*(12), 2093. https://doi.org/10.3390/s16122093
21. Rodbard, D. (2016). Continuous glucose monitoring: A review of successes, challenges, and opportunities. *Diabetes Technology & Therapeutics, 18*(2), 3–13. https://doi.org/10.1089/dia.2015.0417
22. Toschi, E., & Wolpert, H. (2016). Utility of continuous glucose monitoring in type 1 and type 2 diabetes. *Endocrinology and Metabolism Clinics of North America, 45*(4), 895–904. https://doi.org/10.1016/j.ecl.2016.06.003

23. Bellazzi, R., Dagliati, A., Sacchi, L., & Segagni, D. (2015). Big data technologies: New opportunities for diabetes management. *Journal of Diabetes Science and Technology, 9*(5), 1119–1125. https://doi.org/10.1177/1932296815583505
24. Cichosz, S. L., Johansen, M. D., & Hejlesen, O. (2015). Toward big data analytics: Review of predictive models in management of diabetes and its complications. *Journal of Diabetes Science and Technology, 10*(1), 27–34. https://doi.org/10.1177/1932296815611680
25. Devarajan, D., Subramaniyaswamy, V., Vijayakumar, V., & Ravi, L. (2019). Fog-assisted personalized healthcare-support system for remote patients with diabetes. *Journal of Ambient Intelligence and Humanized Computing, 10*, 3747–3760. https://doi.org/10.1007/s12652-019-01291-5
26. Longva, A. M., & Haddara, M. (2019). How can IoT improve the life-quality of diabetes patients? *MATEC Web of Conferences, 292*, 03016. https://doi.org/10.1051/matecconf/201929203016
27. Fernández-Caramés, T. M., Froiz-Míguez, I., Blanco-Novoa, O., & Fraga-Lamas, P. (2019). Enabling the internet of mobile crowdsourcing health things: A mobile fog computing, blockchain and IoT based continuous glucose monitoring system for diabetes mellitus research and care. In *5th International Electronic Conference on Sensors and Applications. Sensors* (Vol. 19(15), p. 3319). IEEE https://doi.org/10.3390/s19153319.
28. Gupta, P., Pandey, A., Akshita, P., & Sharma, A. (2020). IoT based healthcare kit for diabetic foot ulcer. In *Proceedings of ICRIC 2019* (pp. 15–22). Springer International Publishing.
29. Puri, V., Kumar, R., Le, D., Jagdev, S. S., & Sachdeva, N. (2020). BioSenHealth 2.0—A low-cost, energy-efficient internet of things–based blood glucose monitoring system. In *Emergence of pharmaceutical industry growth with industrial IoT approach* (pp. 305–324). Elsevier. https://doi.org/10.1016/B978-0-12-819593-2.00011-X
30. Charles, R. K., Mary, A. B., Jenova, R., & Majid, M. A. (2019). VLSI design of intelligent, self-monitored and managed, strip-free, non-invasive device for diabetes mellitus patients to improve glycemic control using IoT. *16th International Learning and Technology Conference* (Vol. 163, pp. 117-124). Elsevier (Procedia Computer Science). doi:https://doi.org/10.1016/j.procs.2019.12.093.
31. Fernández-Caramés, T. M., & Fraga-Lamas, P. (2018). Design of a fog computing, blockchain and IoT-based continuous glucose monitoring system for crowdsourcing mHealth. *5th International Electronic Conference on Sensors and Applications, 4*(1), 37.
32. Kharbouch, A., El Khoukhi, H., NaitMalek, Y., Bakhouya, M., De Florio, V., El Ouadghiri, D., Latré, S., & Blondia, C. (2018). Towards an IoT and big data analytics platform for the definition of diabetes telecare services. In *Smart application and data analysis for smart cities (SADASC'18)*. SSRN. https://doi.org/10.2139/SSRN.3186346
33. Ara, A., & Ara, A. (2017). Case study: Integrating IoT, streaming analytics and machine learning to improve intelligent diabetes management system. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*. IEEE. https://doi.org/10.1109/ICECDS.2017.8390043
34. Sujaritha, M., Sujatha, R., Nithya, R. A., Nandhini, A. S., & Harsha, N. (2020). An automatic diabetes risk assessment system using IoT cloud platform. In *EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing* (pp. 323–327). Springer International Publishing.
35. Haque, R. U., & Hasan, A. S. (2021). Privacy-preserving multivariant regression analysis over Blockchain-based encrypted IoMT data. In *Artificial intelligence and Blockchain for future cybersecurity applications* (pp. 1–16). IEEE. https://doi.org/10.1007/978-3-030-74575-2_3
36. Matheny, M., Israni, S. T., Ahmed, M., & Whicher, D. (2019). *Artificial intelligence in health care: The hope, the hype, the promise, the peril*. National Academy of Medicine.
37. Chinmay, C. (2019., [SCOPUS, IF-1.09]). *Computational approach for chronic wound tissue characterization* (Informatics in medicine unlocked) (Vol. 17, pp. 1–10). Elsevier. https://doi.org/10.1016/j.imu.2019.100162

38. Chinmay C., Arij N.A., Intelligent internet of things and advanced machine learning techniques for COVID-19, EAI Endorsed Transactions on Pervasive Health and Technology, 21(26) 1-14, 2021. https://doi.org/10.4108/eai.28-1-2021.168505
39. Polu, S. K. (2019). IoMT based smart health care monitoring. *International Journal for Innovative Research in Science & Technology (IJIRST), 5*(11), 58–64.
40. Pateraki, M., Fysarakis, K., Sakkalis, V., Spanoudakis, G., Varlamis, I., Maniadakis, M., . . . Koutsouris, D. (2019). Biosensors and internet of things in smart healthcare applications: Challenges and opportunities. In *Wearable and implantable medical devices - Applications and challenges*. Academic Press, Elsevier. https://doi.org/10.1016/B978-0-12-815369-7.00002-1
41. Ajami, S., & Teimouri, F. (2015). Features and application of wearable biosensors in medical care. *Journal of Research in Medical Sciences, 20*(12), 1208–1215. https://doi.org/10.4103/1735-19
42. National Academy of Sciences. (2013). Engaging patients, families, and communities. In R. S. Mark Smith (Ed.), *Best care at lower cost the path to continuously learning health care in America* (pp. 1–437). National Academy of Sciences.
43. Alotaibi, Y. K., & Federico, F. (2017). The impact of health information technology on patient safety. *Saudi Med Journal, 38*(12), 173–1180. https://doi.org/10.15537/smj.2017.12.20631
44. Sharma, D., Nawab, A. Z., & Alam, M. (2021). Integrating M-health with IoMT to counter COVID-19. In *Computational intelligence methods in COVID-19: Surveillance, prevention, prediction and diagnosis* (pp. 373–396). Springer Nature. https://doi.org/10.1007/978-981-15-8534-0_20
45. Dash, S. P. (2020). The impact of IoT in healthcare: Global Technological Change & the Roadmap to a networked architecture in India. *Journal of the Indian Institute of Science, 100*, 773–785. https://doi.org/10.1007/s41745-020-00208-y
46. Razdan, S., & Sharma, S. (2021). Internet of medical things (IoMT): Overview, emerging technologies, and case studies. *IETE Technical Review*. https://doi.org/10.1080/02564602.2021.1927863
47. Lalmuanawma, S., Hussain, J., & Chhakchhuak, L. (2020). Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV-2) pandemic: A review. *Chaos Solitons Solitons Fractals, 139*, 110059.
48. Sedik, A., Hammad, M., Abd El-Samie, F. E., Gupta, B. B., & Abd El-Latif, A. A. (2021). Efficient deep learning approach for augmented detection of coronavirus disease. *Neural Computing and Applications, 2021*, 1–18. https://doi.org/10.1007/s00521-020-05410-8
49. Turabieh, H., Abu Salem, A., & Abu-El-Rub, N. (2018). Dynamic L-RNN recovery of missing data in IoMT applications. *Future Generation Computer Systems, 89*, 575–583.
50. Khan, S. R., Sikandar, M., Almogren, A., Ud Din, I., Guerrieri, A., & Fortino, G. (2020). IoMT-based computational approach for detecting brain tumor. *Future Generation Computer Systems, 109*, 360–367.
51. Kilic, A. (2020). Artificial intelligence and machine learning in cardiovascular health care. *The Annals of Thoracic Surgery, 109*(5), 1323–1329.
52. Song, H., Bai, J., Yi, Y., Wu, J., & Liu, L. (2020). Artificial intelligence enabled internet of things: Network architecture and spectrum access. *IEEE Computational Intelligence Magazine, 15*(1), 44–51.
53. Rachakonda, L., Bapatla, A. K., Mohanty, S. P., & Kougianos, E. (2020). *Sayopillow: A blockchain-enabled, privacy-assured framework for stress detection, prediction and control considering sleeping habits in the IoMT*. Retrieved from arXiv:abs/2007.07377.
54. Fotopoulos, F., Malamas, V., Dasaklis, T. K., Kotzanikolaou, P., & Douligeris, C. (2020). A blockchain-enabled architecture for IoMT device authentication. In *2020 IEEE Eurasia conference on IoT, communication and engineering (ECICE)* (pp. 89–92). IEEE.
55. Esposito, C., De Santis, A., Tortora, G., Chang, H., & Choo, K. K. (2018). Blockchain: A panacea for healthcare cloud baseddata security and privacy? *IEEE Cloud Computing, 5*(1), 31–37.

56. Girardi, F., De Gennaro, G., Colizzi, L., & Convertini, N. (2020). Improving the healthcare effectiveness: The possible role of EHR, IoMT and blockchain. *Electronics, 9*(6), 884.
57. Noura, M. (2019). *Efficient and secure cryptographic solutions for medical data.* University, Bourgogne Franche-Comté, (theses).
58. Yanambaka, V. P., & Abdelgawad, A. Y. (2021). PIM: A PUF based host tracking protocol for privacy aware contact tracing in crowded areas. In *IEEE Consumer and Electronics Magazine* (pp. 1–1). IEEE.
59. Ma, H., Gao, Y., & Kavehei, O. R. (2017). A PUF sensor: Securing physical measurements. In *IEEE PerCom Workshops* (pp. 648–653). IEEE.
60. Masud, M., Singh, G. G., Alqahtani, S., Muhammad, G., Gupta, B. B., Kumar, P., & Ghoneim, A. (2020). A lightweight and robust secure key establishment protocol for internet of medical things in COVID-19 patients care. *IEEE Internet of Things Journal, 8*, 15694–15703.
61. Massaro, E., Kondor, D., & Ratti, C. (2019). Assessing the interplay between human mobility and mosquito borne diseases in urban environments. *Scientific Report, 9*(1), 16911. https://doi.org/10.1038/s41598-019-53127-z
62. Liaqat, S., Akhunzada, A., Shaikh, F. S., Giannetsos, A., & Jan, M. A. (2021). SDN orchestration to combat evolving cyber threats in internet of medical things (IoMT). *Computer Communications, 160*, 697–705.
63. Cecil, J., Gupta, A., Pirela-Cruz, M., & Ramanathan, P. (2018). An IoMT based cyber training framework for orthopedic surgery using next generation internet technologies. *Informatics in Medicine Unlucked, 12*, 128–137.
64. Askari, Z., Abouei, J., Jaseemuddin, M., & Anpalagan, A. (2021). Energy efficient and real-time NOMA scheduling in IoMT-based three-tier WBANs. In *IEEE internet things journal* (pp. 13975–13990). IEEE.
65. Badotra, S., Nagpal, D., Narayan, S., Panda, T., & S., & Bajaj, S. (2020). IoT-enabled healthcare network with SDN. In *8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)* (pp. 38–42). IEEE.
66. AlShorman, O., AlShorman, B., Al-khassaweneh, M., & Alkahtani, F. (2020). A review of internet of medical things (IoMT) – based remote health monitoring through wearable sensors: A case study for diabetic patients. *Indonesian Journal of Electrical Engineering and Computer Science, 20*(1), 414–422. https://doi.org/10.11591/ijeecs.v20.i1
67. Han, T., Zhang, L., Pirbhulal, S., Wu, W., & de Albuquerque, V. H. (2019). A novel cluster head selection technique for edge-computing based IoMT systems. *Computer Networks, 158*, 114–122.
68. Usman, M., Jan, M. A., He, X., & Chen, J. (2019). P2DCA: A privacy-preserving-based data collection and analysis framework for IoMT applications. *IEEE Journal on Selected Areas in Communications, 37*(6), 1222–1230.
69. Srilakshmi, A., Mohanapriya, P., Harini, D., & Geetha, K. (2019). IoT based smart health care system to prevent security attacks in SDN. In *2019 Fifth International Conference on Electrical Energy Systems (ICEES)* (pp. 1–7). IEEE. https://doi.org/10.1109/ICEES.2019.8719236
70. Zikria, Y. B., Afzal, M. K., & Kim, S. W. (2020). Internet of multimedia things (IoMT): Opportunities, challenges and solutions. *Sensors, 20*, 1–8. https://doi.org/10.3390/s20082334
71. Xu, B., Xu, L., Cai, H., Jiang, L., Luo, Y., & Gu, Y. (2015). *The design of an m-Health monitoring system based on a cloud computing plat form*. Talor & Francis.
72. Andriopoulou, F., Dagiuklas, T., & Orphanoudakis, T. (2016). *Integrating IoT and fog computing for healthcare service delivery*. Springer International Publishing Switzerland.
73. Singh, R. (2016). A proposal for mobile E-care health service system using IOT for Indian scenario. *Journal of Network Communications and Emerging Technologies, 6*(1), 2395-5317.
74. Haleem, A., Javaid, M., & Khan, I. H. (2019). Internet of things (IoT) applications in orthopaedics. *Journal of Clinical Orthopaedics Trauma, 11*(Suppl 1), S105–S106. https://doi.org/10.1016/j.jcot.2019.07.003

75. Bharati, S., Podder, P., Mondal, M. R., & Paul, P. K. (2020). Applications and challenges of cloud integrated IoMT. In *Cognitive internet of medical things for smart healthcare* (pp. 1–19). Springer. https://doi.org/10.1007/978-3-030-55833-8_4
76. Johnson, J. A. (2016). *FDA regulation of medical devices.* Congressional Research Service (CRS).
77. Sun, Y., Lo, F. P.-W., & Lo, B. (2019). *Security and privacy for the internet of medical things enabled healthcare systems: A survey* (p. 7). IEEE Access. https://doi.org/10.1109/ACCESS.2019.2960617
78. Rubí, J. N., & Gondim, P. R. (2019). IoMT platform for pervasive healthcare data aggregation, processing, and sharing based on OneM2M and OpenEHR. *Sensor, 19*, 1–25. https://doi.org/10.3390/s19194283
79. Nanayakkara, N., Halgamuge, M. N., & Syed, A. S. (2019). Security and privacy of internet of medical things (IoMT) based healthcare applications: A review. In *International conference on advances in business management and information technology*. Istanbul.
80. Vaiyapuri, T., Binbusayyis, A., & Varadarajan, V. (2021). Security, privacy and trust in IoMT enabled smart healthcare system: A systematic review of current and future trends. *International Journal of Advanced Computer Science and Applications (IJACSA), 12*(2), 731–737. Retrieved from www.ijacsa.thesai.org
81. Ajagbe, S. A., Adesina, A. O., & Oladosu, J. B. (2019). Empirical evaluation of efficient asymmetric encryption algorithms for the protection of electronic medical records (EMR) on web application. *International Journal of Scientific and Engineering Research, 10*(5), 848–871.
82. Rachakonda, L., Mohanty, S. P., & Kougianos, E. (2020). iLog: An intelligent device for automatic food intake monitoring and stress detection in the IoMT. In *IEEE transactions on consumer electronics*. IEEE.
83. Zhang, T., Sodhro, A. H., & Luo, Z. (2020). *A joint deep learning and internet of medical things driven framework for elderly patients*. IEEE Access.
84. Sayeed, M. A., Mohanty, S. P., Kougianos, E., & Zaveri, H. (2020). iDDS: An edge-device in IoMT for automatic seizure control using on-time drug delivery. In *2020 IEEE International Conference on Consumer Electronics (ICCE)* (pp. 1–6). IEEE.
85. Wei, K., Zhang, L., Guo, Y., & Jiang, X. (2020). Health monitoring based on internet of medical things (IoMT): Architecture, enabling technologies, and applications. *IEEE Access, 4*(8), 27468–27478.
86. Mawgoud, A. A., Karadawy, A. I., & Tawfik, B. S. (2020). A secure authentication technique in internet of medical things through machine learning. *Cryptography and Security*. https://doi.org/10.6084/m9.figshare.13311479.v2
87. Aman, A. H., Hassan, W. H., Sameen, S., Attarbashi, Z. S., Alizadeh, M., & Abdul Latiff, L. (2021). IoMT amid COVID-19 pandemic: Application, architecture, technology, and security. *Journal of Network and Computer Applications, 174*, 102886. https://doi.org/10.1016/j.jnca.2020.102886
88. Jain, S., Nehra, M., Kumar, R., Dilbaghi, N., Hu, T. Y., Kumar, S., Kaushik, A., & Li, C. (2021). Internet of medical things (IoMT)-integrated biosensors for point-of-care testing of infectious diseases. *Biosensors and Bioelectronics, 179*, 113074. https://doi.org/10.1016/j.bios.2021.113074
89. Nasajpour, M., Pouriyeh, S., Pariziy, R. M., Dorodchiz, M., Valero, M., & Arabnia, H. R. (2020). Internet of things for current COVID-19 and future pandemics: An exploratory study. *Research gate*. Retrieved from arXiv:2007.11147v2 [cs.CY] 25 Sep 2020.

90. Busvine, D. (2020). Covid-19: Germany launches smartwatch app to monitor coronavirus spread. Retrieved from https://www.thestar.com.my/tech/tech-news/2020/04/07/covid-19-germany-launches-smartwatch-app-to-monitor-coronavirus-spread
91. Ting, D. S., Carin, L., Dzau, V., & Wong, T. Y. (2020). Digital technology and COVID-19. *National Medicine, 26*(4), 459–461. https://doi.org/10.1038/s41591-020-0824-5
92. Song, Y., Jiang, J., Wang, X., Yang, D., & Bai, C. (2020). Prospect and application of internet of things technology for prevention of SARIs. *Clinical eHealth, 3*, 1–4. https://doi.org/10.1016/j.ceh.2020.02.001
93. Peeri, N., Shrestha, N., Rahman, M. S., Zaki, R., Tan, Z., Bibi, S., & Haque, U. (2020). The SARS, MERS and novel coronavirus (COVID-19) epidemics, the newest and biggest global health threats: What lessons have we learned? *International Journal of Epidemiology, 49*(3), 717–726. https://doi.org/10.1093/ije/dyaa033

Chapter 15
Healthcare Infrastructure in Future Smart Cities

D. Ajitha, Challa Sri Gouri, Shashi Bhanu Eklure, and Chinmay Chakraborty

Abstract Smart cities are defined as those cities which integrates the information with the technology to improve the lifestyle of people and increase the efficiencies of operation which helps the public. As we are aware health sector plays a significant role in our lives. It is imperative to improve the health care infrastructure. The major challenges that are faced in the health sector are limited staff, poor infrastructure, limited beds, and population. We can understand the seriousness of this situation in the current scenario. The best solution to this problem is adapting technologies for the development of health sector. IoT applications are being used in the health sector for the diagnosis of patients. Technologies like artificial intelligence, machine learning etc. can be used to improve the health care facilities and make it even more sophisticated. In this book chapter, we will discuss about the health care infrastructure in future smart cities. When we discuss about smart cities, as we are aware smart cities rely much on sensors. These sensors give us accurate measurements of various parameters and are helpful to us in monitoring the condition of a person. Health issues have become a major issue of concern due to the covid-19 pandemic. Balanced society is only possible when people are healthy. Smart health care in smart cities will pave the way for building a healthy society.

Keywords Smart cities · Health infrastructure · IoT · Artificial intelligence · Machine learning · Sensors · Monitoring devices · Diagnosis

D. Ajitha (✉) · C. S. Gouri · S. B. Eklure
Department of ECE, Sreenidhi Institute of Science and Technology, Hyderabad, India
e-mail: ajithad@sreenidhi.edu.in

C. Chakraborty
Department of Electronics and Communication Engineering, Birla Institute of Technology at Mesra, Ranchi, India
e-mail: cchakrabarty@bitmesra.ac.in

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_15

15.1 Introduction

Health care infrastructure in future smart cities deals with how effectively we use technology to improve the health care facilities and make it more feasible and reliable. The major advantages of smart cities are very less traffic, cleaner air which decreases the risk of getting effected by pollution and other minor problems. Adapting smart cities will help every one of us to change the global health care challenges into the best opportunities. Technologies that are emerging like AI, 5G, and other innovative implementations like smart cameras can help address the problems related to health care [1]. In smart cities, sensors can provide accurate information of different parameters like the temperature and humidity of a particular person, making the analysis easier. This smart system even helps to respond to emergency requirements faster, which helps us improve the conditions and decrease the death rates [2]. To be more specific, this adaption of technology will also help us improve a person's mental condition and assess whether he is affected by depression, anxiety, etc.

Using improved methods diagnosis, care coordination and monitoring the patient and fulfilling his requirements becomes easy. The major point to be discussed is when we use sensors for monitoring the environmental conditions helps residents to make note of pollution and take care of their health to know more about how can this implemented in various places and how infrastructure can become even more sophisticated let us look into this book chapter.

15.2 Major Challenges in Healthcare Systems

Especially when it comes to our country, there are many challenges being faced in the health sector. According to the WHO report India is in 112th position among 191 countries with respect to the health infrastructure. Major challenges are listed as follows. They are:

1. More importance is not being given to the health of rural people (which account to more than 68% of the total population) as a result of which they are prone to multiple diseases.
2. Complete dependence on western health infrastructure. No emphasis on preventive, public health care measures which makes it difficult during risk management.
3. Budget allocated for the health sector is very less (It is allocated only about 0.34% of the total GDP of the country). As we all know India is a country with vast population. Even after considering this the money spent on health sector is very less when compared to all other sectors hence the pace at which the health sector has grown is very low.

4. In some villages in India still there are issues of health infrastructure where poor people and people from poor backgrounds are away from enjoying these modern health facilities and even primary health care is far away to them [3].
5. Shortage of number of doctors and hospitals. The recommended ratio of doctors to population as per WHO norms are1:1000. Some states have been able to reach the target but many states have not reached the goal. Another important point to be considered is still there are many places where there are no primary health facilities also.
6. In India the amount we spend on Medical research is very less. For a country to develop health of its citizens must be given major priority. As funds released for medical research are very less coming up with new medicines and innovative solutions in the field of medicine becomes impossible. Although India is a major drug and vaccines manufacturing country but the country needs to become self sufficient to meet its needs with respect to the various devices also.

Now let us have some deep discussion about some of the major challenges faced in health sector in the well developed countries. With the improved technology, most countries are using AI-based models to diagnose health. When the technology is used for the diagnosis the major issue arising is with keeping the data secure as stored data is prone to data breach or hacking [4]. When we use AI-based integrated software, the people using it must be well aware of handling the software's data. The second major issue with the improved technologies is the cost. As these software models are highly sophisticated, their rising cost makes them unaffordable for many people. Usage of technology to increase productivity in the health sector gives everyone a great experience, and it can help overcome many problems. When it comes to the digital era, cyber attacks also became an issue of concern. As we are storing the entire data using software, making sure it is protected is very important. When this data is hacked, it may lead to many negative consequences [5].

By understanding the major challenges in health sector we are very clear about the condition we are in with respect to the health infrastructure. Now let us focus on how can we integrate our health sector with the technology and discuss about new ways in which we can make our health care system even more sophisticated and secure. In the next topic let us discuss about few innovative ideologies of improving the health care system and how this can be achieved in future smart cities [6]. There are even some cons of using technology for diagnosis. We shall find out ways in which we can overcome some of the limitations in the smart healthcare systems for the future smart cities by surveying the parameters of the system.

15.2.1 Future Smart Cities and Role of Healthcare

The term "smart city" refers to usage to technology to enhance the quality of life of people to ensure faster growth and good quality life for citizens. A smart city may have various amenities which maybe automated to a large scale. However, we shall focus on health care infrastructure, which has become an issue of concern. In the wake of pandemic situations, the basic life support system had failed miserably, catering to the needs of the population, which is the basic motto of any nation. With the enhancement in various t, a person's life of a person has increased so taking care of all age groups of people has become essential [7]. Future smart cities must possess robust health infrastructure so that no person is denied care. The ratio of health workers to that of population has always remained less; hence, the gap between patients and hospitals must be bridged using smart technologies, be it IoT or AI. Future smart city's must be able to make a work-life balance for health workers as their schedule is always hectic. As outbreaks of new viruses and bacteria are becoming quite frequent, the development of healthcare systems must be such that it can handle present and future disease outbreaks.

Although cent percent automation of any sector doesn't seem to be practical but the machinery used till date are very basic and don't even offer partial automation. Hence, future smart cities must be able to at least partially automate the health sector to decrease the burden upon the system. Future smart cities must have systems that can overcome the flaws in the present system. The health care system of the future will offer more choices and convenience to the people. Finding physicians shall be easier and faster. Mainly, the system will reduce time for providing quality healthcare. The hospitals offering healthcare in the future shall offer reduced costs and waiting time will provide precision medicine and reduce human errors, thereby achieving greater customer satisfaction [8]. The health care will be people friendly and will help in increasing the lifetime of people by providing best of best healthcare with greater accessibility and with optimum costs.

15.3 Technology and Healthcare System

Healthcare sector is one of the sectors which seem to be highly developed but actually are lagging behind in many factors. Since healthcare is a high risk sector it has very low acceptance rate of newly developed devices and generally rely upon many of the devices which are developed long ago. The heath services sector faced a huge setback when countries were hit by the severe covid waves and people were left with less life saving drugs and devices. Although the healthcare sector views the Information Technology Industry quite seriously for management of several records and reports but the manufacturers or distributors are still depending upon the old techniques for manufacturing devices [9]. The world of medicine is filled with several devices and equipments which require primary or basic proficiency to operate. Technology has enabled health centers to treat several critical diseases but higher costs of treatments still remain a challenge to the people especially the people having lower income. The main problem is that Medical technology is somewhat expensive leading to rise of prices. Modern technology had increased the accuracy of treatment but emerging technologies can prove to be game changers in the field. The Technologies are being enhanced but higher input costs are also a very crucial factor.

The hospitals and healthcare chains show high resistance towards costly equipments as they fear long-term sustainability of such equipments.

The shift in technology however can help in improving quality care. Technological developments can actually lead to enhanced transparency and people can have higher assurance of their medical advices or treatments and reports which are being provided [10]. Technology can positively help in decreasing the load on primary heath sectors by easing the pressure on doctors and diverting them to online consultations, e-guides for emergency treatment directives using chat bots [11]. Although implementing very basic technologies such as fitness bands and steps tracker apps people have shifted to a very healthy side by tracking their own steps and calories burnt or continuously monitoring their heart rates and blood pressures. Suppose advanced technologies are implemented across the health sector. In that case, people shall adapt to the changes, and it can help build a very people-friendly environment in the health sector.

15.4 Case Studies

15.4.1 Smart Devices

A device that uses different wireless protocols to get connected to other devices is known as smart device. There as various smart devices as mentioned in the following sections.

15.4.1.1 Electronic Health Record

It is a herculean task to keep track of a patient's medical history in a country like India. Until now, the majority of health centers have relied on paper-based medical records that are updated on each subsequent visit. Although the records have been more digitalized over time, the information is not available at all levels or at all times. As we know there are many number of healthcare centers be it a primary level healthcare centre or a multispecialty hospital many times due to lack of patient history suitable treatment is not provided on time which leads to loss of many lives. To overcome this shortcoming in the healthcare system electronic health record becomes a necessity. The basic function of this electronic heath record is to maintain the whole history of patient and to make it available in such a database so that it will be accessible at all levels and good quality healthcare can be provided [12]. The Electronic health record provides the medical history, previous laboratory test reports along with the medicines priorly used.

15.4.1.2 Continuous Glucose Monitoring System

The disease of diabetes is most prevalent disease across the countries. The blood glucose monitoring generally requires blood samples before eating and after eating and then test reports is indicated and even it is time consuming in order to reduce the load on the time consuming testing an IoT based device can help us out by providing real time data to the user and shall help in monitoring the sugar levels at any particular instants of time [13]. The glucose sensor is attached to body and a vital sign sensors are attached then is connected to android gateway where the notification is issued and local data storage takes place [14]. For providing reports it even stores it in the cloud for showing the total data.

15.4.1.3 Health Care System for Parkinson's Disease Patients

Nowadays, Parkinson's disease is a common ailment in the aged group also; this disease is attacking the younger generation too, the people with Parkinson's do suffer from various types of illnesses, but mostly, they have loco motor diseases, thus disabling them from free movements [15]. The monitoring of patients is a challenge hence we need a tool which can help in continuous monitoring of body. The components consist of an EEG sensor, Arduino board, Bluetooth Device, Cloud server. The Data collection is done with the help of an EEG sensor, the EEG sensor decodes the signals from the brain and then sends to the local processor at the arduino board it collects and then processes the data and is forwarded to the compression and encryption phase which in turn sends and gives the simulation results [16].

15.4.1.4 Blood Pressure Monitoring Using IoT

Blood pressure monitoring has become like a daily routine for monitoring blood pressure at some instants of time. Though there are many wearable devices available but the accuracy does not seem to be really good so in turn if the blood pressure is monitored using and smart device the results which are more accurate can help in better health monitoring of a person and the patient can be given timely care [17].

15.4.1.5 Wearable IoT Device for Cardiac Arrests Prediction

Cardiac arrests have become a serious concern as they account for majority of deaths occurring. The monitoring of the heart has become a necessity because of the lifestyle of people, and it has become quite unhealthy, and the heart is getting affected the most [18]. By merely knowing the heart rate, one cannot predict that a cardiac arrest can happen; hence, close monitoring of the heart is necessary. The architecture of the heart monitor consists of the data collection chips, data transmission module, data analysis module, and storage, which also gives real-time data to the user.

15.4.2 IoT Applications in Healthcare

The main applications of IoT in the healthcare sector are to make accessible clinical care, remote monitoring and context awareness. Figure 15.1 shows the applications of IoT.

15.4.2.1 Clinical Care

The clinical care refers to the continuous monitoring of the critical patients using an IoT interface. The patients who require continuous care and monitoring shall have the benefit as a single administrator can take care of several patients together thereby helping the patients as well as the doctors and nurses [19]. Also IoT can help building such interfaces which shall help in resolving the issues with acute disease care by making telemedicine accessible reliable safe and cost effective so that with use of telemedicine there is least loss of time and effectiveness of treatment is not affected.

15.4.2.2 Remote Monitoring

Remote monitoring simply deals with the set of applications used for treatment of the individuals from far distances. The remote monitoring mainly focuses on the section of population which needs healthcare regularly and is prone to get sick (e.g. senior citizens children etc). This helps provide treatment of those people from a far distance and even get quality suggestions and treatments from expert physicians [20].

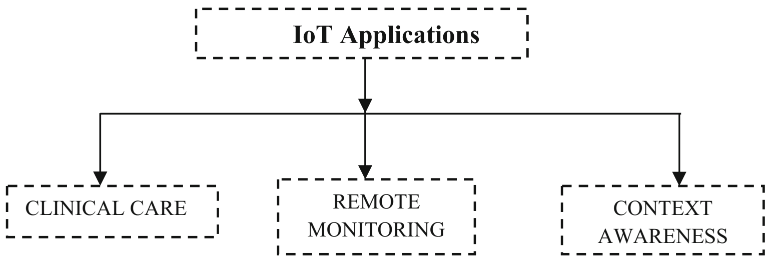


Fig. 15.1 Block diagram of IoT applications

15.4.2.3 Context Awareness

As we know, context awareness means the ability of a system or a component to gather information about its environment at given time [21]. So in IoT the software and hardware components automatically collect data from the surroundings of patient and indicates it to the user so that the treatment is done according to surrounding condition and the variations in the environment are recorded to understand the impacts of surrounding conditions on individuals.

15.4.2.4 Iot Based Detection and Control of Infectious Disease

The emergence of several infectious diseases over the years has caused the scientific community to search for various ways to limit the spread of infection and after the corona virus diseases having been spread exponentially across the globe scientists are looking for effective ways to do contact tracing to limit the reach of virus. Using various sensors for contact tracing and connecting the data of all sensors to the cloud will help in collection of the various parameters including location, Bluetooth, camera, distance monitoring etc. Processing such data can help a lot in finding the potential risks and saving people from getting infected [22].

15.4.2.5 IoT in Self Health Management

With advancement of technology, self management has become a boon as wearable devices being used as well as the devices which are in use are capable of recording the data, preprocessing it storing the data and even showing to the user all the processing and management are being done with ease and has transformed many clinical based tests to self centered tests. The wearable devices have become an effective option and the communication between device and person is very efficient and easy. The quality of lifestyle of people is indirectly improving because of such devices as people are becoming fitness freaks and taking care of all their vital parameters and saving themselves from many potential health risks [23].

15.4.3 Proposed Method

15.4.3.1 Smart Hospital Bed

The smart hospital bed is said to be a device which is capable of performing several operations by itself on giving commands it shall perform the operations such as changing the height of the bed like moving it upwards or downwards, there shall also be an emergency button which will glow the buzzer when the patient requires any help such as the patient wants water or the saline bottle needs to be changed such

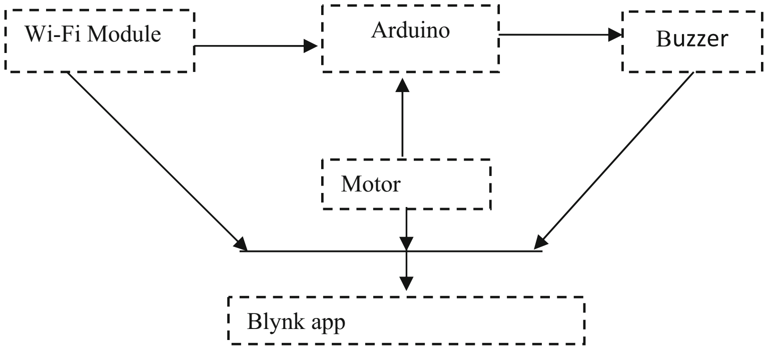


Fig. 15.2 Block diagram for smart hospital bed

micro operations can be performed by just seeding the working devices with the arduino board for its operation. The app will help in performing the requisite operations and help in smooth functioning of the operations.

The block diagram of smart bed shown in Fig. 15.2. Wi-Fi module is used for wireless transmission of data for this movement of bed we use motors which are connected to arduino. To alert the patient when it's time to take medicines we use buzzers. This entire system is controlled by Blynk app.

15.4.3.2 Components Required

Blynk App

The Blynk App is an application especially for the Internet of Things. The app can remotely control the hardware; it can display the sensors data, store the data collected, and visualize the data. It can control the Arduino, raspberry Pi etc. over the internet.

Wi-Fi module

The Wi-Fi Module is used in the transmission module of and IoT based device. The function of the wifi module is to host the application and offload all the wifi networking functions from another application processor.

Motor

A Motor is an electronic device or an electrical machine which converts the electrical energy into mechanical energy. The function of the motor is said to move the bed in upward or downward direction for easy movement of the patient.

Buzzers

A buzzer is a beeper or audio signaling device which can be mechanical electro-chemical or piezoelectric. The buzzers are used for confirmations of inputs or processing of the command.

Arduino Board

An Arduino board is open source hardware and software. Arduino board generally is able to read the inputs. The microcontroller board is based on the ATmega168. The board is equipped with the sets of digital and analog inputs and outputs. The board consists of 14 digital input output pins and is programmable with the arduino integrated development environment. It can be powered by an external battery of about 9 volts.

15.5 Big Data Analytics in Healthcare

Big data generally refers to set of large data which is practically not possible to store physically. Big data enable integration of large data related to healthcare to be stored at a unified server [24]. If the single data base is able to incorporate the needs of the whole sector in that case, the treatment process shall be simplified as all data related to research, clinical trials, and treatment and prescriptions. Big data is an efficient tool which can help to build models. Big data shall help people to record even a small procedure for example a diabetic patient who takes insulin can record the time and measure how much insulin is administered [25]. For aged persons who have problems related to memory can record the time and amount of medicine taken so as to refer afterwards and take only required amount of medicine [26]. Big data Analytics are very useful and shall enhance the efficiency of IoT and AI models as big data can store huge amount of data and hence can facilitate the use of this data by other technologies. If the prediction models are made by use of big data and AI then the model shall give highly effective and precise results which can be practically believed and shall bridge the gap between modernization and health care system. Big data can be a game changer technology for sectors having huge data storages. Big data can solve maximum problems of precision medicine [27]. Big data exhibits some features like it helps to improve personalized care to patients, It is helpful for implementing preventive strategies. It predicts health outcomes and excellent tool for risk assessment in patients [28]. Big data can help governments to get the whole data of population and helps in detecting the health index of population and reduces the adverse effects in patients. Big data can help in cost reduction as it shall provide data thereby helping in finding diseases at earliest and reducing burden of scores of tests.

15.6 Artificial Intelligence and Its Effectiveness in Healthcare

Artificial Intelligence and emerging technologies are being developed not to replace human resources but to make a meaningful impact on the whole sector for its all-around and enhanced development and to cope with the shortcomings in healthcare systems [29]. AI also we have three types of AI first one being artificial narrow intelligence, secondly Artificial General Intelligence and Artificial Super Intelligence. The first type Artificial Narrow Intelligence is primitive type of AI which had ability to perform a task and only a specific task at a time. The artificial narrow intelligence is already in use the chat bots are an example of artificial narrow intelligence. The second type Artificial general intelligence is the mid-level AI which is a process which is at par with human brain and the third type of AI Artificial Super Intelligence which is said to be way more advanced than human brains [30]. For providing healthcare and good quality health care main principles followed are Availability, Accessibility, acceptability and Quality. Due to less health infrastructure the healthcare system fails to follow these principles but addition of such technologies helps in making the infrastructure better and brings it up to a level where it shall be able to meet the requirements of the people [31].

15.6.1 The Aspects of Implementations of Artificial Intelligence in Healthcare

- Human Resource Crisis: Approximately 400 million people across the world do not have access to healthcare at all and around 5 billion people cannot afford the basic healthcare. AI shall help in making the minimum and basic facilities available to those affected [32].
- In Poor Countries: In poorer countries and small isolated nations healthcare is scarcely available lack of basic technologies tend to increase the threat to such countries as they are left far behind when compared to developing or developed nations if a cost effective model is made which shall be handy easy to use and accessible then such countries can be uplifted from the health crisis.
- For AI to be applied in healthcare at first large data must be stored so that the AI can analyze it and make predictions AI is basically having Machine learning and Basic Language Processing.
- ML is capable of processing available data directly whereas the natural language processing (NLP) has to convert the available data to machine readable language and then it processes the data so ML is slightly faster than that of NLP [33, 34].
- For more complex analysis of data Deep learning is used as it is capable of doing a critical analysis of data and said to produce best results when compared to others.

15.6.2 Applications of Artificial Intelligence in Healthcare

Emerging technologies are becoming prevalent in many sectors and so is the healthcare sectors by using such technologies one can change transform many aspects of patient care. Artificial Intelligence isn't just a single model but it is classified as generally on the basis of Deep Learning, Machine Learning and Neural Networks [35].

Machine learning is the most common form of Artificial intelligence. The purpose of using Machine learning in the Medical field is to provide Precision Medicine to the patients. It basically predicts which protocol must be followed to succeed in providing precision treatment [36].

15.6.2.1 Artificial Intelligence in Radiology

The interest of Artificial Intelligence has seen an exponential growth since the technology of deep learning has achieved appreciable success as it has the potential to recognize the complex patterns, with appropriate integration of technology the inaccuracies in the disease detections can be eliminated and a more reliable infrastructure can be developed. Chest X-rays are the most common radiology tests conducted these are used for detecting the various diseases in the lungs [37]. With the Deep learning technology most of the data being stored the tested reports are then compared to rightly detect the disease with which the person is affected. Since in the physical reports a very clear and magnified view of the detected patches are sometimes not rightly judged which leads to disease getting more prevalent in the particular body part, whereas the data analyzed by the AI software does a segmentation process which does the in-depth analysis to find out the exact cause [38].

Pulmonary analysis in the computerized tomography (CT), CT scan is generally considered as the gold standard test in broad range of highly prevalent pulmonary diseases, since CT had high resolution and is in three dimension it shows better results than that of an X-ray scan [39]. To efficiently detect the abnormalities the CT scan. Large data can be stored and AI can be applied for recognizing diseases.

AI systems also do play an important role in the detection of cancer related diseases. AI can help in the detection, segmentation and tumor growth prediction. For instance, detecting pancreatic cancers is generally very hard since the pancreas has variable shapes and sizes. When it comes to tumor detection in the pancreas, it becomes even more complex [40]. Even after multiple tests, sometimes the cancers remain very undetectable, leading to worsening of diseases. Also, pancreatic cancer patients have one of the lowest survival rates.

15.6.2.2 Artificial Intelligence in Robotic Surgeries

While in operation theatres, the particular surgeons must be very precise while making any type of incisions or any surgical tasks [41]. The repetitive tasks are challenging for better assistance to surgeons. The advancements in these emerging technologies help in better surgeries that are performed. The surgical robots are programmed devices that are very controlled in their movements its depth and speed are defined and repetitive movements are performed with ease. Deep learning automates the behavior of the machine; hence even a sub-millimeter precision is possible. Already eye surgeries are automated, and on the lines, many different surgical robots are being developed. The automation will ease the stress of precise surgeries and help in betterment of health infrastructure.

15.6.2.3 Artificial Intelligence in Supporting Clinical Decisions

The improvements and advancements in the various technologies like deep learning and machine learning have led to increased interests and larger affinity towards the development of clinical decision support systems. The development of clinical decision support devices will lead to the enhancement of medical provisions, and shall give more affordable advisories.

Such systems will help the medical fraternity provide better advice to the people, be it critical surgeries or any general medications [42]. The main purpose of the support systems is to provide requisite guidance and assurance as more specific advice leads to a higher probability of success in the treatment [43]. Moreover, with time, doctors' decisions and the evidence-based treatment strategies found through the decision systems will get high acceptance from patients.

15.6.2.4 Nursing and Managerial Assistance Using Artificial Intelligence

The excess workload on healthcare professionals has prompted the industry to start exploring tools like chat bots aided by artificial intelligence for engaging in conversation with patients. The chat bots can effectively converse with users but also it can direct them the best and effective care as the chat bots are available round the clock they can respond to the queries of the users as well as self examine them [44]. The virtual assistants can even facilitate wellness checks through the responses of the user.

15.6.3 Benefits of Ai in Healthcare

Artificial Intelligence has ability to add many convenient efficient and advantageous technologies in the healthcare sector, some of the advantages are as under [45].

1. Artificial intelligence has the ability to analyze and process big data efficiently and even helps in giving future predictions.
2. The accuracy achieved through AI is higher than humans hence helping to reduce errors in predictions.
3. AI is helpful in revolutionizing the surgical procedures as machines don't get tired and produce precise results.
4. AI helps the physicians to observe health patterns of patients easily as it records and show the whole data recorded for a particular person this is helping the physicians to provide precision medicine also [46].
5. High intensity works are being performed with ease by the help of robots and computers.
6. AI is helping the health system to become autonomous and being less dependent upon humans for various kinds of work.
7. AI is useful in providing widespread accessibility to less developed regions and nations as its providing connectivity across the globe.

15.7 Smart Healthcare: Impact on Health Sector

15.7.1 Disease Diagnosis and Treatment

As we know already the artificial intelligence is widely applied in the research and development sector but at the present stage there is a need for such emerging technologies to help in the prevention of epidemic diseases and help in achieving the aim of a healthy world with minimal diseases [47]. A world free of epidemic outbreaks and even free from seasonal ailments. Artificial intelligence with help of gathered data can help in finding exact causes of ailments and providing timely treatments in order to reach maximum outcome from medicines and even have a healthy population. The uses of such technologies will help in decreasing human errors and provide a step ahead approach in healthcare.

15.7.2 Precision Medicine

The pharma industry has always tried to produce such medicines which should have high efficiency and minimum side affects on the patients. But the side affects of medicines depend upon the patients body type. The AI can help this problem in such a way that there should be storage of large data of numerous patients who exhibit various responses to different medicines this can help doctors to prescribe only those medicines which shall suit the body type of the particular patients.

15.7.3 Big Data of Electronic Health Records

The electronic health record is basically the total medical history of many patients stored in a single database. This is helpful for easy reference of patients' medical history for providing the treatment in accordance with the previous ailments which the patients had. This single database will make the healthcare facilities accessible across the country so that the patient gets the right care at the right time irrespective of the hospital or health centre he or she uses.

15.7.4 Drug Manufacturing

The usage of machine learning at an early stage can help in precision manufacturing of drugs, in the recent pandemic while in development of vaccines the environmental factors have to be monitored meticulously, the changes in temperature or pressure in surroundings lead to chemical changes of the drugs. The drugs if initially monitored and compared with the available data can help in early determination of the efficiency of the medicine well in advance and if the drugs are having good efficiency and prediction technique is having good success rate then stockpiling of drugs can help in overcoming the shortage of many lifesaving drugs. And millions of people can be saved from the prevalent diseases and the herd immunity of the population is achieved thereby breaking the chain of transmission of disease [48].

15.7.5 Clinical Trials and Research

If the clinical trials which are performed with large number of participants the side effects of the drugs is generally observed and in many of the cases the previous records of participants can help in prediction of possible side effects and the real time monitoring of participants can be done for increased efficiency [49]. Even when large numbers of participants are there then the compiling of the data of the trials can be done with ease thereby data can be published at earliest.

15.7.6 Prediction of Epidemics

At present data can be collected from various locations which have seen epidemic outbreaks. The factors which had contributed to outbreaks can be studied and preventive measures can be taken up at the earliest.

The temperatures of the physical conditions which had lead to outbreaks is studied and hence the local environment can be made as such that the diseases do not grow with time and humans or any animals aren't affected by any of the viruses.

15.7.7 IoT DEVICES

An IoT device which would enable widespread communication and physicians can send their data to the platform and those who access the data would be able to get real time consultancies and well as stored data can be accessed in case of emergencies. The patients hence shall be offered any time consultancies with doctors and especially in emergency cases it would do a great help to the patients with high risk diseases doctors also will have wider approach to their patients.

15.8 Challenges Faced by Healthcare Workers

The emergence of the corona virus pandemic has put forth scores of challenges in the lives of healthcare workers. The health care workers are working under extreme pressure and stress in a field like healthcare, not only in pandemics but also in general situations. They also work for long shifts, and intense or critical healthcare requires continuous monitoring of patients [50].

In unprecedented situations like shortage of beds and medicines the health workers have to take many decisions that how to provide best care with inadequate or constrained resources, they have to think that in what way they can align their lives with friends family as well as patients [51]. The health workers have to maintain a balance between the personal and professional lives. The health workers are undergoing moral injuries. After seeing number of adverse situations everyday they have to continue to work.

The nurses, doctors, and health workers always have to handle the less availability of resources in the health sector even after the emergence of the highly infectious corona virus disease. Still, our healthcare sector is working with minimal automation [52]. Evenwhen such diseases are being spread still manual care is required still the healthcare workers depend upon masks PPE kits and sanitizers. And in such cases the hospitals aren't even equipped with semi automated devices such as pill dispensers or remote operated food trays; still devices are being searched for monitoring patients and giving them proper care.

The pressure on the health sector is such that a single doctor has to treat hundreds of people and in countries like India there is vast population but the health infrastructure is still far from sufficient. The healthcare sector is a sector which has high risk and even less income promotions which also takes toll on the mental health of the workers [53].

The healthcare sector has faced less manpower than required as they require very high skills there is also very less resources. The health care workers undergo through anxiety due to the environment experienced by them in the hospitals. The health workers somehow loose their social contact with their near and dear ones. Most of the doctors and nurses seem to have most of the stress because of the patients more than their own families.

Although the health workers are doing their own duties but the level of responsibility on them are really high. The doctors are nurses who do not just have to think about their families, but many patients lives lies in their hands and working under such circumstances even make number of doctors depressed.

15.9 Conclusion and Future Scope

It is clear from the above discussions that the healthcare in future smart cities will be more sophisticated. Considering the public health smart cities are very important [54]. Smart cities will enhance the potential of the health care systems and will bring major improvements [55]. In smart systems the health care analysis depends on the data base. In this book chapter we discussed about the application of IoT in health care systems. We also proposed the smart bed which is one of the major applications of IoT in health care system. There are many challenges in smart health care systems [56]. In the future, new technologies will also emerge which will be very helpful in accurate diagnosis of patients. There are various health care smart devices such as Electronic Health record, continuous glucose monitoring system, wearable IoT devices, Blood pressure system using IoT etc. [57]. In this book chapter we also discussed about how well technology can be used in improvising the health care system. This shows effectiveness of technology in health care systems [58]. In proposed methodology we discussed about smart bed system. We also explored about the ways in which AI can be used in making the systems sophisticated [59]. The future scope in the work must be focused upon eliminating the system vulnerabilities such as data breach so that the dependability upon such technologies can be greater and even the public shall be satisfied as their data will be safe. The technologies developing should be implemented in phased manner because making a smart city isn't a small task when technologies will be developed and implemented over the years then only the goal of a smart city and robust infrastructure can be completed [60]. Smart technologies can help in reducing carbon emissions which can avoid health related challenges. Integration of technologies with development and databases can help us in achieving the desired targets. Automated computer aided tools can be used for accurate and to address large number of people [61]. In case of harmful diseases like cancer Support Vector Machine base classifier can be used for higher degree of accuracy in detection of diseases [62]. Smart phone enabled compression technique can be used for finding the healing status of chronic wounds [63]. Various technologies can be used for continuous health monitoring to make a robust post pandemic health model [64]. Generative design methodologies can be used for creating functional Internet of Medical things based bio medical devices [65]. Analytical approaches and technological solutions can be an added advantage to future smart cities [66]. Future smart cities can enhance the quality of living of people with best health and environment techniques [67].

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Shah, R., & Chircu, A. (2018). IoT and AI in healthcare: A systematic literature review. *Issues in Information Systems, 19*(3), 33–41.
2. Ghani, A. (2019). Healthcare electronics—A step closer to future smart cities. *ICT Express, 5*(4), 256–260.
3. Ismagilova, E., Hughes, L., Rana, N. P., & Dwivedi, Y. K. (2020). Security, privacy and risks within smart cities: Literature review and development of a smart city interaction framework. *Information Systems Frontiers, 21*, 1–22. https://doi.org/10.1007/s10796-020-10044-1
4. Palanica, A., Flaschner, P., Thommandram, A., Li, M., & Fossat, Y. (2019). Physicians' perceptions of chatbots in health care: Cross-sectional web-based survey. *Journal of Medical Internet Research, 21*(4), e12887.
5. Lee, S. M., & Lee, D. (2020). Lessons learned from battling COVID-19: The Korean experience. *International Journal of Environmental Research and Public Health, 17*(20), 7548.
6. Manohara, M., Pai, M., Ganig, R., Pai, R. M., & Sinha, R. K. (2021). Standard electronic health record (EHR) framework for Indian healthcare system. *Health Services and Outcomes Research Methodology, 21*, 339–362. https://doi.org/10.1007/s10742-020-00238-013
7. Gopal, K. M. (2019). Strategies for ensuring quality health care in India: Experiences from the field. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine, 44*(1), 1.
8. Balsari, S., Fortenko, A., Blaya, J. A., Gropper, A., Jayaram, M., Matthan, R., Sahasranam, R., Shankar, M., Sarbadhikari, S. N., Bierer, B. E., & Mandl, K. D. (2018). Reimagining health data exchange: An application programming interface–enabled roadmap for India. *Journal of Medical Internet Research, 20*(7), e10725.
9. Yasaka, T. M., Lehrich, B. M., & Sahyouni, R. (2020). Peer-to-peer contact tracing: development of a privacy-preserving smartphone app. *JMIR mHealth and uHealth, 8*(4), e18936. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/32240973
10. Chatterjee, S., Kar, A. K., Dwivedi, Y. K., & Kizgin, H. (2019). Prevention of cybercrimes in smart cities of India: From a citizen's perspective. *Information Technology & People, 32*(5), 1153–1183.

11. Haque, S. A., Aziz, S. M., & Rahman, M. (2014). Review of cyber-physical system in healthcare. *International Journal of Distributed Sensor Networks, 10*(4), 217415.
12. Ganiga, R., Pai, R. M., Manohara Pai, M. M., & Sinha, R. K. (2020). Security framework for cloud based electronic health record (EHR) system. *International Journal of Electrical and Computer Engineering, 10*(1), 455.
13. Gia, T. N., Ali, M., Dhaou, I. B., Rahmani, A. M., Westerlund, T., Liljeberg, P., & Tenhunen, H. (2017). IoT-based continuous glucose monitoring system: A feasibility study. *Procedia Computer Science, 109*, 327–334.
14. Villena Gonzales, W., Mobashsher, A. T., & Abbosh, A. (2019). The progress of glucose monitoring—A review of invasive to minimally and non-invasive techniques, devices and sensors. *Sensors, 19*(4), 800.
15. Al Rasyid, M. U., Saputra, F. A., & Christian, A. (2016). Implementation of blood glucose levels monitoring system based on wireless body area network. In *2016 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)* (pp. 1–2). IEEE.
16. Siam, A. I., Abou Elazm, A., El-Bahnasawy, N. A., El Banby, G., Abd El-Samie, F. E., & Abd El-Samie, F. E. (2019). Smart health monitoring system based on IoT and cloud computing. *Menoufia Journal of Electronic Engineering Research, 28*, 37–42.
17. Hashim, N., Noordin, N., Idris, F., Yusoff, S. N., & Zahari, M. (2020). IoT blood pressure monitoring system. *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS), 19*(3), 1384–1390.
18. Majumder, A. K., ElSaadany, Y. A., Young, R., & Ucci, D. R. (2019). An energy efficient wearable smart IoT system to predict cardiac arrest. *Advances in Human-Computer Interaction, 12*, 2019.
19. Nausheen, F., & Begum, S. H. (2018). Healthcare IoT: Benefits, vulnerabilities and solutions. In *2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 517–522). IEEE.
20. Postolache, O., Hemanth, D. J., Alexandre, R., Gupta, D., Geman, O., & Khanna, A. (2020). Remote monitoring of physical rehabilitation of stroke patients using IoT and virtual reality. *IEEE Journal on Selected Areas in Communications, 39*(2), 562–573.
21. Armgarth, A., Pantzare, S., Arven, P., Lassnig, R., Jinno, H., Gabrielsson, E. O., Kifle, Y., Cherian, D., Sjöström, T. A., Berthou, G., & Dowling, J. (2021). A digital nervous system aiming toward personalized IoT healthcare. *Scientific Reports, 11*(1), 1–1. https://doi.org/10.1038/s41598-021-87177-z
22. Hu, P. IoT-based contact tracing systems for infectious diseases: Architecture and analysis. In *GLOBECOM 2020–2020 IEEE Global Communications Conference 2020 Dec 7* (pp. 1–7). IEEE.
23. Chakraborty, C., Roy, S., Sharma, S., Tran, T., Dwivedi, P., & Singha, M. (2021). IoT based wearable healthcare system: Post COVID-19. *The Impact of the COVID-19 Pandemic on Green Societies Environmental Sustainability, 1*, 305–321.
24. Wang, T., Bhuiyan, M. Z., Wang, G., Rahman, M. A., Wu, J., & Cao, J. (2018). Big data reduction for a smart city's critical infrastructural health monitoring. *IEEE Communications Magazine, 56*(3), 128–133.
25. Baum, S. (2013). A remote monitor embedded in insulin pen caps could help personalize diabetes treatment. *MedCityNews*.
26. Clim, A., Zota, R. D., & Tinica, G. (2019). Big data in home healthcare: A new frontier in personalized medicine. Medical emergency services and prediction of hypertension risks. *International Journal of Healthcare Management, 12*(3), 241–249. https://doi.org/10.1080/20479700.2018.1548158
27. Rehman, A., Naz, S., & Razzak, I. (2021). Leveraging big data analytics in healthcare enhancement: Trends, challenges and opportunities. *Multimedia Systems, 21*, 1–33.
28. Sheikh, A., Anderson, M., Albala, S., Casadei, B., Franklin, B. D., Richards, M., Taylor, D., Tibble, H., & Mossialos, E. (2021). Health information technology and digital innovation for national learning health and care systems. *The Lancet Digital Health, 3*(6), e383–e396.

29. Rigby, M. J. (2019). Ethical dimensions of using artificial intelligence in health care. *AMA Journal of Ethics, 21*(2), 121–124.
30. Dong, W., Guan, T., Lepri, B., & Qiao, C. (2019). PocketCare: Tracking the flu with mobile phones using partial observations of proximity and symptoms. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 3*(2), 1–23.
31. Davenport, T., & Kalakota, R. (2019). The potential for artificial intelligence in healthcare. *Future Healthcare Journal, 6*(2), 94.
32. Hossain, M. M., Sharma, R., Sultana, A., Tasnim, S., & Faizah, F. (2019). Globalising artificial intelligence for improved clinical practice. *Indian Journal of Medical Ethics, 9*, 1–2.
33. Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., Wang, Y., Dong, Q., Shen, H., & Wang, Y. (2017). Artificial intelligence in healthcare: Past, present and future. *Stroke and Vascular Neurology, 2*, 4.
34. Tekkeşin, A. İ. (2019). Artificial intelligence in healthcare: Past, present and future. *Anatolian Journal of Cardiology, 22*(Suppl 2), 8–9.
35. Fogel, A. L., & Kvedar, J. C. (2018). Artificial intelligence powers digital medicine. *NPJ Digital Medicine, 1*(1), 1–4.
36. Gunning, D., & Aha, D. (2019). DARPA's explainable artificial intelligence (XAI) program. *AI Magazine, 40*(2), 44–58.
37. Jin, D., Harrison, A. P., Zhang, L., Yan, K., Wang, Y., Cai, J., Miao, S., & Lu, L. (2021). Artificial intelligence in radiology. *Artificial Intelligence in Medicine, 2021*, 265–289. Academic Press.
38. Peng, Y., Yan, K., Sandfort, V., Summers, R. M., & Lu, Z. (2019). A self-attention based deep learning method for lesion attribute detection from CT reports. In *2019 IEEE International Conference on Healthcare Informatics (ICHI)* (pp. 1–5). IEEE. https://doi.org/10.1109/ICHI.2019.8904668
39. Chang, H. Y., Jung, C. K., Woo, J. I., Lee, S., Cho, J., Kim, S. W., & Kwak, T. Y. (2019). Artificial intelligence in pathology. *Journal of Pathology and Translational Medicine, 53*(1), 1.
40. Isensee, F., Petersen, J., Klein, A., Zimmerer, D., Jaeger, P. F., Kohl, S., Wasserthal, J., Koehler, G., Norajitra, T., Wirkert, S., & Maier-Hein, K. H. (2018). nnu-net: Self-adapting framework for u-net-based medical image segmentation. arXiv preprint*, arXiv*, 1809.10486.
41. Balagurunathan, Y., Mitchell, R., & El Naqa, I. (2021). Requirements and reliability of AI in the medical context. *Physica Medica, 83*, 72–78.
42. Chae, S., Kwon, S., & Lee, D. (2018). Predicting infectious disease using deep learning and big data. *International Journal of Environmental Research and Public Health, 15*(8), 1596.
43. Filipp, F. V. (2019). Opportunities for artificial intelligence in advancing precision medicine. *Current Genetic Medicine Reports, 7*(4), 208–213.
44. Haldorai, A., & Ramu, A. (2021). Artificial intelligence and medical decision support in advanced healthcare system. In *Computational vision and bio-inspired computing* (pp. 781–793). Springer.
45. Yager, R. R. (2017). Generalized regret based decision making. *Engineering Applications of Artificial Intelligence, 65*, 400–405.
46. Chan, R., & Morse, A. (2018). Artificial intelligence-enabled technologies and clinical decision making. *University of Western Ontario Medical Journal, 87*(2), 35–36.
47. Lee, D., & Yoon, S. N. (2021). Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. *International Journal of Environmental Research and Public Health, 18*(1), 271.
48. Dubey, A. (2020). Showcasing the impact of machine learning in healthcare. *Bioinformatics & Proteomics Open Access Journal, 4*(1), 1–4.
49. Zhang, L., Lu, L., Summers, R. M., Kebebew, E., & Yao, J. (2017). Convolutional invasion and expansion networks for tumor growth prediction. *IEEE Transactions on Medical Imaging, 37*(2), 638–648.
50. Gordon, A., Lyons, C., Rao, S., & Finoli, L. (2020). Health care Workers' challenges in the care of a COVID-19 patient. *Critical Care Nursing Quarterly, 43*(4), 400–406.

51. Huang, L., Lin, G., Tang, L., Yu, L., & Zhou, Z. (2020). Special attention to nurses' protection during the COVID-19 epidemic. *Critical Care, 24*, 1–3.
52. Peiffer-Smadja, N., Lucet, J. C., Bendjelloul, G., Bouadma, L., Gerard, S., Choquet, C., Jacques, S., Khalil, A., Maisani, P., Casalino, E., & Descamps, D. (2020). Challenges and issues about organizing a hospital to respond to the COVID-19 outbreak: Experience from a French reference Centre. *Clinical Microbiology and Infection, 26*(6), 669–672.
53. Lai, J., Ma, S., Wang, Y., Cai, Z., Hu, J., Wei, N., Wu, J., Du, H., Chen, T., Li, R., & Tan, H. (2020). Factors associated with mental health outcomes among health care workers exposed to coronavirus disease 2019. *JAMA Network Open, 3*(3), e203976.
54. Jin, K, & McGorman, L.. (2020). *Data for good: New tools to help health researchers track and combat COVID-19*. https://about.fb.com/news/2020/04/data-for-good
55. Pulgarín, N. G., Aljure, L. D., & Parra, O. J. (2019). eHeart-BP, prototype of the internet of things to monitor blood pressure. In *2019 IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)* (pp. 58–63). IEEE.
56. Mishra, A. (2021). Transparent AI: Reliabilist and proud. *Journal of Medical Ethics, 47*(5), 341–342.
57. Sethi, P., & Sarangi, S. R. (2017). Internet of things: Architectures, protocols, and applications. *Journal of Electrical and Computer Engineering, 26*, 2017.
58. Harrer, S., Shah, P., Antony, B., & Hu, J. (2019). Artificial intelligence for clinical trial design. *Trends in Pharmacological Sciences, 40*(8), 577–591.
59. Alandjani, G. (2018). Features and potential security challenges for IoT enabled devices in smart city environment. *International Journal of Advanced Computer Science and Applications, 9*(8), 231–238.
60. Alter, S. (2020). Making sense of smartness in the context of smart devices and smart systems. *Information Systems Frontiers, 22*(2), 381–393.
61. Chakraborty, C. (2019). Computational approach for chronic wound tissue characterization. *Informatics in Medicine Unlocked, 17*, 100162. https://doi.org/10.1016/j.imu.2019.100162
62. Krishnan, M. M., Banerjee, S., Chakraborty, C., Chakraborty, C., & Ray, A. K. (2010). Statistical analysis of mammographic features and its classification using support vector machine. *Expert Systems with Applications, 37*(1), 470–478.
63. Chakraborty, C. (2021). Performance analysis of compression techniques for chronic wound image transmission under smartphone-enabled tele-wound network. In *Research anthology on telemedicine efficacy, adoption, and impact on healthcare delivery* (pp. 345–364). IGI Global.
64. Dwivedi, P., Sarkar, A. K., Chakraborty, C., Singha, M., & Rojwal, V. (2021). Application of artificial intelligence on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence., 9*, 1–8. https://doi.org/10.1080/0952813X.2021.1958063
65. Dilibal, C., Davis, B. L., & Chakraborty, C. (2021). Generative design methodology for internet of medical things (IoMT)-based wearable biomedical devices. In *2021 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)* (pp. 1–4). IEEE.
66. Chakraborty, C., Lin, J. C., & Alazab, M. (2021., ISBN: 978-3-030-72138-1). Data-driven mining, learning and analytics for secured smart cities: Trends and advances. In *Advanced sciences and technologies for security applications*. Springer. https://doi.org/10.1007/978-3-030-72139-8
67. Pramanik, J., Samal, A. K., Pani, S. K., & Chakraborty, C. (2021). Elementary framework for an IoT based diverse ambient air quality monitoring system. *Multimedia Tools and Applications., 2*, 1–23.

Chapter 16
Wearable Sensors and Pervasive Computing for Remote Healthcare

Abhinay Thakur and Ashish Kumar

Abstract Technology has become an integral and vital part of modern life, influencing the way we all live and work. With the increasing demand for automated, remote and intelligent lifestyles, the necessitates of advancement in real-time healthcare services in smart cities has also been increased tremendously. The development of a smart healthcare monitoring systemthat is capable of observing elderly people remotely is the prime theme of this chapter. The utilization of wearable devices/sensors in the ubiquitous healthcare service allows monitoring various physiological vital signs such as heart rate, respiratory rate, body temperature, oxygen level for a long period and performance of preventive and control check-ups outside medical facilities. Being associated, the pervasive computing devices based on the blend of internet and wireless technologies allow sending the vital health information in the data model to the physicians. This chapter focuses on several systems, such as RPM, the role of AI, IoT and data mining. Additionally, we discuss the recent developments, opportunities and challenges in the field of wearable sensors and pervasive computing systems relevant to the field of healthcare to establish a common foundation for further research.

Keywords Wearable sensors · Heart rate · SpO_2 · Chronic disorder · Electrocardiograms · Wireless body area network · AI · IoT · Data mining · Pervasive computing · Help-AAL

16.1 Introduction

Longer lifespans and lower fertility rates are increasing the number of the elderly worldwide, making population aging the main concern for many communities. By 2050, it is predicted that around 20% of the world's population would be 60 or older [1, 2]. Contemporary healthcare systems will face significant issues as a result of

A. Thakur · A. Kumar (✉)
Department of Chemistry, Faculty of Technology and Science, Lovely Professional University, Phagwara, India

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_16

such circumstances, including an increase in age-related disorders, vulnerability and a caretaker crisis. It is anticipated that technology will assist in addressing issues by allowing elderly persons to live more independently and thereby relieve caretakers of their burden. Wearable sensors offer novel meaning to individualized healthcare by allowing big data and AI to be utilized to achieve exact forecasts and safety assessments for large groups of people who would otherwise be impossible to manage using traditional approaches. After gathering enough data, a detailed relationship between specific vital signs or similar health indicators may be discovered and wearable sensors could make data collection as well as assessment of health features easier. These sensors are primarily designed to being portable self-contained and less expensive than traditional statistical procedures due to their lack of stationary components. The increasing usage of smart mobile devices has had a substantial impact on the number of people who seek medical help. Remote patient monitoring (RPM) is a key component in the wearable sensor revolution. The percentage of patients utilizing smartphones has increased from 35,000 in 2013 to approximately 7 million in 2018 [3–5]. As a result, RPMs exert a significant effect on patients in a variety of areas. RPM systems were proven to be effective and prospective in the care and prevention of consequences for SCI patients in several studies and they should be addressed in both physical and mental disorders. It continued to stress the importance of RPM in allowing practitioners to monitor several patients at once. The Internet of Things (IoT) seems to be a game-changing platform that helps anything to become smart. IoT has a considerable effect on a range of disciplines, the most enticing of which being the medical field. Samiya Khan and MansafAlam [6] focuses on the utilization of IoT to personalize healthcare services, and this technique could be especially advantageous for the aged and those that already have a chronic ailment. IoT has the potential to transform the healthcare industry by permitting for earlier detection and accurate diagnosis, as well as efficacious patient tracking after an individual has left the hospital. A WBAN is a compact network of sensors in the medical area that includes a pressure sensor, gyroscopes, a pulse oximeter, a GPS device, and electrooculography (ECO). The use of pervasive computing technology in health care is primarily focused on establishing tools and methods that place the patient "at the center" of the healthcare process. It comprises remote monitoring, remote counseling and assistive devices from a technological standpoint. This opens up great opportunities in the healthcare sector, especially for diagnostic and communication equipment. This chapter describes our approach to discuss several wearable sensors systems and pervasive computing systems that use omnipresent devices to provide continuous monitoring of patient's vital signs such as temperature, heart rate and other vital signs in the critical postoperative period after they've been relieved to home care. Figure 16.1 is showing an overview of infectious disease transmission patterns, symptoms, and clinical care utilizing wearable sensors [7]. Sandeep Kumar Sood et al. [8] presented an intelligent healthcare system that uses cloud computing, IoT and fog computing paradigms to identify, analyze, and notify dengue virus (DeV) affected people in real-time to manage DeV disease epidemic. The suggested system employs a Naive Bayesian Network (NBN) in order to potentially evaluate DeV-infected patient and generates real-time

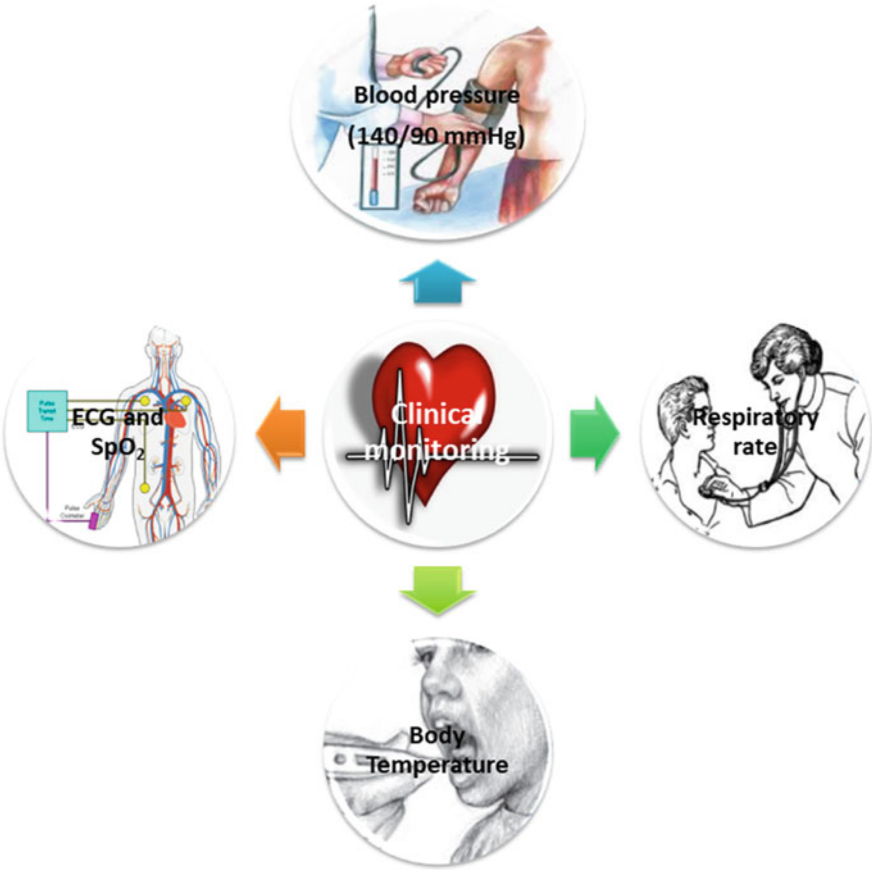


Fig. 16.1 Overview of infectious disease transmission patterns, symptoms, and clinical care utilising wearable sensors

notifications for recommending and informing pertinent individuals to take essential steps asap. In addition, the suggested methodology employs Social Network Assessment in the cloud component to provide a GPS-based worldwide threat evaluation of the DeV outbreak on Google Maps and to avoid infection propagation. Several quantitative measurements and testing approaches are used to demonstrate the usefulness of the recommended system's NBN-based DeV contamination diagnostics, warning production, and GPS-based risk rating capability.

Similarly, in a survey conducted by Joy Rakesh, Kavitha & Julian, [9] the current state of the art in Human Activity Recognition (HAR) using wearable sensors, as well as every HAR system's general design and overview of the critical elements. They proposed a two-tiered classification system based on educational method (semi-supervised or supervised) and reaction duration (either online or offline). Response time, teaching method, obtrusiveness, adaptability, prediction accuracy and other critical design concerns were compared qualitatively across 28 systems. They explicitly disclose in their article that the goal of a HAR platform is to respond to a user's actions. Antonio Pugliese et al. [10] demonstrated the employment of the Play Access platform as a tool for telerehabilitation hemophiliac children. Their technology, which is available as an Android Accessibility Service, permits users to substitute touchscreen interaction with a variety of interfaces, including individualized body movements sensed by wearable Bluetooth inertial sensors. As a result, Play Access may turn existing mobile games into fully functional exergames.

16.1.1 The Necessity Of an Intelligent Health Care System

Owing to the enormous growth in population, conventional health care is incapable to meet every single individual's demands. Medical services are not accessible or inexpensive to all while having superb infrastructures and cutting-edge technology. The mainpurpose of intelligent health care is to assist consumers by informing people regarding their physiological conditions and providing knowledge concerning their health. Smart health care allows people to handle various emergency circumstances on their own. The use of available resources to their full extent is aided by intelligent health care. It assists in remote patient monitoring as well as the reduction of treatment costs for the user. It also enables medical professionals to expand their offerings across geographic constraints. With the growing drive towards smart cities, a successful intelligent healthcare system ensures that its residents live a healthy lifestyle. Functional and non-functional needs are two types of intelligent health needs. Functional requirements tackle certain requirements of intelligent healthcare infrastructure. For instance, The operating range of a thermometer, the frequency with which a temperature-monitoring system operates, and the data gathering mechanism may vary depending on the requirements. As a result, functional requirements are unique to each element used in that healthcare system, depending on how it is used. Nonfunctional requirements are less explicit. Nonfunctional requirements are characteristics that can be used to assess the quality of a healthcare system. There are two types of nonfunctional requirements in intelligent health care: productivity objectives and ethics policy. Performance standards could be further split into hardware and software specifications due to the huge amount of verticals associated with developing an entire intelligent healthcare system. Minimal power consumption, quality of service, overall dependability, enhanced user experiences, improved productivity, and system adaptability to update to the latest versions and advancements are all necessary characteristics for an effective smart and intelligent healthcare system. Sung-Jong Eun et al. [11] proposed the emergence of an intelligent healthcare management system to assist hypertensive sufferers in managing their health. A wrist-worn ambulatory blood pressure monitoring device is included in the system, which can examine the regularity of observed blood pressures. A model of a tonometric wrist-worn ambulatory blood pressure monitoring system that is easily transportable, easy to wear, and potential of enhancing the stability of measured bio-signals has been developed. In attempt to affirm the prototype's accuracy, the observed blood pressure values compared to those of existing popular apparatus. In addition, when compared to existing classification techniques, the presented analytical method was proven to be more efficient. Finally, patients with hypertension might have their health status assessed for a limited period of time. Similalrly, Zehao Zhang et al. [12] emphasised the importance of establishing AI for preventative health intervention policies in China, given the country's deep ageing tendency. The ageing population is confronted with a rising disease burdens, a high disability rate, and a low level of social engagement. The problem was overcome by proposing the Low Fertility Economic State Aging Model (LFESAM), which was designed to shape unequal ageing distributions based on health-care views. The sustainable provision of treatment has been prioritised in the traditional health-care model, resulting in an unfair distribution of ageing. As a result of significant advancements, LFESAM has a number of advantages over traditional health-care systems, and it aids in the distribution of the ageing population. Under the trend of profound ageing in China, the Chinese government is accountable for providing intelligent health care services and the necessity of developing preventive health intervention policies in its early stages of development.

The ultimate goal of intelligent health care technology is to deliver prompt smart medical service. In practical approaches, the system must also include ambient intelligence to improve the quality of service following these criteria.

- **Minimizing the number of readmissions**. Readmissions could be reduced in a cost-effective and patient-centered manner by health care systems. Clinicians can get regular updates about which patients are at risk of readmission and how to mitigate risk.
- **Lowers hospital-acquired infections (HAIs).** Health systems may minimize HAIs like central-line associated bloodstream infections (CLABSIs), which kill 40% of CLABSI patients, via anticipating patients who have a chance to acquire a CLABSI. Clinicians should analyze high-risk people using patient-specific risk indicators and help to lower that risk [9, 13].
- **Reduce the length of time spent in the hospital (LOS).** By examining patients who are likely to have a prolonged stay and checking that best practices are being followed, health systems could minimize LOS: enhance patient satisfaction**.**
- **Predict the onset of chronic illness.** Machine learning could assist healthcare systems in detecting patients suffering chronic diseases that have been misdiagnosed or diagnosed, predicting the likelihood of chronic illness, and providing patient-specific preventative treatments.

16.2 Wearable Sensors

Wearable sensors improve the reliability of human life in ways that cannot be done just through the use of a smartphone, and consumers have expressed a strong desire to wear these devices in practice. Wearables include things like smart jewelry, smartwatches, smart eyewear, electronic clothes, skin patches, etc. [14]. Wearable devices could detect, collect, and store physiological data, which is not achievable with smartphones alone, and so improves human life quality. Wearables make it easier and more natural to conduct micro-tasks like validating incoming messages and analyzing urgent data right away. Wearables may deliver value-added services such as psychosocial surveillance, indoor location and mapping, health coverage analytics, sports analytics, and accounting transactions to name a few. The market for wearable technology is forecasted to increase by $57,653 million by 2022, up from $19,633 million in 2016 [15–17]. Wearable technology allows for real-time digital measurement of characteristics related to an individual's health. It is recognized as an important component in the fitness community and current lifestyle, including photoplethysmography-based heart rate monitors and gyro sensor activity trackers among the wide assortment of accessible gadgets. Only a few wearables have been certified for use in the healthcare system, which presents a considerable issue. Nonetheless, there are further prospects for creating and customizing wearable gadgets for healthcare applications. During a visit to a general care practitioner, the four most important metrics in the healthcare system like heart rate, blood pressure, temperature, breathing rateare normally confined. Continuous observations are conceivable, however, they are constrained in mobility; nonetheless, wearable sensors allow for high-precision transverse measurements. The major purpose of integrating wearable devices into the health system is to offer qualitative, clinically relevant data to patients and clinicians. Wearable gadgets could track and record data about a person's physiological status and mobility behavior in real-time. Flexible sensors incorporated in textile fibers, clothes, and rubber bands, as well as sensors attached physically to the individual body, can be used in wearable sensor-based health monitoring equipment. Real-time surveillance of a person's mobility activity or routinemight enhance detectors, gait patterns and posture assessment, and rest evaluation. Wearable health monitoring systems frequently include electronic sensors, signal processing modules, actuators and wireless communication components. Sensor data is delivered to a local processing node by employing compatible communication provisional steps, commonly a short-range and low power utilizing wireless systems available like ZigBee, Bluetooth, and Near Field Communications.

Kańtoch [18] researched to develop a system for automatically detecting sedentary behavior linked to cardiovascular risk using quantitative physical activity measurements. Wearable sensor data was used to quantify the consumer intensity and variability of processed accelerometer statistics resulting in a feature vector. A clinically approved short physical performance battery (SPPB) assessment task and an interventional technique supposed to be healthy for the elderly were used to verify the method. Linear Discriminant Analysis, Support Vector Machines were explored

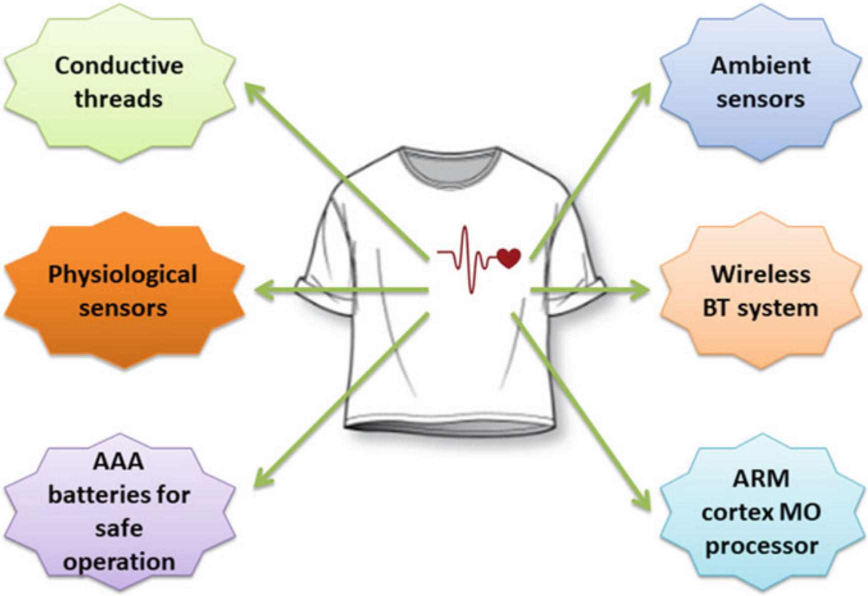


Fig. 16.2 The system prototype

and compared to obtain the recognition system. With an efficiency of 95.00 percent 2.11 percent, this system was able to recognize the sedentary activities. According to the results of the experiments, measuring sedentary activity patterns using a smart shirt and machine learning approach can yield high accuracy. The main advantage of the new technology is that it can be used to continuously observe patient behavior in an available scenario, which might help with the early detection of increased cardiovascular risk. The system prototype of a wearable t-shirt having all the monitoring sensors attached is shown in Fig. 16.2 [18].

Pandian et al. [19] discussed wearable physiological monitoring devices that are clever medical monitoring devices that give the client or a remote monitoring station real-time data. Wearable physiological monitoring, which incorporates sensors and wires into the wearer's clothing, has a variety of disadvantages. To address the concerns raised before, each physiological sensor was connected to a network of sensors that included sensors, processing devices, and a wireless transmitter. A wearable WSN of physiological sensors embedded into the individual's vest collects data and transmits it to a distant monitoring station continuously, allowing the individual's health state to be monitored remotely. These systems can track the health of those who operate in high-risk environments, including as troops on the battlefield, firefighters, and mine employees. These technologies could also be used to keep track of the health of elderly persons at home. Additionally, Po Yang et al. [20] presented a thorough presentation on innovative multimodal wearable intelligence strategies for dementia treatment. In Healthcare 4.0, a survey was conducted to examine multimodal wearable intelligence technologies for dementia care. From

2010 to 2020, they conducted a comprehensive literature assessment, analyzing pertinent papers from three major academic databases. The terms ‘wearable computing,’ ‘wearable intelligence,’ and ‘dementia,’ as well as ‘healthcare,’ were used as search terms (H). In addition, research projects connected to IoT, e-health, smart healthcare, and other similar topics were investigated by searching the EU, TSB, and EPSRC sponsored projects portal. Through this survey, they revealed that wearable intelligence-enabled technologies in dementia care would allow safer and easier preventive care, reduced total costs, greater patient-centered practice, and improved durability.

Farman ali [21] presented a new cloud-based healthcare observation system with a big data analytics algorithm for accurately storing and analysing health records and enhancing classification accuracy. Data mining algorithms, ontology, and bilateral long short-term memory are all used in the proposed huge data analytics engine. Healthcare data can be effectively modified using data mining techniques, lowering the data’s complexity. The proposed ontology in the fields of diabetic and heart rate provide semantic information about elements and features, as well as their relationships. Bi-LSTM accurately recognises healthcare information in order to forecast pharmacological adverse effects and unusual patient conditions. Furthermore, the suggested approach determines an individual’s health status using data such as hyperglycemia, heart rate, mental health, and drug evaluations. Java and the Protégé Web Ontology Interpretation toolset were used to construct this framework. The results show that the developed approach accurately manages large datasets and improves medical condition categorization and drug adverse reactions prognosis.

16.2.1 Monitoring Vital Health Signs

Medical workers routinely monitor patient vital signs, which plays an important role in patient health and clinical results. Regular monitoring allows healthcare personnel to monitor changes in patient circumstances, detect early deterioration, and avoid injury or errors. The ability to notice minor changes in vital signs quickly is critical, as delays in commencing proper therapy can have a negative impact on the patient’s health and safety [22]. A limited number of sensors, each of which can transfer data straight to a local gateway, can be used to build some systems. The systems are attached to certain systems via a body sensor network, in which the central BSN node receives information cum data from the sensors and does minimal analysis before transferring it to the advanced processing unit. Imran et al. [23] demonstrated a closed-loop IoT healthcare environment based on an intelligent task modeling approach for senior individuals’ healthcare monitoring design. As a case study, a health monitoring network centered on the suggested design was constructed for elder individuals’ health monitoring in the residential, emergency, and healthcare facilities. The technology uses biological sensors to identify and tell authorities of deteriorating conditions so that they can intervene sooner. Wearable biomedical sensors are used to measure body temperature, pulse rate, blood sugar level, and individual body posture. To identify abnormalities in the health sensing data, thresholds and machine learning-based techniques were appliedThe proposed architecture's performance is measured using round trip duration, dependability, assignment error frequency, and delay metrics. In IoT contexts, the suggested architecture for elder client health monitoring could give reliable approaches for crucial activities.

16.2.1.1 Body Temperature

When the body's temperature increases as a result of an inflammation or infection caused by a variety of illnesses, it is a critical indication that symbolizes the body's health and gives essential information [24]. Fever is a common symptom of infectious disorders, defined as a sustained rise in human internal temp over the normal level (36.5–37.5 °C) to a range optimal for innate immunity. Nonetheless, it's possible to get to the conclusion that fever protects sick persons. An elevation in the body temperature is often not always a fever; this might indicate increased heat production while decreased heat loss, and it's categorized as acute (lasting less about 7 days) and sub-acute (lasting about 2 weeks), or chronic (lasting >2 weeks) depending on how long it lasts (more than 2 weeks).

Jansi, Amutha & Radha, 2019 created the SW-SHMS (smart healthcare monitoring system) to address the difficulties of offering monitoring of patients at home while avoiding hospitalization. According to the findings, there is still a big demand for an integrated healthcare system that can monitor older citizens in homes in real-time. It can greatly assist in building a simple and efficient manner for senior and disabled persons to live independently without worry about a disaster or emergency healthcare situation by continuously checking their health. SW-SHMS collects physiological data from patients via wearable sensors and sends it to the cloud for analysis and processing. As a result, any anomalies found in a patient's dataset would be communicated to the doctors via the medical or hospital portal. Because of its modular and extendable design, SW-SHMS is a reliable and cost-effective option for remote patient monitoring. Furthermore, the findings indicate that by utilizing the proven SW-SHMS system that can virtually and in real-time monitor patient symptoms, the system might significantly contribute to the betterment of medical services [25].

16.2.1.2 Blood Oxygen Saturation (SpO_2) Monitoring Systems

The amount of oxygenated hemoglobin in the blood is measured by peripheral capillary oxygen saturation (SpO_2). Health issues such as anemia, cardiovascular illness, lung disease, sleep apnea might cause oxygen levels in the blood to drop [26]. It can also be lowered after engaging in strenuous physical activity. To guarantee the efficient functioning of cells and tissues, a sufficient amount of oxygen (>94%) must be maintained in the blood. As a result, it's critical to keep an eye on your SpO_2, especially if you have respiratory or heart problems. The pulse oximeter is commonly used to detect blood-oxygen levels in a quick and non-invasive manner. SpO_2 is calculated using the absorption properties of blood in infrared (940 nm) and red (660 nm) light. As hemoglobin is oxygenated, its hue changes from dark red to brilliant red, limiting the absorption of red light. Light absorption in blood changes as arterial blood volume changes during diastolic and systolic stages of the heart, culminating in a time-varying signal termed a photo-plethysmograph (PPG). In measuring SpO_2, the PPG signal can be used to assess respiration rate, heartbeat, and pulse rate. It can also be used to estimate blood pressure by using a pulse transit period when combined with an ECG signal. Near-infrared and red light-emitting diodes (LED) are commonly used for light emitters in the pulse oximeter. After absorption, the photodetector detects the remaining light (PD). PPG or SpO_2 sensors can be classified into two classes based on their operating principles: oximetry using transmittance and reflectance. In transmittance oximetry, the LEDs and PD are positioned on opposite ends of a translucent part of the body, including fingertips, an earlobe, the palm, sole of small neonates. The PD collects light that passes through this part. PPG signal measurements are now performed with fingertip-based transmittance pulse oximeters. This method is problematic for lengthy monitoring. The LEDs and PD are placed next to one other on the same surface of the body in reflectance oximetry, and the PD measures the strength of the reflected light. It can measure PPG signals from a variety of locations on the body, making it suitable for non-invasive wearable platforms.

Postolache et al. [27] used embedded primary software program to derive the blood oxygen level and HR value from the PPG signals (SpO_2 values). To acquire more precise HR measurements, an adaptable threshold peak detector technique was applied. The SpO_2 calculation procedure uses the “normalized ratio”, R, and a polynomial model of $SpO_2 = SpO_2(R)$ empirical characteristic. An 8-byte data matrix stores the PPG patterns (wave), the average period among two consecutive PPG peaks (DELTA), the HR, the SpO2 value, and the 3D accelerometer voltage values digital codes (ACCEL X, ACCEL Y, and ACCEL Z). For a specified USART baud rate up to 19,200 bps, the update percentage employed in the trials was higher than 20 updates/s and lower than 200 updates/s. For various optical sensing device placements on the forearm, the recommended approach’s sustainability was investigated.

16.2.1.3 Respiratory Rate

It is a vital indicator that can indicate the presence of cardiorespiratory diseases like asthma, cardiac arrest, or congenital respiratory problems [28]. It is critical for monitoring insomnia and observing infants with Sudden Infant Death Syndrome (SIDS). Comparative differences in the respiratory rate, rather than heart rate or blood pressure, are more important in distinguishing among persons in a steady or threatening situation. With age, the usual range of respiratory rate changes. The respiratory rates of preterm and newborn infants should be 40–60 and 30–50 beats per minute, respectively, but the respiratory rates of nutritious children in their first 2 years should be 20–40 beats per minute. Healthy persons with non-respiratory problems have a respiratory rate of 12–20 beats per minute, whereas the elderly have a rate of around 19 beats per minute. As a response, the respiratory rate reduces from childhood through early adolescence, while the respiratory rate increases in older people. Infection and other serious disorders are often indicated by an erratic respiratory rate. Adult patients with a respiratory rate greater than 24 beats per minute must be continuously monitored; those with a respiratory rate greater than 27 beats per minute must seek medical help immediately.

Rault et al. [29] evaluate energy-efficient context recognition algorithms for healthcare applications that make use of wearable sensors. They carried out a one-of-a-kind comparison study to see how each category of energy-saving mechanisms may be applied to different techniques used in health and wellness applications. They offer energy-saving solutions for a variety of applications. They also highlight the impact of the technique on the desired time and accuracy. As a result, they aid the designer in making the final decision on the most effective worldwide energy conservation approaches.

16.2.1.4 Heart Rate

High heart rates are a risk factor for pulmonary and cardiovascular illnesses like hypotension, hypoglycemia, arrhythmia, and chronic obstructive pulmonary disorder [30, 31]. Lower heart rates usually imply efficient muscle activity, which is why athletes' heart rates can be as low as 30 beats per minute. Gender, age, physical activity, lifestyle and other factors all influence the normal heart rate. Before diagnosing heart rate anomalies, it is medically vital to be aware of the patient's history and personal information. Figure 16.3. depicts the bases of a normal heartbeat ECG pattern.

Electrocardiograms are devices that measure the electrical activity of the heart using electrodes attached to the chest (ECG) [32]. Impedance CardioGram, a 4-electrode resistance procedure in which electrodes are put on the neck and waist, could be used to evaluate pulsatile blood flow (ICG). The heart rate and pulsatile flow are measured using a stethoscope or an ultrasound sensor. Photoplethysmography measures variations in optical transmission caused by vascular dilatation and contraction (PPG) [33, 34]. Plethysmography is a technique that helps doctors record variations in tissue or organ content. Cardiac and pulmonary functions are assessed using variations in blood volume and lung volume. An artificial light source and a detector are used to measure the changes. PPG uses wearable sensors to track changes in blood volume induced by vascular dilatation and contraction in the epidermis and hypodermis. The PPG signal measures blood oxygen saturation, stroke volume, heart rate, and vascular stiffness providing a plethora of information about the heart and circulatory system. Around 800–11,000 nm, it's also the wavelength range to analyze infrared sources for optical imaging, as well as the skin's melanin absorption level. To estimate oxygen

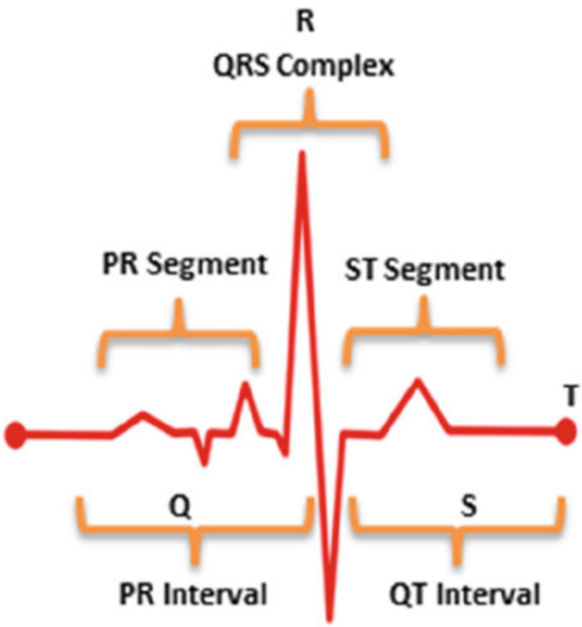


Fig. 16.3 A typical ECG signal and the various waves, segments, and intervals

saturation, a pulse oximeter detects the absorbance intensity of oxygenated and non-oxygenated hemoglobin, which ranges from 600 to 800 nmin. The incorporation of PPG sensors in wrist-worn devices enables wireless communication. The ease with which transmission circuitry and batteries may be linked to the strap is the primary benefit of wrist-worn gadgets. Despite the fact that the sensor must always be placed in eyeglasses or earbuds, it could alternatively be mounted in the ear lobe considerably improves the signal-to-noise ratio due to the huge volume of the vasculature. The drawback is that the ear lobe temperature drops, causing peripheral vasoconstriction and a lower signal-to-noise ratio.

Szydło & Konieczny, 2016 [50] utilized a Personal Pulsometer, which calculates heart rate using the phone's camera. The concept is to use the phone flashlight to illuminate the camera and then place the index finger over it. The light from the flashlight is dispersed in the finger, and the amount and intensity of redness viewed by the camera are influenced by blood flowing through the user's veins. The generated image is subjected to a Fast Fourier Transform, which analyses interesting frequencies and calculates heart rate.

16.2.1.5 Cardiovascular Monitoring System

Electrocardiograms (ECGs) are a non-intrusive way to measure and record changes in heart potential. It is the simplest widely utilized and successful diagnostics tool for detecting heart-related disorders such as arrhythmia, which clinicians have employed for decades. Certain arrhythmias, such as myocardial infarction (MI), are not life-threatening, but they are triggered by a weak or injured heart and therefore can result in cardiac arrest if not treated immediately. If a patient has a heart attack, they should seek medical care straight away because it could be fatal if they don't. Any anomalies in heart rate can be detected and diagnosed quickly enough to avoid these repercussions, which demands outpatient continuous ECG monitoring. Some serious arrhythmias are rare and could only be detected after a long period of observation. In a traditional 12 lead ECG system, electrical impulses from the heart are examined in 12 different spatial configurations using ten Ag-AgCl electrodes (hydrogel method/wet ECG) connected to various locations in the body [22]. A conduction medium b/w the electrode and skin are provided by a conducting gel in the electrode pad's center. This conducting gel, despite being the only device on the market at the time, can be poisonous and irritating to the skin, rendering it unsuitable for protracted ambulatory measurement. Only a few electrodes are utilized in a peripheral ECG monitoring device, resulting in inadequate data. Wearable and portable continual ambulatory monitoring systems must be able to be utilized comfortably without interfering with a person's regular activities.

16.2.1.6 Blood Pressure (BP)

Hypertension, often known as high blood pressure, raises the threat of cardiovascular disease is the major reason for death globally and is the second primary factor of disability behind childhood starvation. According to the WHO, 1.13 billion individuals suffer from hypertension, which increases the risk of brain, heart, and renal disorders. The pressure produced by flowing blood on the walls of blood vessels is known as blood pressure (BP) and is a vital indicator. As a result, high blood pressure is classified when the highest blood pressure is measured whenever the heartbeats or when systolic blood pressure $>$ 140 mmHg, as well as lowest BP measured when the heart is resting or when diastolic blood pressure $>$ 90 mmHg. Qiang Lin et al. [35] proposed an AI-based fuzzy assisted Petri net (AI-FAS) technique for stress detection on HR and blood pressure monitoring. The duration between two consecutive QRS complexes in the ECG waveform was used to estimate the normal HR. However, due to pathological responses and noise created by time-variant physiology, recognising ECG patterns is difficult. The variance of the heart rate was calculated using a time and frequency analysis. The stress evaluation for HR was evaluated using fuzzy assisted Petri nets. The transitory time of each pulse is used to monitor blood pressure for stress management. The interpretability of fuzzy systems is measured against the accuracy of two independent requirements. Furthermore, the results show that the performance rate of 93.55%, accuracy of 89.01%, memory of 89.50%, and adaptability of 89.901% in stress management has been numerically validated.

16.3 Commercial Available Wearable Computing in Healthcare

16.3.1 CHRONIOUS

CHRONIOUS developed a smart wearable platform for patients with Renal Insufficiency, COPD and CKD. A T-shirt containing embedded sensors served as the major component, with additional sensors placed in the patient's living environment at home. If health and behavioral statistics depart from expected trends, the system sends out an alert. A multi-parametric expert program recognizes the collected data and sends an alarm to the healthcare professional via a specialized and secure website in emergency scenarios. The integrated platform, which could be used both indoors and outside, enables real-time patient monitoring and evaluation and can be used to treat a variety of chronic conditions. Furthermore, a semantic information retrieval solution meets the need for current clinical data.

CHRONIOUS established the framework in clinical studies including 100 patients in medical centers and patients' homes. The goal was to offer the doctor accurate information about the patient's health. The patient's ability to self-monitor was not emphasized. The portal was built as a prototype for future generations of "chronic disease management systems," with foundation functioning as the key constituent [36]. The home patient monitor's performance and user interface left a lot of room for improvement in a future project. It was the first time they saw the need for pervasive and wearable computing systems in a patient's home with inhabitants who had never used the technology before. The fact that staying at home has always been preferred to being in the hospital invigorated patients. When a user is unable to use the monitoring system, their dissatisfaction affects their perception of the solution's accessibility.

16.3.2 REMPARK and Help-AAL

Other Joint-AAL programmes with a higher emphasis on commercialization of alternatives, in this case for Parkinson's disease patients, including REMPARK and Help-AAL. Wearable and pervasive computing technologies were utilized in both studies to keep track of patients, learn about their needs, and give medications when sensors showed that it was necessary. The solution's applicability was the focus, thus only minor hardware adjustments were required. There was a high level of user acceptance due to the patients' immediate need for aid.

REMPARK's Personal Health System (PHS) possesses closed-loop control monitoring, reaction, and therapy capacities for Parkinson's Disease (PD) patients, which used wearable monitoring methods to track the motor condition of PD patients in real-time, as well as assessment of ON/OFF/Dyskinesia condition in operating condition all through anesthesia situations. The gait guiding system offers real-time assistance to patients in carrying out their daily chores [37]. The data analysis aids the neurologist in charge of a disease management solution in getting precise and reliable information in order to select the optimal treatment option for the individual.

16.3.3 USEFIL

User acceptability requires bridging the gap between technology advancements and the specific needs of the elderly. In practice, this entails developing inconspicuous in-home monitoring and online communication systems that are sophisticated yet economical. Commercialized off-the-shelf technology for relevant services aided the elderly in maintaining personal autonomy and daily routines in the USEFIL initiative [7]. The system had to be installed without requiring any adjustments to the person's home, and it had to be unobtrusive once it was in place. The most important feature was that the technology was installed with the user's consent and that user interfaces were tailored to the user's needs.

16.4 Pervasive Computing

The purpose of pervasive healthcare (PH) is to leverage pervasive computer technology aim of providing round-the-clock healthcare to people in their homes and outdoor, rather than in traditional medical institutions like hospitals and medical clinics. Monitoring symptoms, consulting a doctor, and receiving treatment are all part of the traditional health management concept. Pervasive healthcare aims to change this by allowing consumers to obtain healthcare services from any location at any time. It generates huge installation of equipment and sensors (both wired and wireless) to continuously monitor patients. This allows it to provide medical practitioners with precise health information, enabling faster diagnosis and treatment of health problems [19, 38]. As a result, by promoting enhanced patient-caregiver involvement, pervasive healthcare holds the power to provide precise, rapid, and error-free care to everyone. This is especially important today as the population is steadily aging, medical institutions are experiencing staffing shortages, healthcare costs are skyrocketing, and medical error rates are at an all-time high.

Pervasive computing is designed so:

- Without even being aware of or disturbed by the intricacy of its surroundings, such as networking, devices, software, and databases, a user could be as productive as possible in her activities. This allows them to concentrate on their job rather than the finer points of the supporting environment.

- The system's intelligence prevents user mobility and environmental changes from making the user more aware of his surroundings. This means that mobility and other changes are handled in such a way that he is unaware of them.
- The customer doesn't want to know which network their data is being sent over, which database or server is processing his or her transactions, or how changes in one location influence bandwidth, processing, or the environment's security. This means that the customer cannot see the many components engaged in the procedure.

16.4.1 Security Threats in Pervasive Healthcare Systems

In contrast to today's predominantly paper-based records, a pervasive healthcare system captures and stores health data in an electronic format—EPRs. However, adopting EPRs exposes health data to several security risks that were not present while using paper-based records. It could result in unauthorized access to and manipulation of critical patient health information. The causes of this newfound vulnerability are as follows:

- Paper-based health data is often extremely structured and replicating it is a time-consuming and labor-intensive procedure. EPRs are retained on networked systems for accessibility reasons, so they can be accessed from anywhere and copied quickly.
- For faster and simpler retrieval, more sensitive data has been incorporated into a patient's EPR. HIV status, mental health information, and genetic data are all examples.
- Because pervasive healthcare systems are networked, EPRs can easily be relocated across administrative or even national boundaries, avoiding any local legal difficulties.

As a result, the ability of pervasive healthcare systems to effectively receive, share, preserve, and interpret based on electronic health data opens up various avenues for privacy and security infractions. The following are amongst the most pressing issues confronting the world's ubiquitous healthcare systems:

- Unauthorized accessibility to a person's health data.
- Manipulation of a patient's health data with the intent of causing inaccurate diagnosis and treatment.
- In the event of an emergency, intentionally creating false signals or suppressing legitimate alerts generated by the system.
- Inequality towards patients based on their socioeconomic status.

16.5 Role of Data in Sending Vital Health Information to the Physician

The healthcare monitor system consists of a web portal that allows remote access to webpages and a healthcare cloud that keeps all data collected. Healthcare providers can visit the website at any time and from any location to monitor patients' vital signs and deliver adequate and accurate medical healthcare as needed.

- Real-time dynamics: obtains real-time physiological data from a patient. When a member of the healthcare team notices that a patient's physiological data is aberrant, or the patient requests assistance, the team decides to look into the patient's current health status.
- Status Overview: compiles all existing physiological info for all patients and provides six physiological statistics for each patient [39].
- Device Transmission: indicates which patient will receive which device. The information is stored in a Device-Patient database, which has four columns: sensor device ID, allocation ID, patient ID, and the date and time the patient first used the device. In fact, the MoPSSrecognizes the patient who is using the sensor device by looking up the ID in the Device-Patient database, which is part of the Physiological Information Database.
- Patient-Healthcare Record: This section shows the patient's medical history. The patient's blood pressure, blood type and various physiologic data are displayed.

Each of the four alternatives has six sub-options that correspond to the six physiological facts. To acquire correct patient data, the inquirer can select a portion of or all options from the main menu, as well as a portion of or all sub-options from designated panels. All of the specified physiological data is updated every 5 s with newly received data stored in the Physiological Information Database to produce a real-time impact. Additionally, there are three types of information display items: real-time monitoring, real-time query, and abnormality notice. The patient's all aberrant physiological info is retrieved using a real-time query tool. To keep the range of the display as small as possible, all typical data will be hidden. In real-time, the real-time monitor feature displays a fraction (selected) or the cumulative of the six primary real-time physiological data. The purpose of an anomalies notification is to convey a signal to healthcare personnel informing them of an unusual condition or incidence.

16.6 Role of RPM

16.6.1 Monitoring for Chronic Diseases

Physical or mental difficulties include asthma, diabetes, cardiovascular disease, obesity, stroke, and other chronic disorders. These illnesses, which account for the majority of human health concerns, cause over two-thirds of all fatalities globally. As the population has risen, chronic disease has become increasingly widespread, and hospital infrastructure is inadequate to serve all patients [40]. Furthermore, to satisfy the needs of patients and execute therapy programs, chronic diseases necessitate specialist home care. Moreover, the majority of caretakers and relatives lack the essential time and experience, putting patients' quality of life in jeopardy on a regular basis [41].

Hugo Saner et al. [42] evaluated the importance of a contactless, low-cost, and non-intrusive low-frequency detector framework for detecting early signs of HF decompensation based on information from putative data processing and observational discrepancy of the statistics with interventional procedures in a 91-year-old aged who had been suffering from a severe heart problem for a year. Weeks before the decompensation, the environmental sensor system noticed an increase in breathing rate, bathroom usage at night, heart rate, tossing and turning in bed, and a drop in physical exercise. Given the constantly increasing prevalence of HF and the resulting expenditures to healthcare infrastructure and society, the feasibility of this technique must be tested in larger groups of HF patients.

Nora El-Rashidy et al. [41] discussed about RPM systems, which are focused on collecting patient vital signs utilising invasive and noninvasive approaches and transmitting them to doctors in real time. These data could aid doctors in making the best decision possible at the correct time. The study's main purpose was to highlight future research opportunities in remote patient monitoring, discuss the significance of AI in building RPM platforms, and present an analysis of RPM's current status, benefits, issues, and potential further prospects. To conduct literature research, five databases were chosen (i.e., IEEE-Explore, science direct, Springer, science.gov and PubMed). They followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a basic technique for systematic evaluations and conceptual analysis. RPM, electronic health record, data miningcloud computing, internet of things,, clinical decision support system and wireless body area network were among the search terms used to review 56 publications. RPM's efficacy in enhancing healthcare service, speeding up diagnostics, and lowering costs was proven by the findings of this study.

16.7 Role of AI

AI tools aid and improve human work rather than completely replace the work of physicians and other healthcare professionals. AI can help healthcare staff with a variety of jobs, like administrative duties, medical treatments, and patient engagement, and specialized assistance in fields like image analysis, patient monitoring and medical device automation. Artificial intelligence (AI) is more pervasive in routine work life. For instance, SK Telecom's AI speaker "Aria" in South Korea is a smart audio gadget. When the carrier is incapable to use conventional devices due to catastrophes, physical constraints, or unforeseen effects, Aria can conduct emergency calls [43, 44]. Aria phones the care center's authorized family members when an aged patient collapses and shouts, "Aria, please help!" A considerable number of aged people that reside independently have previously benefited from this assistance. Aria could also assist in the preparation of recipes. When a person asks Aria for help with seafood preparation, aria would guide them through the process from beginning to end. If you have your own money, Aria can also help you. Aria may recommend the ideal credit card for using depending on the interest rate and annual charges, as well as remind the client of their credit card due dates on a monthly basis. Many firms are now leveraging AI-based technology to provide healthcare solutions and services. IBM's "Watson for Oncology," which supports clinicians by suggesting appropriate treatment alternatives, is perhaps the most widely used AI product in the healthcare industry. Smart robots having artificial intelligence can also do activities and support physicians with specific diagnoses, therapies, cost efficiency, and quicker response to patient needs. The Moorfields Eye Hospital in London, run by the National Health Service Foundation (NHSF), has introduced an AI solution that can detect eye illness symptoms and recommend world-renowned doctors and experts. The AI-powered approach was able to detect eye problems in over 15,000 British patients using optical coherence tomography. "With 94 percent accuracy, the proper referral decisions for over 50 eye illnesses were made, beating world-leading eye professionals." Dr. Pearse Keane of Moorfields Eye Hospital discussed, "The quantity of eye scans is rapidly increasing, outpacing the ability of professional to analyze them." As a result, AI-based technology has the potential to dramatically minimize diagnostic time. The role of AI is not limited to this field. For instance, Rudresh Dwivedi et al. [45] built on improved R-CNN, developed a unique technique for categorizing grape leaves as healthy or unhealthy using GLDDN (a sort of AI functional system). The concatenation focus method feature map is sent to RPN for multitask learning, which labels and diagnoses sick regions in leaves. Multi-task learning entails pooling by cropping area proposals to recognize and identify objects in order to determine whether they are infected. The technique is unique in that it combines attention-based multilevel feature map creation, object identification, and categorization into a single framework. The research shows that the provided strategy is effective, as it achieves a recognition accuracy of 99.93% for the dataset. The proposed model is computationally efficient, intuitive, and accurate, and it has the potential to replace expert on-site identification.

16.8 Role of IoT

In recent years, the Internet of Things (IoT) has become increasingly important in everyday life. The Internet of Things (IoT) integrates sensors, motors, and communication networks to enable sensing and gathering of datasets from the human body and environment for further analysis and computation. The prevalence and changing trends of intelligence in every physical thing enable the development of human-centric pervasive applications to make people's lives easier. Embedded sensors with a wide range of capabilities provide a ubiquitous platform for data acquisition and analysis. This opens up more opportunities for resource management and utilization efficiency, as well as the capacity to track human activities for health and wellness [46]. The devices' minimal weight and small size allow them to be donned and carried while on the go. IoT technology allows organizations of all sizes to automate, and it is a fundamental element of the fourth industrial digital transformation. Precision agriculture, water usage control, and parking management are among the commercial applications for which it has developed a standardized market. The Internet of Things has an impact on the industry, ecology, entertainment, sport, social computing, food manufacturing, farming, economics, medicine, city lives, astrophysics, and other sectors of life. Nowadays, human lives are dependent on e-healthcare services, and the Internet of Things (IoT) plays an important part in the healthcare system. Researchers are working on developing intense ways for the creation of breakthrough e-healthcare techniques. The benefits of IoT applications in the e-healthcare system are cost-effectiveness, safety, and reliability. By 2020, the global IoT e-healthcare industry is expected to grow from $32.4 billion to $163.2 billion.

WIoT (Wearable Internet of Things) devices generate a large amount of personal health data. Cloud computing, fog computing, and big data are all important enablers for using WIoT services. These allowing services over large health data improve clinical processes at remote or local servers in health care systems. To analyze patient medical data, the classic remote healthcare information systems use signal processing techniques, data transferand finally naive machine learning frameworks placed on a distant server [32]. This method has a number of disadvantages, such as the fact that it is ineffective for resource-constrained wearable IoT devices. Processor, storage, power, and networking capabilities are all limited in WIoT devices. Traditional processes lack resource optimization, medical condition prediction, and dynamic assessment available data. Furthermore, basic machine learning approaches do not create data, make judgments, or identify key underlying patterns in medical data.

16.9 Role of Data Mining

A pervasive healthcare system necessitates a large amount of diverse data with limited understanding. This is also why, in order to make real-time decisions, it is necessary to find hidden linkages among data and categorize them effectively. To identify the hidden information in the enormous data set, various data mining tools are available. In this chapter, an in-depth examination of the following categories has been offered:

- Classification is used in data mining to predict the outcome of a widespread healthcare analysis. The aim is to use professional development to generate a brief model hypothesis and use that method to forecast a specific technology for an annotated class. Various probability-based algorithms are used in healthcare systems to classify activities, including the Conditional Random Field, Hidden Markov Model and Expectation Maximization.

- Integrated classifiers with five base data classifiers and a meta classifier as Boosting (AdaBoost) for strengthening the classification to control the common sight of unbalanced data from a single accelerometer data are used to recognize eight activities. Framework for Bayesian Inference with the Multivariate Gaussian Bayes classifier, feature selection is utilized to rank the significance of features to distinct activity classes. By observing the chewing action, another pattern recognition methodology is applied to detect the activity. It uses a non-invasive method to determine when you eat and when you don't. Vector Machine is used to train sensor data for autonomous detection. A decision support system (DSHDPS) is built using a Naive Bayes classifier to detect discriminatory medical profiles such as distinct health metrics and age, sex, and so on. It can predict the chance of people acquiring heart disease using DSHDPS proposes a generalized paradigm for continuous activity monitoring in a smart ubiquitous landscape that is context-aware. Automatic recognition of ADL is carried out in a smart space with essentially three classifiers to organize sequential data and construct random variables across the class label: HMM, CRF, and Naive Bayes.
- Body Sensor Network: Use machine learning in the BSN5 online application to detect gait freezing on a smartphone from wearable devices. Offline at the base station, guided machine learning algorithms such as C and RF are implemented, and the FoG-detection classifier is programmed to categoriestypical digital files encoded with Weka classifier online. Patients' motions are tracked using online body acceleration sensors, which are utilized to detect FoG automatically by evaluating the frequency component.
- Remote Healthcare Monitoring: It is challenging to manually track, detect, label, and classify patients' body actions in multiple environments for continuous nursing home care. For automatic tracking and tagging of body motions in nursing homes, clustering of motion frames is proposed to classify individual person-regions in temporal duration. By transforming similarities spaces into clustering, a suggested HMM model observes and infers the patient's behavior pattern. The interlaced tasks as cluster AALO are suggested in the same timeframe to instantly identify each cluster of the group of activities and used an unmonitored training algorithm that also enables practicing Activities of Daily Life (ADL) cluster models instantaneously using the envisaged Flocking algorithm of deep classification. To remotely monitor the walking style of different gait-affected people, a cluster in the 2D feature space of walking speed and heights is used. Similar behaviors in various rooms at the same time, however, cannot be tracked. K-means temporal segmentation recognizes the human activity pattern.
- Privacy in Mobile Networks: A mobile network's Location-Based Service (LBS) describes the importance of maintaining privacy. It uses a flocking algorithm rather than a predefined set of clusters to evaluate the various daily activities in

developing a smart home environment. The flocking clustering approach, suggests and executes three rules for measuring similarity and dissimilarity. Using k sets of centroid and mean square error, it presents a k-means data stream clustering algorithm (AG-KCDSC) for data processing in sensor networks. This technique is completely reliant on a wireless sensor network, which comprises multiple small sensor nodes that observe, gather, and send physical data from a location over a wireless channel. One of the key concerns in the WSN is node failure that causes higher packet drop, latency, and energy usage throughout the communication. Sundresan Perumal et al. [47] presented Artificial Neural Network (ANN) premised Node Failure Detection (NFD) using cognitive radio for analyzing node failure region. The data was sent from the source node to the base station using the ad hoc on-demand distance vector (AODV) routing protocol. The Mahalanobis distance was implemented to identify a nearby node to a node failure, as it was utilized to design a routing path with no node failures. Throughput, drop rate, energy utilization, delivery rate, number of nodes alive, end to end delay and overhead ratio were all evaluated for the proposed ANN-NFD technique. When relates to the H2B2H protocol, the ANN-NFD approach had a high packet delivery rate of 0.92 for 150 nodes. As a result, the ANN-NFD approach ensures data consistency throughout transmission even when nodes and batteries fail.

16.10 Wireless Body Area Networks

The Wireless Body Area Network (WBAN), which aims to create a wider network using a compilation of wearable sensors and actuators, has increased in prominence in the field of health monitoring. It is made of medically implanted devices that provide accurate and comprehensive health data. WBAN, in fact, necessitates continual research across multiple layers, including physical, MAC, and network. Furthermore, crucial properties like autonomy and low price encourage the use of wearables without either requiring extensive medical treatment, allowing for a large-scale deployment of wearables. Figure 16.4. represents a futuristic healthcare system to monitor and treat patients with the help of AI and pervasive computing.

Carlos A. Tavera et al. [48] explicitly underlined the importance of WBAN in managing the healthcare system at a high level utilising AI in their review. Experts contend that WBAN technology is increasingly being adopted in applications that involve individuals and their health, hence enhancing the role of technology in individuals' healthcare. WBAN devices can assist identify diseases, facilitate therapy, and lessen the need for ongoing medical attention by providing constant information about patients and their pathologies. It's vital to continually improve the reliability of data collected through the WBAN, and also gadget autonomously. It will allow the development of innovative reliable designs based on artificial intelligence capable of providing perpetual prognosis and tracking for diseases that affect a significant part of the population, while also taking full leverage of currently

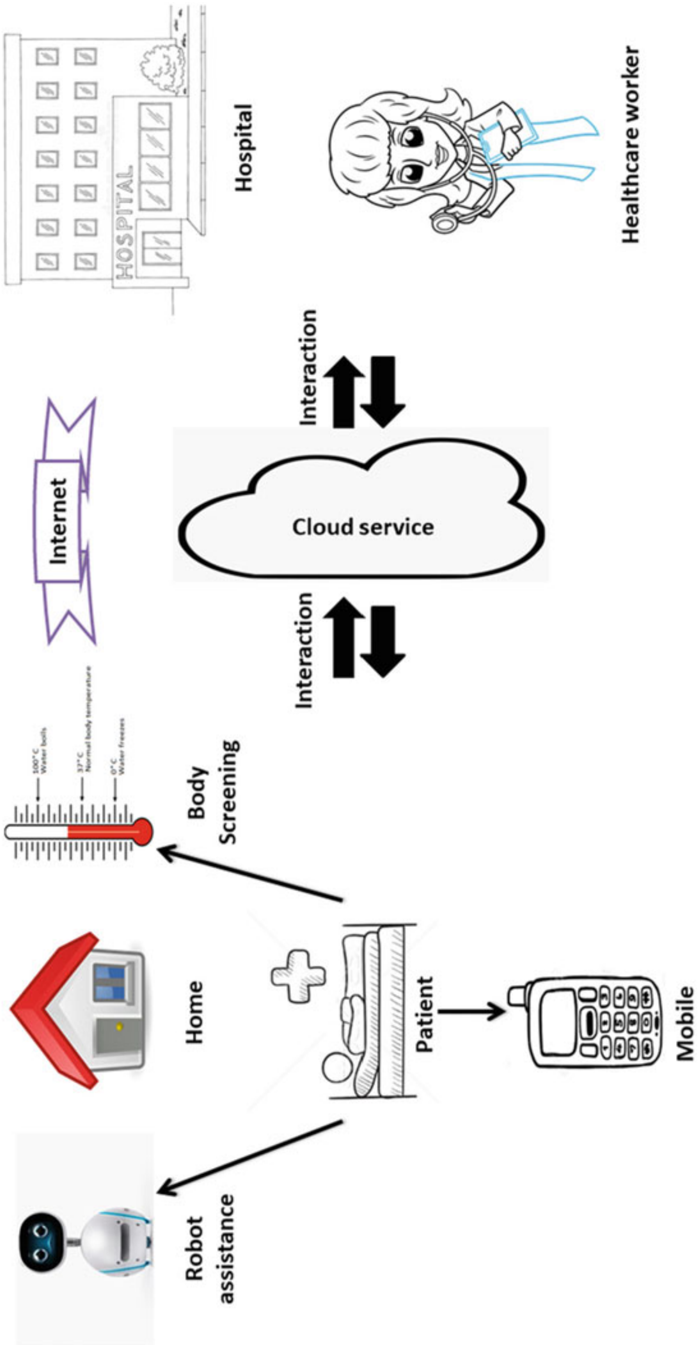


Fig. 16.4 A futuristic healthcare system

underway technological advancements such as tactile internet and subjective devices.

Chinmay Chakraborty et al. [49] in their article, discussed the main components of body area sensor networks in telemedicine systems for healthcare management in many circumstances, such as research challenges, primary condemnations and obstacles. They discussed the necessities for exceptionally low- prevention of wearable/implantable sensors, power operation, privacy and security, intelligent processing of patient vital data, lightweight, emergency medical care, real-time connectivity over heterogeneous networks, standardization, low complexity, interoperability, and low cost as important issues and challenges related to WBAN. This article may serve as a source of inspiration for future research projects. A futuristic healthcare systemhas been shown in Fig. 16.4. which comprises of patients'shome care by the utilization of several technologies and influence of cloud system in contrast to the hospital and its healthcare workers.

16.11 Opportunities and Challenges

16.11.1 Opportunities

Technologies are being created, and some have been shown to improve health outcomes, lower healthcare costs, improve quality of life, and reduce the number of medical appointments. Deep, unattended home monitoring by utilizing a tri-axial accelerometer in older people as well as another gadget for step mapping in patients with a variety of diseases has been shown to enhance health outcomes. Smart homes are only one example of systems that have the ability to reduce healthcare expenses while enhancing the quality of life. Hyperspectral monitoring, continuous vital parameter surveillance, and people-centric sensing systems are just a few instances of technology that could help elderly people avoid emergencies.

16.11.2 Challenges

Down below, several challenges faced by an individual who utilizes wearable sensors have been discussed deeply:

- Environmental attributes: Contextual information about the individual's environment is conveyed through temperature, moisture, audio volume, and other aspects. The individual may be sleeping if the music volume and light intensity are both low. Light sensors, Microphones, thermometers andhumidity sensors have all been used in previous systems. Individuals can carry out each action in a range of conditions, including climate, audio volume, and illumination, thus those sensors alone may not be sufficient.

- Location: All kinds of location-based services are possible due to the Global Positioning System (GPS). Current cellular phones have GPS units, rendering this sensor ideal for context-aware applications such as determining the user's method of mobility. Through ontological reasoning, the user's current location could also be utilized to predict their behaviors. A person who is in a park is unlikely to brush their teeth; however, they may be jogging or walking. Also, among other things, the Google Places Web Service makes it simple to access information about locations. GPS systems, on the other hand, do not perform well indoors and are highly energy-intensive, especially in real-time tracking applications. As a result, this sensor is frequently used in conjunction with accelerometers. Finally, because users do not always want to be tracked, location data poses a privacy risk. Encryption, obscurity, and anonymization are among the measures required to secure privacy in location data.
- Energy consumption: Context-aware apps dependupon the gadgets like mobile devices with limited battery life, such as sensors and cell phones. Improving the battery life is a necessary characteristic in most cases, especially for medical and military applications that must supply important data. Surprisingly, the majority of HAR approaches disregard energy consumption thatis mostly driven by a processor, transmission, and visual demands. The developer should minimize the amount of data provided because communication is frequently the least intensive experience. Data compression and aggregation are common energy-saving techniques, but they require large computations, which can slow down applications. Another approach is to do feature extraction techniques within the integration device, obviating the need to send raw signals to the server on a frequent basis.

16.12 Conclusion

Wearable sensors are predicted to gain a lot of attention since there is a pressing need for long-lasting, accurate, and low-cost sensors that may be worn every day without causing irritation or discomfort, especially for real-time illness monitoring. The use of these sensors in everyday life is shifting away from direct skin attachment and more towards watch-style bands, fabrics, and facemasks. Despite significant improvements, wearable sensors suffer common difficulties. To begin, large-scale, successful clinical assessment investigations are necessary to acquire medical community acceptability, which is also due to a current paucity of data for evaluating whether vital sign evolution could aid in the diagnosis or the collection of a deeper understanding of illness development. Second, there are concerns with wireless connectivity, power control and battery, data protection, and anonymity. Various transmission strategies are used to send all patient data to the second layer. Cloud and web servers make up the second tier, which collects, analyze, and store data for eventual use. Regular inspections might be performed using low-cost sensors in the not-too-distant future, with all patient data being recorded and uploaded into a sophisticated EHR. This analysis could help PM researchers better understand the implications of published evidence and plan future research to overcome challenges and limits, thus addressing the gap identified in this chapter. Wearable sensors for identifying cancer-related compounds and biomarkers are currently being developed. To confirm the presence of the tyrosine enzyme biomarker on the skin's surface and then behind skin lesions for rapid skin cancer detection, wearable bandages and microneedle electrochemical sensing devices have been created. Machine learning and data mining are important applications of artificial intelligence that are developing in tandem with the development of increasingly accurate, delicate, and steady electronics. Algorithms based on data could be used to discover trends and assist people in understanding how their habits impact their health. Assimilation of information from multiple sources (e.g., emotion, perceived stress, meal log) would broaden the expertise base for algorithm design to improve the overview of past behaviours and experiences, as well as estimate future behaviours and their health consequences.

However, lack of resources, insufficient funding, and uncertainties about future telehealth legislation, privacy issues, limited technology skills, and limitations of access resulting in inadequate internet connectivity are all obstacles to virtual care model rollout. Chronic disease management software, distant and constant diagnostics, and digital COVID preventive interventions digital tools are all urgently required, as are chronic sickness management software and digital COVID prevention. It should be must be considered thatthe medical sector takes the lead in implementing technological innovations by lobbying for scientifically rigorous research standards for validating the technology and digital solutions, as well as best practices to assure the safety of patients and well-being.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Fouad, H., Mahmoud, N. M., El Issawi, M. S., & Al-Feel, H. (2020). Distributed and scalable computing framework for improving request processing of wearable IoT assisted medical sensors on pervasive computing system. *Computer Communications, 151*, 257–265. https://doi.org/10.1016/j.comcom.2020.01.020
2. Jiang, P., Winkley, J., Zhao, C., Munnoch, R., Min, G., & Yang, L. T. (2016). An intelligent information forwarder for healthcare big data systems with distributed wearable sensors. *IEEE Systems Journal, 10*, 1147–1159. https://doi.org/10.1109/JSYST.2014.2308324

3. Jiang, S., Xue, Y., Giani, A., & Bajcsy, R. (2009). Robust medical data delivery for wireless pervasive healthcare. 8th IEEE Int Symp dependable. *Autonomic and Secure Computing (DASC), 2009*, 802–807. https://doi.org/10.1109/DASC.2009.87
4. Kristoffersson, A., & Lindén, M. (2020). Wearable sensors for monitoring and preventing noncommunicable diseases: A systematic review. *Information, 11*, 1–31. https://doi.org/10.3390/info11110521
5. Neves, P., Stachyra, M., & Rodrigues, J. (2008). Application of wireless sensor networks to healthcare promotion. *Journal of Communications Software and Systems, 4*, 181–190. https://doi.org/10.24138/jcomss.v4i3.218
6. Khan, S., & Alam, M. (2021). Wearable internet of things for personalized healthcare: Study of trends and latent research. *Studies in Computational Intelligence, 932*, 43–60. https://doi.org/10.1007/978-981-15-9735-0_3
7. Al-Halhouli, A., Albagdady, A., Alawadi, J., & Abeeleh, M. A. (2021). Monitoring symptoms of infectious diseases: Perspectives for printed wearable sensors. *Micromachines, 12*, 620. https://doi.org/10.3390/mi12060620
8. Sood, S. K., Sood, V., Mahajan, I., & Sahil. (2021). An intelligent healthcare system for predicting and preventing dengue virus infection. *Computing, 1*, 1–39. https://doi.org/10.1007/s00607-020-00877-8
9. Joy Rakesh, Y., Kavitha, R., & Julian, J. (2021). Human activity recognition using wearable sensors. *Advances in Intelligent Systems and Computing, 1177*, 527–538. https://doi.org/10.1007/978-981-15-5679-1_51
10. Pugliese, A., Milano, P., Begnozzi, V., Milano, P., Gualtierotti, R., & Peyvandi, F. (2021). *Rehabilitation through accessible mobile gaming and wearable sensors*. Association for Computing Machinery.
11. Eun, S. J., & Kim, J. Y. (2021). Development of intelligent healthcare system based on ambulatory blood pressure measuring device. *Neural Computing and Applications, 33*, 4599–4610. https://doi.org/10.1007/s00521-020-05114-z
12. Zhang, Z., Muthu, B. A., & Sivaparthipan, C. B. (2021). The necessary of constructing preventive health intervention policy under the trend of deep aging in China. *Journal of Ambient Intelligence and Humanized Computing, 12*, 3539–3547. https://doi.org/10.1007/s12652-020-02594-8
13. Leu, F., Ko, C., You, I., Choo, K. K. R., & Ho, C. L. (2018). A smartphone-based wearable sensors for monitoring real-time physiological data. *Computers and Electrical Engineering, 65*, 376–392. https://doi.org/10.1016/j.compeleceng.2017.06.031
14. Malwade, S., Abdul, S. S., Uddin, M., Nursetyo, A. A., Fernandez-Luque, L., Zhu, X., Katie, K., Cilliers, L., Wong, C. P., Bamidis, P., & Li, Y. C. J. (2018). Mobile and wearable technologies in healthcare for the ageing population. *Computer Methods and Programs in Biomedicine, 161*, 233–237. https://doi.org/10.1016/j.cmpb.2018.04.026
15. Kameas, A., & Calemis, I. (2010). *Handbook of ambient intelligence and smart environments*. Springer.
16. Miller, J. C., Skoll, D., & Saxon, L. A. (2021). Home monitoring of cardiac devices in the era of COVID-19. *Current Cardiology Reports, 23*(1), 1. https://doi.org/10.1007/s11886-020-01431-w
17. Neethirajan, S. (2017). Recent advances in wearable sensors for animal health management. *Sensing and Bio-Sensing Research, 12*, 15–29. https://doi.org/10.1016/j.sbsr.2016.11.004
18. Kańtoch, E. (2018). Recognition of sedentary behavior by machine learning analysis of wearable sensors during activities of daily living for telemedical assessment of cardiovascular risk. *Sensors (Switzerland), 18*, 1–17. https://doi.org/10.3390/s18103219
19. Pandian, P. S., Safeer, K. P., Gupta, P., Shakunthala, D. T., Sundersheshu, B. S., & Padaki, V. C. (2008). Wireless sensor network for wearable physiological monitoring. *Journal of Networks, 3*, 21–29. https://doi.org/10.4304/jnw.3.5.21-29

20. Yang, P., Bi, G., Qi, J., Wang, X., Yang, Y., & Xu, L. (2021). Multimodal wearable intelligence for dementia Care in Healthcare 4.0: A survey. *Information Systems Frontiers, 1*, 1–18. https://doi.org/10.1007/s10796-021-10163-3
21. Ali, F., El-Sappagh, S., Islam, S. M. R., Ali, A., Attique, M., Imran, M., & Kwak, K. S. (2020). An intelligent healthcare monitoring framework using wearable sensors and social networking data. *Future Generation Computer Systems, 114*, 23–43. https://doi.org/10.1016/j.future.2020.07.047
22. Majumder, S., Mondal, T., & Deen, M. J. (2017). Wearable sensors for remote health monitoring. *Sensors (Switzerland), 17*(1), 130. https://doi.org/10.3390/s17010130
23. Imran, I. N., Ahmad, S., & Kim, D. H. (2021). Health monitoring system for elderly patients using intelligent task mapping mechanism in closed loop healthcare environment. *Symmetry (Basel), 13*, 1–28. https://doi.org/10.3390/sym13020357
24. Romero, L. E., Chatterjee, P., & Armentano, R. L. (2016). An IoT approach for integration of computational intelligence and wearable sensors for Parkinson's disease diagnosis and monitoring. *Health and Technology (Berl), 6*, 167–172. https://doi.org/10.1007/s12553-016-0148-0
25. Jansi, R., Amutha, R., & Radha, S. (2019). Remote monitoring of children with chronic illness using wearable vest. *Multimedia Tools and Applications, 78*, 24681–24706. https://doi.org/10.1016/B978-0-12-816948-3.00008-8
26. Zheng, Y., Cao, J., Chan, A. T. S., & Chan, K. C. C. (2008). Sensors and wireless sensor networks for pervasive computing applications. *Journal of Ubiquitous Computing and Intelligence, 1*, 17–34. https://doi.org/10.1166/juci.2007.003
27. Postolache, O., Girão, P. S., & Postolache, G. (2013). Pervasive sensing and M-health: Vital signs and daily activity monitoring. *Smart Sensors, Measurement and Instrumentation, 2*, 1–49. https://doi.org/10.1007/978-3-642-32538-0_1
28. Monton, J. L. B., Martinez-Millana, A., Han, W., Fernandez-Llatas, C., Sun, Y., & Traver, V. (2018). Wearable sensors integrated with internet of things for advancing ehealth care. *Sensors (Switzerland), 18*, 1–18. https://doi.org/10.3390/s18061851
29. Rault, T., Bouabdallah, A., Challal, Y., & Marin, F. (2017). A survey of energy-efficient context recognition systems using wearable sensors for healthcare applications. *Pervasive and Mobile Computing, 37*, 23–44. https://doi.org/10.1016/j.pmcj.2016.08.003
30. Chan, M., Estève, D., Fourniols, J. Y., Escriba, C., & Campo, E. (2012). Smart wearable systems: Current status and future challenges. *Artificial Intelligence in Medicine, 56*, 137–156. https://doi.org/10.1016/j.artmed.2012.09.003
31. Tahmasbi, A., Adabi, S., & Rezaee, A. (2016). Behavioral reference model for pervasive healthcare systems. *Journal of Medical Systems, 40*, 1–23. https://doi.org/10.1007/s10916-016-0632-0
32. Suresh Kumar, S., Dashtipour, K., Abbasi, Q. H., Imran, M. A., & Ahmad, W. (2021). A review on wearable and contactless sensing for COVID-19 with policy challenges. *Frontiers in Communications and Networks, 2*, 1–10. https://doi.org/10.3389/frcmn.2021.636293
33. Trossen, D., Pavel, D., Platt, G., Wall, J., Valencia, P., Graves, C. A., Zamarripa, M. S., Gonzalez, V. M., Favela, J., Lövquist, E., & Kulcsár, Z. (2007). Sensor networks, wearable computing, and healthcare applications. *IEEE Pervasive Computing, 6*, 58–61. https://doi.org/10.1109/MPRV.2007.43
34. Varshney, U. (2007). Pervasive healthcare and wireless health monitoring. *Mobile Networks and Applications, 12*, 113–127. https://doi.org/10.1007/s11036-007-0017-1
35. Lin, Q., Li, T., Shakeel, P. M., & Samuel, R. D. J. (2021). Advanced artificial intelligence in heart rate and blood pressure monitoring for stress management. *Journal of Ambient Intelligence and Humanized Computing, 12*, 3329–3340. https://doi.org/10.1007/s12652-020-02650-3
36. Liang, X., Barua, M., Chen, L., Lu, R., Shen, X., Li, X., & Luo, H. (2012). Enabling pervasive healthcare through continuous remote health monitoring. *IEEE Wireless Communications, 19*, 10–18. https://doi.org/10.1109/MWC.2012.6393513

37. Raad, M. W., & Yang, L. T. (2009). A ubiquitous smart home for elderly. *Information Systems Frontiers, 11*, 529–536. https://doi.org/10.1007/s10796-008-9119-y
38. Pramanik, P. K. D., Upadhyaya, B. K., Pal, S., & Pal, T. (2019). *Internet of things, smart sensors, and pervasive systems: Enabling connected and pervasive healthcare*. Elsevier.
39. Shyamkumar, P., Rai, P., Oh, S., Ramasamy, M., Harbaugh, R. E., & Varadan, V. (2014). Wearable wireless cardiovascular monitoring using textile-based nanosensor and nanomaterial systems. *Electronics, 3*, 504–520. https://doi.org/10.3390/electronics3030504
40. Bonato, P. (2010). Wearable sensors and systems. From enabling technology to clinical applications. *IEEE Engineering in Medicine and Biology Magazine, 29*, 25–36. https://doi.org/10.1109/MEMB.2010.936554
41. El-Rashidy, N., El-Sappagh, S., Islam, S. M. R., El-Bakry, M. H., & Abdelrazek, S. (2021). Mobile health in remote patient monitoring for chronic diseases: Principles, trends, and challenges. *Diagnostics, 11*, 607. https://doi.org/10.3390/diagnostics11040607
42. Saner, H., Schuetz, N., Buluschek, P., & Du, P. G. (2021). Case report : Ambient sensor signals as digital biomarkers for early signs of heart failure decompensation. *Frontiers in Cardiovascular Medicine, 8*, 1–6. https://doi.org/10.3389/fcvm.2021.617682
43. Andreu-Perez, J., Leff, D. R., Ip, H. M. D., & Yang, G. Z. (2015). From wearable sensors to smart implants-toward pervasive and personalized healthcare. *IEEE Transactions on Biomedical Engineering, 62*, 2750–2762. https://doi.org/10.1109/TBME.2015.2422751
44. Atallah, L., Lo, B., & Yang, G. Z. (2012). Can pervasive sensing address current challenges in global healthcare? *Journal of Epidemiology and Global Health, 2*, 1–13. https://doi.org/10.1016/j.jegh.2011.11.005
45. Dwivedi, R., Dey, S., Chakraborty, C., & Tiwari, S. (2021). Grape disease detection network based on multi-task learning and attention features. In *IEEE Sensors Journal*. IEEE. https://doi.org/10.1109/JSEN.2021.3064060
46. Tarniţă, D. (2016). Wearable sensors used for human gait analysis. *Romanian Journal of Morphology and Embryology, 57*, 373–382.
47. Perumal, S., Tabassum, M., Narayana, G., Ponnan, S., Chakraborty, C., Mohanan, S., Basit, Z., & Quasim, M. T. (2021). Ann based novel approach to detect node failure in wireless sensor network. *Computers, Materials and Continua, 69*, 1447–1462. https://doi.org/10.32604/cmc.2021.014854
48. Tavera, C. A., Ortiz, J. H., Khalaf, O. I., Saavedra, D. F., & Aldhyani, T. H. H. (2021). Wearable wireless body area networks for medical applications. *Computational and Mathematical Methods in Medicine, 2021*, 5574376. https://doi.org/10.1155/2021/5574376
49. Chakraborty, C., Gupta, B., & Ghosh, S. K. (2013). A review on telemedicine-based WBAN framework for patient monitoring. *Telemed e-Health, 19*, 619–626. https://doi.org/10.1089/tmj.2012.0215
50. Szydło, T., & Konieczny, M. (2016). Mobile and wearable devices in an open and universal system for remote patient monitoring. *Microprocessors and Microsystems, 46*, 44–54. https://doi.org/10.1016/j.micpro.2016.07.006

Chapter 17
A Wavelet-Based Robust Medical Image Watermarking Technique Using Whale Optimization Algorithm for Data Exchange Through Internet of Medical Things

Khosro Rezaee, Maryam SaberiAnari, and Mohammad R. Khosravi

Abstract Medical image plays a vital role in altering the diagnostic process. Using the Internet of Things (IoT) in healthcare applications, the diagnosis process will be more successful in medical image analysis. However, to accomplish privacy-preserving medical image exchange, we need a solid and secure approach. The primary objective of the proposed model in this chapter is to watermark the medical image by preserving the privacy of individuals based on a hybrid approach for telemedicine and the use of the IoT. Firstly, discrete wavelet transform (DWT) estimates the coefficients to incorporate the singular values. The optimum embedding coefficients are then determined using the Whale Optimization Algorithm's cost function evaluation (WOA). The watermark medical image is embedded using the singular value decomposition (SVD) and inverse SVD (ISVD) methods. Despite the combination of different attack methods, PSNR and NC were associated with a 22% and 17% improvement in the watermark process, respectively. The proposed watermarking method generates high PSNR values and produces results of outstanding quality with preserving privacy. Additionally, it presents high correlation results when combined attacks occur and requires less computational processing time.

Keywords Medical image watermarking · Privacy-preserving · IoT system · Whale optimization algorithm · Discrete wavelet transform · Singular value decomposition

K. Rezaee (✉)
Department of Biomedical Engineering, Meybod University, Meybod, Iran
e-mail: Kh.rezaee@meybod.ac.ir

M. SaberiAnari
Department of Computer Engineering, Technical and Vocational University (TVU), Tehran, Iran
e-mail: saberi-m@tvu.ac.ir

M. R. Khosravi
Department of Computer Engineering, Persian Gulf University, Bushehr, Iran
e-mail: M.khosravi@sutech.ac.ir

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_17

17.1 Introduction

17.1.1 Medical Data and IoT

The development of technology-based on big data and information analysis is currently a popular study topic. Developing an information analysis's main objectives is to create essential support and provide a good living condition. The emphasis is on general development and sustainable growth, and the aim is to examine the facilitate technology in multiple fields. The key support components of automatic devices involve information technology (I.T.) connection and digitalization. One of the new fields in I.T. connection is IoT deployment. Thus, the IoT represents an essential part of automated technology [1–3].

The IoT platform is built on a worldwide infrastructure based on the connection network that links peculiarly identifiable items by utilizing the information collected by the actuators and sensors and the technology employed for localization and communication. Healthcare and medicine constitute many of the various promising utilization fields for IoT deployment. Hence, IoT can give birth to numerous medical applications, including remote exercise programs, health monitoring, incurable disorders, and aging care.

Accordance with medication and treatment by healthcare professionals at home is different significant possible employment. Accordingly, different sensors, medicinal equipment, imaging tools, and distinguishing methods may be regarded as useful objects or devices forming the foundation of the IoT. Healthcare services based on IoT are anticipated to decrease expenses, improve life quality, and enhance users' experience. In standard IoT-powered healthcare, traditional healthcare is substituted with computerized healthcare. Adopting an IoT infrastructure-based healthcare scheme is associated with numerous obstacles at administrative and technical levels [4, 5]. From a technical perspective, the protection of Electronic Patient Records (EPR) is a key problem that requires consideration. At present, a large amount of medical information, including imaging from different tissues and DMI, is being transmitted worldwide to provide electronic healthcare that includes telemedicine and telehealth via unsecured channels of the infrastructure network. The transfer of critical data through unsecured networks may result in simple access, which then, one after another, creates a danger to the authenticity and safety of medicinal information [6, 7].

Numerous content authentication and security problems may be addressed via the use of different technologies such as cryptography and data hiding, which is employed to protect information through transit and conceals the data, which may arouse suspicion in an eavesdropper, thus increasing the likelihood of an attack. Cryptography has shown to be a viable alternative method for protecting and authenticating information sent across insecure networks. Steganography and watermarking are two major categories of data hiding [8]. Numerous studies on medical image watermarking are being conducted to ensure the diagnostic integrity of medical information [9].

A digital watermark within a cover medical image might be a hospital logo, a physician's logo, or a doctor's signature. Digital watermarking techniques must have imperceptibility, robustness, payload, and security properties [10]. The two basic types of digital image watermarking methods are the transform domain and the spatial domain. The spatial domain approach, also known as pixel domain, embeds the watermark directly into the pixel values of the host image. The host image is combined using simple processes. Approaches like correlation-based, spread spectrum and least significant bit are used in the spatial domain. The transform domain approach is the alternative option. The most commonly used transformation algorithms are discrete wavelet transform (DWT), discrete Fourier transform (DFT), and discrete cosine transform (DCT). One of the transformation strategies transforms the host image into the frequency domain. These approaches adjust the translated coefficients rather than changing the pixel values directly.

17.1.2 Medical Image Watermarking

In recent years, the systems based on the Internet of Things (IoT) [11–15] and Cloud computing [16–18] are strongly dependent on internet services and networks for multimedia communications. Besides, Cyber-security has various analyses, including IoT and cloud forensics [19–22] and medical applications [23, 24]. Recently, digital watermarking (DW) schemes have grown as efficient multimedia security designs [25]. DW is a suggestion to embed a section of data called a watermark part in the host signal such as, audio, video, and image for the information covering scheme.

DW methods are categorized as spatial domain and frequency methods to embed the watermark [26, 27]. Studies involved in the DW domain encountered many difficulties in producing innovative algorithms to assist several watermarking purposes and obtain different multimedia attacks. Makbol et al. [28] presented an image watermarking method utilizing SVD and RDWT models.

Besides, Rastegar et al. [29] proposed a watermarking scheme employing SVD and radon transform. Furthermore, hybrid watermarking procedures strive to develop robustness with proper imperceptibility [30–32].

DW is required to protect images and prevent the publication and disclosure of personal information in uses that are considered unauthorized [33, 34]. Therefore, some analyses attempt to consider different circumstances to prevent the publication of personal information. One of these popular plans is watermarking based on methods such as machine learning models. The main goal of the image watermarking technique is to organize and develop a high-penetration algorithm.

With the development of the current medical scheme, digital medical image (DMI) performs a more significant purpose in the telemedicine part. It is simple to access some protected information in the process of medical data transmission. Therefore, it is essential to present digital watermarking technology from the security perspective into the medical care scheme. Distinguishing records include critical data such as patients' essential data and physician's examination outcomes. Some studies utilize the invisibility and robustness of digital watermarks for preserving patient's privacy from embedding distinguishing records into analogous DMI as secure watermark data. Meanwhile, authentication data is required, and therefore, authentication can be performed by extracting useful features from the watermark. DMI assists as an influential source for physicians to recognize patients' situations. Differences in their data may influence physicians' analysis outcomes. Once errors have proceeded, severe medical occurrences may be generated. Accordingly, any procedure that may produce a loss of DMI data should be prevented.

Most modern watermarking algorithms train a learner based on feature vectors. Previous methods considered different models that contained encrypted DMI watermarking capabilities in the host images. There are two important points to consider here: first, the correct insertion of the image about to be watermarked, and two, the capability to recover the encrypted message or image. Alongside these matters, watermark accuracy and needed time for this process are of importance. Therefore, our purpose here is to reduce the processing time and reach a minimum error rate in image watermarking, extraction, and retrieval processes.

The optimization algorithm is one of the best searching methods in the answer zone; recently, many evolutionary and meta-heuristic optimization algorithms have been used in complex problems [35]. Evolutionary [36–38] and meta-heuristic [39, 40] algorithms are also useful in watermarking and optimize many different processes in this field.

The present chapter is focused on minimizing the objective function by identifying appropriate singular values that fit the wavelet domain, as well as other criteria such as Normalized Correlation (NC), Peak Signal-to-Noise Ratio (PSNR), and Mean Squared Error (MSE). This research has several objectives, including introducing a wavelet image watermarking approach based on singular value analysis and the Whale Optimization Algorithm (WOA: known as a new and effective optimization algorithm). Such an image watermarking model or algorithm will be effective if it can present different factors such as PSNR and NC in their optimal condition. Secondly, we are after a robust and secure watermarking method that can withstand different attacks. Some intended contributions of this chapter are:

- *Robustness and security:* WOA significantly helps to improve the robustness of the watermarking method. The robustness of the proposed privacy system makes it possible for medical images to withstand severe attacks.
- *Imperceptibility and quality:* The watermarked DMI quality is supposed to be protected with a high clearance by proficiently choosing the remarkably appropriate domain for the watermarking procedure.
- *Privacy-preservation:* The proposed watermarking-based method is useful in patient privacy-preservation or medical image watermarking and telemedicine in IoT platform.
- *Computational complexity:* Compared to similar methods, the computational complexity of our suggested watermarking procedure is satisfyingly low.

The remaining sections of the chapter are as follows: The second section discusses related work. The optimal method for the watermarking procedure is introduced in Sect. 17.3. The dataset, findings, and discussion used in our studies are explained in Sect. 17.4. Finally, in Sect. 17.5, the study's findings and potential plans are given.

17.2 Related Work

In recent decades, many developments in the field of storage and exchange of information have led to numerous studies and research. We know that information may be tampered with, changed, or infringed contrary to copyright law. The watermarking importance was discussed at the beginning of the chapter, and it was stated that different watermarking methods could overcome problems in the desired category such as medical imaging problem [41]. Some ways have a better ability in watermarking, and others have drawbacks. Sometimes bit change techniques are used, and therefore, various outputs are obtained between different images, which often depend on the image's quality, resolution, and format. In the meantime, methods that have the ability to detect the presence of a hidden image can also be seen in the detection of tampering and possible sabotage of sample images (such as DM images). Comparing several watermarking techniques and consequently finding the possible advantages and disadvantages can be useful in creating an efficient watermarking model. In the continuation of this chapter, the previous methods will be studied, and information from each research will be provided.

Based on BCH and wavelet error-correcting code, Giakoumaki et al. [42] developed a method for medical image watermarking. At various decomposition stages and sub-bands, this approach embeds three watermarks in the DWT host signal: index, signature, reference, and caption.

Kannammal et al. [43] described a method for watermarking medical images that involves inserting the watermark into a specific sub-band of the host image.

Hemdan et al. [44] suggested a hybrid method for improving capacity based on combining 2 gray-scale images utilizing fusion procedure. Similarly, Hemdan et al. [45] developed an efficient and robust watermarking method based on three-level DWT wavelet fusion of 2 gray-scale images. The suggested approach enhances implanted capacity while having a negligible impact on the image quality of the host.

The wavelet coefficients are used with a zoomed image method to get a high-quality image [46]. Similarly, wavelets and block truncation are employed to optimize the image compression-decompression process [47]. In [48], a novel image watermarking method based on interpolation and wavelets was presented. CLAHE and DWT are utilized to provide a new method for image reconstruction [49].

Many additional important frequency domains in image processing, such as DCT, are utilized for palm and face print identification using dynamic weighted discrimination power analysis [50, 51]. Fusion was utilized at the feature level in [52] for palm-print fusion (PPF)models. Additionally, [53] discusses how to choose discriminative characteristics for fusion. The 2DPalmPhasor Code suppression and correlation analysis and are discussed in [52, 53]. They developed an authentication mechanism for a cancelable palm print system through multi-directional two-dimensional PPF.

Furthermore, the authors propose a blind image watermarking approach based on DWT and SVD models [54]. DWT is used in this method to extract various frequency sub-bands of a medical image's wavelet decomposition from the images' Region of Interest (ROI). Block-SVD, on the other hand, is used to extract a variety of singular matrices from the ROI's low-frequency sub-band LL.

Researchers are familiar with the generally positive effects of singular value decomposition and wavelet field usage on the watermarking process, leading optimization algorithms onto steganography in examples such as [36–38, 55–58]. These algorithms use evolutionary and meta-heuristic optimization methods to improve image watermarking; for example, [36–38] use the particle swarm optimization (PSO) algorithm to improve two-dimensional and three-dimensional watermarking in the multi-object analysis of colored images. Others use evolutionary algorithms such as the Genetic algorithm to improve watermarking.

Study [39] proposed a method based on the Cuckoo Search algorithms to improve watermarking robustness against different attacks. Other studies have used the Cuckoo search algorithm to optimize the wavelet field process [40].

Mishra et al. [16] used the Firefly algorithm and singular value analysis in the wavelet field to perform gray image watermarking [35]. Ali et al. [56] used the Differential Evolution (DE) procedure to solve the optimum global problem, which might not be looked upon in the genetic algorithm (GA) due to the existence of local optimums. Also, the Genetic algorithm was used in the wavelet field based on singular value decomposition to improve image watermarking [57].

In another work, Ali et al. [58] presented an image watermarking model based on the Artificial Bee Colony (ABC) algorithm and the SVD approach. The image was first converted to wavelet format. After separating the sub-bands into non-overlapping blocks and picking the suitable information embedding blocks, the decomposed singular value of each block was chosen. Their process led to estimating the image's least and maximum change resistance by setting the appropriate threshold. They employed the ABC algorithm for this assignment and, comparing the findings to those from previous studies, revealed that it was highly resilient to various attacks.

Sharma et al. [59] proposed a time-saving optimization technique based on machine learning algorithms for determining the best embedding parameter for watermarking photos. The optimization parameters were determined using ant colony optimization (ACO).

In the RDWT-SVD domain, Anand et al. [60] used a secure and resilient dual watermarking method. Firefly optimization was used to achieve a balance between robustness and imperceptibility in their design.

Singh et al. [61] presented an innovative strategy for copyright security of multi-spectral images utilizing kernel extreme learning machine (KELM) and PSO algorithm-based watermarking method.

Singh et al. [62] also introduced a robust watermarking system utilizing a chaotic kbest gravitational search algorithm (CKGSA) in SVD and DCT areas.

Amrit et al. [63] suggested proper optimization designs that were applied to determine the scaling factor for the embedding scheme.

Selvaraj et al. [64] presented a watermark model based on the whirlpool algorithm through a hash function to produce the hash value. The suggested structure has consisted of two blocks: extracting process and Regular-Singular (R–S) Vector compression and watermark embedding.

17.3 Proposed Model

17.3.1 Discrete Wavelet Transform

The DWT has been widely utilized in recent years in the field of image processing. The image is transformed by wavelet using wavelet filters, including Haar and other similar filters. Each filter divides the image into a series of frequencies. TheDWT procedure divides an image into four principal components: a diagonal component (HH), a vertical (LH), a lower resolution approximation image (LL), and a horizontal (HL). This procedure may then be repeated indefinitely to get a multi-scale wavelet decomposition [65], as depicted in Fig. 17.1. By embedding watermarks in the bands with high-resolution (i.e., LH, HH, and HL), it is possible to increase watermark robustness while minimizing image quality degradation [66]. The DWT has several meaningful characteristics, including the fact that identifying of watermarks at lower resolutions is computationally efficient, as each successive resolution level involves a small number of frequency bands in addition to the higher resolution sub-bands that aid in locating texture patterns and the edge [67].

Fig. 17.1 DWT decomposes a medical image to different frequency sub-bands

17.3.2 Embedding Procedure

Figure 17.2 shows that embedding is the first watermarking step, which requires the host and watermark images. Therefore, the DWT is implemented on the host and watermark images. Afterward, the SVD is performed for low-frequency coefficients of both images. The embedding process is performed using Eq. (17.1):

$$S_{Watermarked} = S_{orginal} + \alpha S_{watermark} \tag{17.1}$$

Here, $S_{watermarked}$ are the special values of the watermarked image, $S_{original}$ the special values of the host image, $S_{watermark}$ the special values of the watermark image, and a is the embedding coefficient. The watermarked images are obtained from the reverse discrete wavelet transform, which is calculated from the singular value decomposition based on the reverse result values.

17.3.3 WOA

Humpback whales can determine the position of their hunt and surround it. Since the optimized design space in the search space is not determined by comparisons, the whale algorithms consider hunting the goal as the best current candidate or at least as something close to the optimal state. Other search factors change their positions in relation to the best search factor when the best search factor is identified.

This behavior can be explained as follows:

$$D = \left| \vec{C}\vec{X}^*(t) - \vec{X}(t) \right| \tag{17.2}$$

$$\vec{X}(t+1) = \vec{X}^*(t) - \vec{A}.\vec{D} \tag{17.3}$$

where t denotes the current iteration, A and C denote the coefficient vectors, X^* is the best current solution's position vector, and X denotes the position vector. Notably,

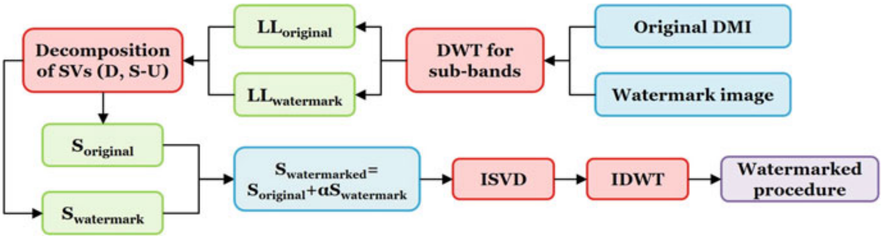


Fig. 17.2 Shows that embedding is the first watermarking step

X^* must be updated in every iteration if any preferable solutions are found. The A and C vectors is computed as Eq. (17.4):

$$\vec{A} = 2\vec{a}.\vec{r} - \vec{a} \tag{17.4}$$

$$\vec{C} = 2\vec{r} \tag{17.5}$$

During iterations (in both the exploration and extraction phases), a will be progressively reduced from 0 to 2, and r will be a random vector between [0–1]. The following two strategies are intended to simulate the humpback whale bubble-net behavior mathematically:

- Contraction Envelopment Mechanism: This behavior is caused by increasing the a value in Eq. (17.4). The A oscillation range is reduced by a. In other words, A is a random value in the ($-a$ to a) range, while a is decreased from 2 to 0 during the iterations. By selecting the random A value between the 1 to -1 range, the new search factor space can be defined anywhere between the original factor space and the current optimal space.
- Spiral Envelopment: This method, first, calculated the distance between the whale at X and Y and the bait at X^* and Y^*. Also, the equation is produced for the distance between the whale and bait to imitate the spiral motion of the humpback whale:

$$\vec{X}(t+1) = \vec{D}' e^{bl}.\cos(2\pi l) + \vec{X}^*(t) \tag{17.6}$$

Here, we have $D' = \left|\vec{X}^*(t) - \vec{X}(t)\right|$, which refers to the span between the i_{th} whale and the bait (best current solution), b is a coefficient for describing the logarithmic spiral shape, and l is a random number between [-1 to 1].

Notably, the humpback whale swims around the bait in a contracting circle down a spiral-shaped path. We have considered a 50% change for the whale to select the contraction or spiral envelopment models to pattern this simultaneous behavior and update the whale position during the optimization. Thus, the mathematical pattern is defined as:

$$\vec{X}(t+1) = \begin{cases} \vec{X}^*(t) - \vec{A}.\vec{D} & f p \leq 0.5 \\ \vec{D}' e^{bl}.\cos(2\pi l) + \vec{X}^*(t) & if\, p \geq 0.5 \end{cases} \tag{17.7}$$

In which p is a random value between 0 and 1. The humpback whales randomly search for bait beside the bubble-net method. The resulted design is as follows. The proposed method of this study uses the whale algorithm; therefore, this section is dedicated to describing this algorithm in detail. The A vector is used with random values bigger than -1 or smaller than +1 to distance the search factor from the source whale forcefully. Random factor selection is employed during the exploration phase, unlike using data from the best search factor in the extraction phase to update the search factor position. This mechanism and $\left|\overrightarrow{A}\right| > 1$ highlight exploration and allows the whale procedure to conduct a global exploration. Equations (17.8) and (17.9) express this rule:

$$\overrightarrow{D} = \left|\overrightarrow{C}\overrightarrow{X}_{rand} - \overrightarrow{X}\right| \tag{17.8}$$

$$\overrightarrow{X}(t+1) = \overrightarrow{X}_{rand} - \overrightarrow{A}.\overrightarrow{D} \tag{17.9}$$

In this case, X_{rand} is the randomly generated position vector (i.e., random whale) from the current group. The whale method begins by generating a set of random solutions. After each repetition, the search factors adjust their position based on the randomly picked search factor or the current best response. For exploration and extraction, the a parameter is lowered from 2 to 0. During the position update phase, a random search factor is picked at $\left|\overrightarrow{A}\right|>1$, whereas the optimal solution is chosen when the search factors are at $\left|\overrightarrow{A}\right|>1$. Based on the p value, the whale algorithm can choose between a circular or spiral movement. After attaining the end targets, the whale algorithm will finally finish.

17.3.4 Cost Function

The a coefficient is known as the information embedding coefficient but how this coefficient must be selected so that it will not affect the host image quality while causing no disruptions in watermark image extraction during different attacks. Therefore, it will be difficult or even inappropriate to use trial and error or even random methods for selecting the optimized a value for different images in different situations. Hence, the meta-heuristic whale algorithm was used and defined based on the changes implemented in the last section. The optimized a is selected as follows:

$$Minimize f = 10 \times \left|PSNR - PSNR_{\mathrm{target}}\right| + \left(1 - \frac{1}{N}\sum_{i=1}^{N} NC_i\right) \tag{17.10}$$

In which, N is the number of attacks, and NC_i is the normalized correlation after the i^{th} attack. The attacks defined for this paper are average filter, median filter, salt-and-pepper noise, rotations, and size change.

$$NC(W, W^*) = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left(W_{i,j} \oplus W^*_{i,j} \right)'}{n \times n} \tag{17.11}$$

In which, W and W^* are the watermark and extracted images. Also, $PSNR_{target}$ is the target PSNR value. Equation (17.12) is defined for PSNR:

$$PSNR(I, \dot{I}) = \frac{(I_{Max})^2}{\frac{1}{n \times n} \sum_{i=1}^{n} \sum_{j=1}^{n} \left(I_{i,j} - \dot{I}_{i,j} \right)^2} \tag{17.12}$$

In which, I and $\dot{I}$ are the host and watermarked images. On the other hand, I_{max} is the possible maximum lighting for the image I. Imagine that the watermarked image is 25% of the original watermark image size. To put it another way, if the watermarked image is n × n pixels, the host image will be $2n \times 2n$ pixels. These principles can be used to generalize the embedding and watermark extraction techniques. The correlation dimension of the watermarked and host images are calculated after the embedding process. Before that, the watermarked image will be attacked to check the algorithm embedding correctness. Afterward, the WOA algorithm fitness is calculated to perform global and local searches using the WOA algorithm. During the next two steps, correlation and the benchmark criteria are estimated to find a new watermarked image using the searched coefficients if the estimation values were better than the previous state.

17.4 Results

The research data consists of many medical images, each of which is used in various topics for medical analysis. The suggested algorithm has been implemented on a set of medical images.

Among images, there are 90 Retina images of people who are suspected of having diabetes (which among them, there were 40 healthy people and 50 diabetes), 80 magnetic resonance images with FLAIR quality (i.e., 35 images were from healthy people, and the rest were images from three types of brain tumor). Eventually, 50 histopathological images of different people and leukemia, mammography images, lung cancer images, and microscopic images that symptoms were seen in a total of 20 images, and no other symptoms are seen in other images.

The first set of images has been collected from the McConnell database related to the imaging research institute located at McGill University in Canada for the neurological process. Retina images are also from The Drive database. The most important task is to separate Retina's area from the rest of the image parts. Finally, histopathology images have been downloaded from various treatment centers and the web. These images are also used to diagnose multiple diseases such as cancer.

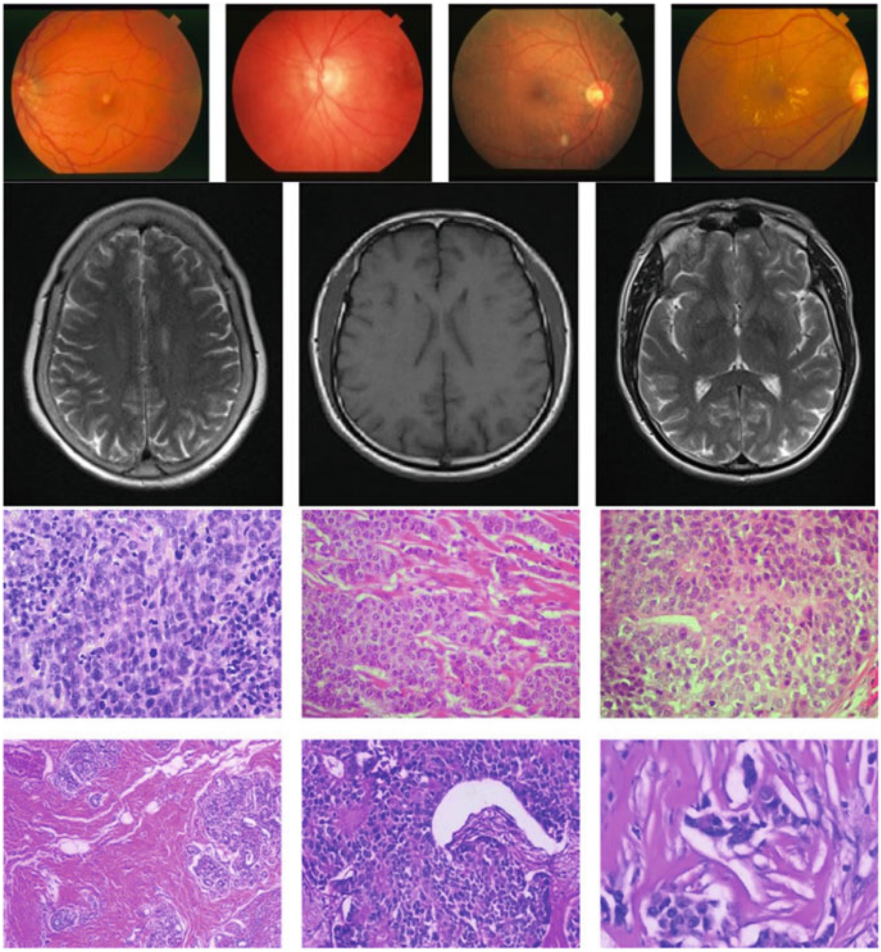


Fig. 17.3 Shows DMIs that the first row is Retina images, the second row is MR images, and the third row is histopathology images

Sample images from the first, second, and third datasets have been illustrated for watermarking in Fig. 17.3, respectively. Each of these images has been converted to JPEG format, and they have a resolution of 600 DPI with dimensions of 512×512. Furthermore, three face images have been used for watermarking and embedding in medical images that. All of them have been set to 32×32 and are shown in Fig. 17.4.

The optimization process requires an attack on the first stage of watermarked images. For this purpose, four attacks are used, including:

- rotating (about 30 degrees)
- resizing (increasing size with the bicubic method)

Fig. 17.4 Images that have been watermarked in medical images as every person's personal information

- changing resolution (using sharp filter method)
- manipulated image (deleting some parts of the image)

For this purpose, transparency and robustness are two parameters that are evaluated. So, it is necessary to calculate the correlation parameter between host and watermarked images.

In addition to this calculation, correlation among watermarked images and extracted images also should be considered. Then correlation values in analyses of the fitness functions related to one of the answers of the WOA algorithm are used. The fitness function values of an interrelated response are evaluated by transparency (NC) and robustness factors, and then these values are estimated per generation. The target function that should be minimized as cost function is specified in Eq. (17.13) below:

$$F_i = \left[\frac{1}{t}\sum_{i=1}^{t} corr_w\left(W, W_i^*\right)\right]^{-1} - corr_I(I, I_W) \tag{17.13}$$

In this equation, I is the original image, W is the watermarked image, I_W is the basic watermarked image, W^* is extracted watermarked image, $corr_W$ represents robustness, and finally represents the number of attack methods. Equation (17.14) is used to calculate the cost function:

$$Fit_i = \frac{1}{F_i} \tag{17.14}$$

The peak of signal to noise ratio (PSNR) index is another criterion that we need in calculations which are defined in Eq. (17.15):

Table 17.1 The effect of the attack on the method is shown individually as well as in combined mode and calculating values based on PSNR index, NC, and time

Type of attack	Watermarking method	PSNR	NC	Time (sec)
Rotating	Wavelet	36.11	0.9334	8 ± 2.35
	Wavelet + SVD	38.15	0.9456	61 ± 3.48
	Wavelet + SVD + WOA	39.87	0.9677	71 ± 4.38
Resizing	Wavelet	36.74	0.9566	9 ± 3.17
	Wavelet + SVD	39.23	0.9712	49 ± 6.29
	Wavelet + SVD + WOA	42.29	0.9807	87 ± 6.34
Changing resolution	Wavelet	33.23	0.9044	13 ± 3.21
	Wavelet + SVD	35.79	0.9077	56 ± 8.87
	Wavelet + SVD + WOA	38.60	0.9322	96 ± 5.98
Manipulated image	Wavelet	26.38	0.7546	15 ± 3.71
	Wavelet + SVD	27.51	0.7716	67 ± 8.62
	Wavelet + SVD + WOA	31.29	0.8342	83 ± 6.27
Combining attack methods	Wavelet	19.08	0.5918	34 ± 3.34
	Wavelet + SVD	23.12	0.6530	81 ± 4.34
	Wavelet + SVD + WOA	24.67	0.7142	103 ± 11.04

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE_{avg}}\right) \tag{17.15}$$

In which MSE_{avg} is calculated as in Eq. (17.16):

$$MSE_{avg} = \frac{MSE_R + MSE_G + MSE_B}{3} \tag{17.16}$$

The higher the PSNR value, the more transparent our watermarking will be, and vice versa, the greater the watermarking error, method's transparency will be considered lower. On the other hand, to analyze the robustness level of extracted watermark normalized correlation (NC) criterion is used. This is defined as in Eq. (17.17):

$$NC = \frac{\sum_i \sum_j W(i,j) \times W^*(i,j)}{\left[\sum_i \sum_j W(i,j)^2 \times W^*(i,j)^2\right]^{0.5}} \tag{17.17}$$

Table 17.1 demonstrates the effect of attacking methods individually and combining techniques, and calculating PSNR index, NC, and time. The minimum time spent for each image was seen for rotation by 30 degrees attack in the proposed method. Also, the highest PSNR rate (implying transparency) and highest normalized correlation level (implying robustness) are shown. This table is the result of the embedding and final extraction of images.

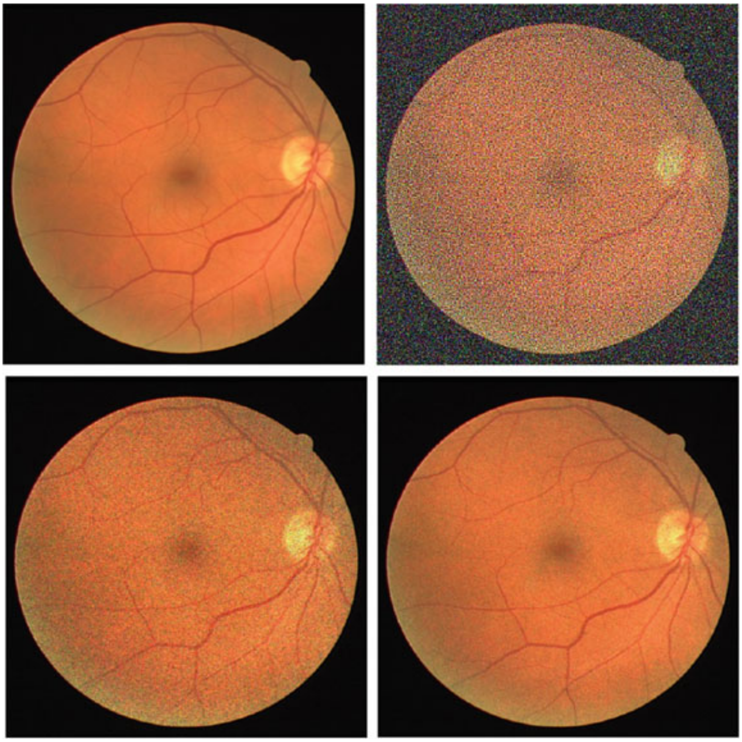


Fig. 17.5 Applying hybrid watermarking scheme on the Retina image; from up to down and from left to right respectively: original image, watermarked image with DWT-SVD method (PSNR and NC values are 21.16 dB and 0.83 respectively), watermarked image with DWT-SVD approach, and WOA (PSNR and NC values are 37.54 and 0.93 respectively) and watermarked image with DWT-SVD way and optimized WOA (PSNR and NC values are 41.43 and 0.96 respectively)

In Figs. 17.5, 17.6, and 17.7, we observe each hybrid algorithm's demonstration on different medical images by calculating PSNR and NC values. The proposed algorithm's performance is effective in watermarking people's images in every category of medical imaging. Furthermore, in Fig. 17.8, we observe the performance of the proposed algorithm against attacks. Among them, resizing has less effect on identifying a watermarked image. PSNR and NC were 41.37 and 0.94, respectively. Additionally, manual manipulation was the most destructive.

17.5 Conclusion

This chapter introduced a combined image watermarking scheme based on IoT and optimization approaches for telemedicine employment. In this regard, the first approximate coefficients are formed to embed the singular values by using the

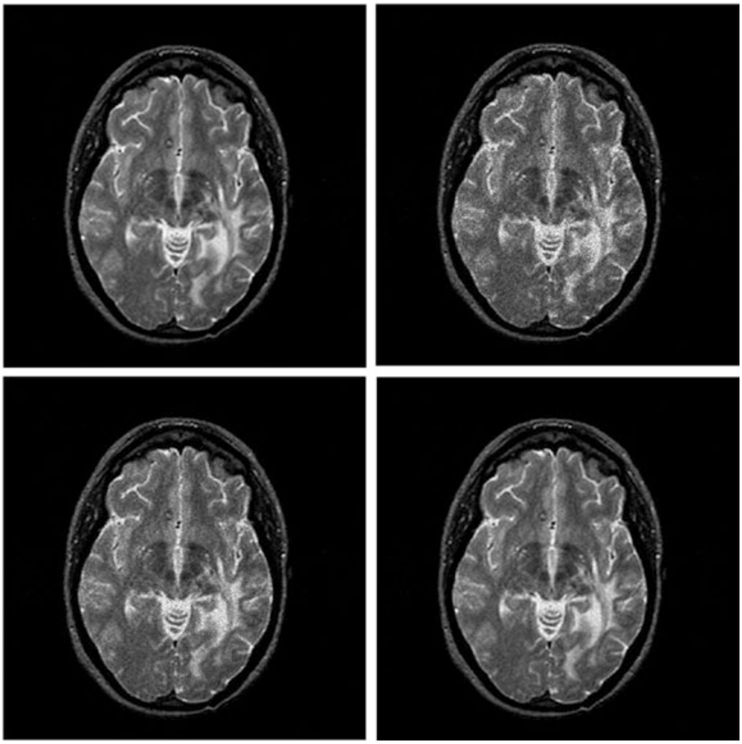


Fig. 17.6 Applying hybrid watermarking scheme on the MR image; from up to down and from left to right respectively: original image, watermarked image with DWT-SVD method (PSNR and NC values are 26.44 dB and 0.88 respectively), watermarked image with DWT-SVD process and WOA (PSNR and NC values are 39.08 and 0.95 respectively) and watermarked image with DWT-SVD method and optimized WOA (PSNR and NC values are 43.64 and 0.97 respectively)

DWT onto the medical images. Besides, the optimum embedding coefficients were determined based on the cost function evaluation of the WOA. We improved the imperceptibility and robustness of the watermarking model. In addition, the experimental outcomes demonstrated that the proposed model in the watermarking application could resist attacks. Moreover, the IoT principles were employed in DMI analysis, which could be established as an emerging system that improves processing and handling watermarking inquiry in a real-time mode. The robustness of the proposed watermarking design for medical images made it efficient using a combination of conventional watermarking methods, the WOA algorithm, and the IoT platform. Our results indicated that the proposed privacy model is superior in terms of maintaining high robustness and satisfactory fidelity for healthcare applications based on IoT platforms and DMI services in the case of severe attacks. A hybrid security architecture for different DMIs watermarking procedure and various biomedical signals can be examined in future work.

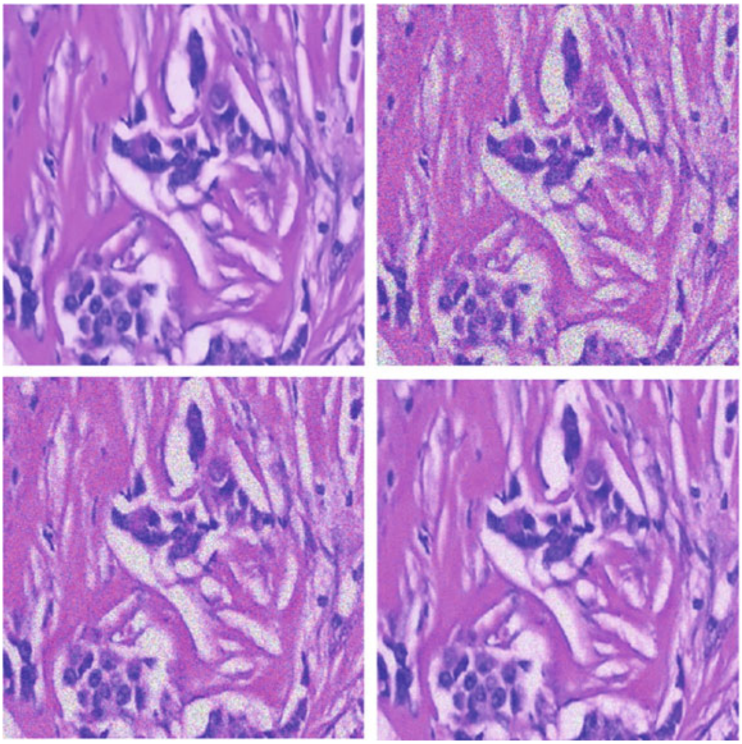


Fig. 17.7 Applying hybrid watermarking scheme on the histopathology image; from up to down and from left to right respectively: original image, watermarked image with DWT-SVD method (PSNR and NC values are 27.76 dB and 0.89 respectively), watermarked image with DWT-SVD way and WOA (PSNR and NC values are 36.29 and 0.93 respectively) and watermarked image with DWT-SVD process and optimized WOA (PSNR and NC values are 44.19 and 0.97 respectively)

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

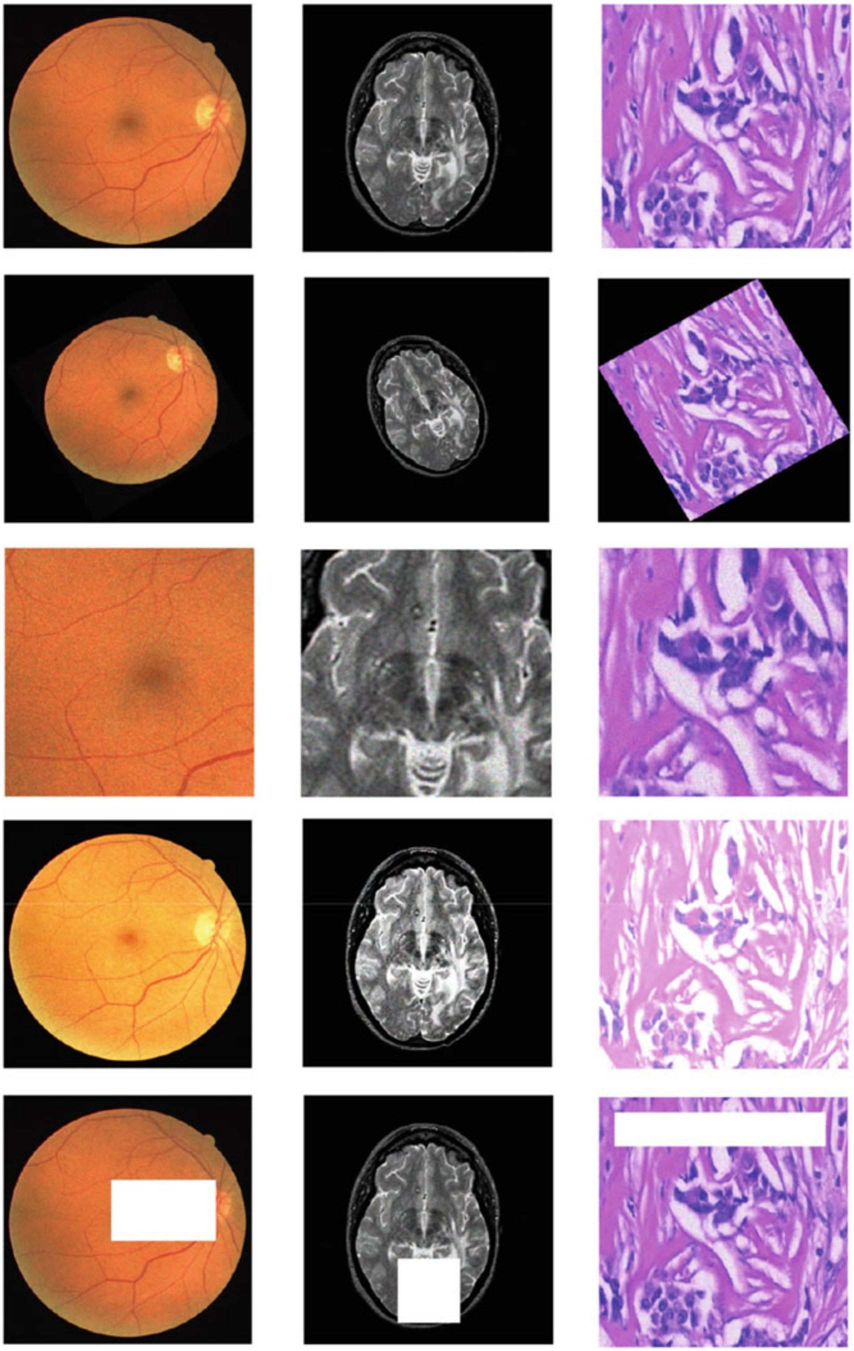


Fig. 17.8 The effect of different attacks on watermark images (first row), rotation attack (second row), resized image (third row), contrast manipulation attack (fourth row), and manual manipulation attack (fifth row)

References

1. Das, S., & Kundu, M. K. (2013). Effective management of medical information through ROI-lossless fragile image watermarking technique. *Computer Methods and Programs in Biomedicine, 111*(3), 662–675.
2. Le Nguyen, B., Lydia, E. L., Elhoseny, M., Pustokhina, I., Pustokhin, D. A., Selim, M. M., et al. (2020). Privacy preserving blockchain technique to achieve secure and reliable sharing of IoT data. *Computers, Materials & Continua, 65*(1), 87–107.
3. Zuo, J., Lu, Y., Gao, H., Cao, R., Guo, Z., & Feng, J. (2020). Comprehensive information security evaluation model based on multi-level decomposition feedback for IoT. *Computers, Materials & Continua, 65*(1), 683–704.
4. Bi, W., Yu, F., Cao, N., Huo, W., Cao, G., Han, X., et al. (2020). Research on data extraction and analysis of software defect in IoT communication software. *Computers, Materials & Continua, 65*(2), 1837–1854.
5. Ross, A., Banerjee, S., & Chowdhury, A. (2020). Security in smart cities: A brief review of digital forensic schemes for biometric data. *Pattern Recognition Letters, 138*, 346–354.
6. Ray, A., & Roy, S. (2020). Recent trends in image watermarking techniques for copyright protection: A survey. *International Journal of Multimedia Information Retrieval, 9*, 249–270.
7. Nyeem, H., Boles, W., & Boyd, C. (2013). A review of medical image watermarking requirements for teleradiology. *Journal of Digital Imaging, 26*(2), 326–343.
8. Singh, L., Singh, A. K., & Singh, P. K. (2020). Secure data hiding techniques: A survey. *Multimedia Tools and Applications, 79*(23), 15901–15921.
9. Dey, N., Ashour, A. S., Chakraborty, S., Banerjee, S., Gospodinova, E., Gospodinov, M., & Hassanien, A. E. (2017). *Watermarking in biomedical signal processing. In intelligent techniques in signal processing for multimedia security* (pp. 345–369). Springer.
10. Podilchuk, C. I., & Delp, E. J. (2001). Digital watermarking: Algorithms and applications. *IEEE Signal Processing Magazine, 18*(4), 33–46.
11. Atlam, H. F., Hemdan, E. E. D., Alenezi, A., Alassafi, M. O., & Wills, G. B. (2020). Internet of things forensics: A review. *Internet of Things, 11*, 100220.
12. Díaz, M., Martín, C., & Rubio, B. (2016). State-of-the-art, challenges, and open issues in the integration of internet of things and cloud computing. *Journal of Network and Computer Applications, 67*, 99–117.
13. El-Din, H. E., & Manjaiah, D. H. (2017). Internet of nano things and industrial internet of things. In *Internet of things: Novel advances and envisioned applications* (pp. 109–123). Springer.
14. Rezaee, K., Rezakhani, S. M., Khosravi, M. R., & Moghimi, M. K. (2021). A survey on deep learning-based real-time crowd anomaly detection for secure distributed video surveillance. In *Personal and Ubiquitous Computing* (pp. 1–17). Springer.
15. Khosravi, M. R., & Samadi, S. (2019). Reliable data aggregation in internet of ViSAR vehicles using chained dual-phase adaptive interpolation and data embedding. *IEEE Internet of Things Journal, 7*(4), 2603–2610.
16. Lv, C., Zhang, J., Sun, Z., & Qian, G. (2020). Information flow security models for cloud computing. *Computers, Materials & Continua, 65*(3), 2687–2705.
17. Qin, J. (2020). An encrypted image retrieval method based on SimHash in cloud computing. *Computers, Materials & Continua, 63*(1), 389–399.
18. Liu, Z., Yang, Y., Gu, W., & Xia, J. (2020). A multi-tenant usage access model for cloud computing. *Computers, Materials & Continua, 64*(2), 1233–1245.
19. Jabeen, T., Ashraf, H., & Ullah, A. (2021). A survey on healthcare data security in wireless body area networks. *Journal of Ambient Intelligence and Humanized Computing, 12*, 9841–9854.
20. Amiroon, S., & Fachkha, C. (2020). Digital forensics and investigations of the internet of things: A short survey. In *2020 3rd International Conference on Signal Processing and Information Security (ICSPIS)* (pp. 1–4). IEEE.

21. Qadir, S., & Noor, B. (2021). Applications of machine learning in digital forensics. In *2021 International Conference on Digital Futures and Transformative Technologies (ICoDT2)* (pp. 1–8). IEEE.
22. Usman, N., Usman, S., Khan, F., Jan, M. A., Sajid, A., Alazab, M., & Watters, P. (2021). Intelligent dynamic malware detection using machine learning in IP reputation for forensics data analytics. *Future Generation Computer Systems, 118*, 124–141.
23. Rezaee, K., Rezaee, A., Shaikhi, N., & Haddadnia, J. (2020). Multi-mass breast cancer classification based on hybrid descriptors and memetic meta-heuristic learning. *SN Applied Sciences, 2*(7), 1–19.
24. Rezaee, A., Rezaee, K., Haddadnia, J., & Gorji, H. T. (2020). Supervised meta-heuristic extreme learning machine for multiple sclerosis detection based on multiple feature descriptors in MR images. *SN Applied Sciences, 2*(5), 1–19.
25. Hemdan, E. E. D. (2021). An efficient and robust watermarking approach based on single value decompression, multi-level DWT, and wavelet fusion with scrambled medical images. *Multimedia Tools and Applications, 80*(2), 1749–1777.
26. Wang, B., Kong, W., Li, W., & Xiong, N. N. (2019). A dual-chaining watermark scheme for data integrity protection in Internet of Things. *Cmc-computers Materials & Continua, 58*(3), 679–695.
27. Qasim, A. F., Meziane, F., & Aspin, R. (2018). Digital watermarking: Applicability for developing trust in medical imaging workflows state of the art review. *Computer Science Review, 27*, 45–60.
28. Makbol, N. M., & Khoo, B. E. (2013). Robust blind image watermarking scheme based on redundant discrete wavelet transform and singular value decomposition. *AEU-International Journal of Electronics and Communications, 67*(2), 102–112.
29. Rastegar, S., Namazi, F., Yaghmaie, K., & Aliabadian, A. (2011). Hybrid watermarking algorithm based on singular value decomposition and radon transform. *AEU-International Journal of Electronics and Communications, 65*(7), 658–663.
30. Ganic, E., & Eskicioglu, A. M. (2005). Robust embedding of visual watermarks using discrete wavelet transform and singular value decomposition. *Journal of Electronic Imaging, 14*(4), 043004.
31. Lagzian, S., Soryani, M., & Fathy, M. (2011). Robust watermarking scheme based on RDWT-SVD: Embedding data in all subbands. In *2011 International Symposium on Artificial Intelligence and Signal Processing (AISP)* (pp. 48–52). IEEE.
32. Vali, M. H., Aghagolzadeh, A., & Baleghi, Y. (2018). Optimized watermarking technique using self-adaptive differential evolution based on redundant discrete wavelet transform and singular value decomposition. *Expert Systems with Applications, 114*, 296–312.
33. Al-khassaweneh, M. (2019). Robust and invisible watermarking technique based on Frei-Chen bases. In *2019 IEEE International Conference on Electro Information Technology (EIT)* (pp. 1–4). IEEE.
34. Mastorakis, S., Zhong, X., Huang, P. C., & Tourani, R. (2021). Dlwiot: Deep learning-based watermarking for authorized iot onboarding. In *2021 IEEE 18th Annual Consumer Communications & Networking Conference (CCNC)* (pp. 1–7). IEEE.
35. Mahdavi, S., Shiri, M. E., & Rahnamayan, S. (2015). Metaheuristics in large-scale global continues optimization: A survey. *Information Sciences, 295*, 407–428.
36. Saxena, N., & Mishra, K. K. (2017). Improved multi-objective particle swarm optimization algorithm for optimizing watermark strength in color image watermarking. *Applied Intelligence, 47*(2), 362–381.
37. Papakostas, G. A., Tsougenis, E. D., & Koulouriotis, D. E. (2014). Moment-based local image watermarking via genetic optimization. *Applied Mathematics and Computation, 227*, 222–236.
38. Soliman, M. M., & Hassanien, A. E. (2017). 3D watermarking approach using particle swarm optimization algorithm. In *Handbook of research on machine learning innovations and trends* (pp. 582–613). IGI Global.

39. Issa, M. (2018). Digital image watermarking performance improvement using bio-inspired algorithms. In *Advances in soft computing and machine learning in image processing* (pp. 683–698). Springer.
40. Ali, M., & Ahn, C. W. (2018). An optimal image watermarking approach through cuckoo search algorithm in wavelet domain. *International Journal of System Assurance Engineering and Management, 9*(3), 602–611.
41. Rezaee, K., Haddadnia, J., & Tashk, A. (2017). Optimized clinical segmentation of retinal blood vessels by using combination of adaptive filtering, fuzzy entropy and skeletonization. *Applied Soft Computing, 52*, 937–951.
42. Giakoumaki, A., Pavlopoulos, S., & Koutsouris, D. (2006). Secure and efficient health data management through multiple watermarking on medical images. *Medical and Biological Engineering and Computing, 44*(8), 619–631.
43. Kannammal, A., Pavithra, K., & Rani, S. S. (2012). Double watermarking of DICOM medical images using wavelet decomposition technique. *European Journal of Scientific Research, 70*(1), 46–55.
44. Hemdan, E. E. D., El-Fishawy, N., Attiya, G., & Abd El-samie, F. (2013). C11. Hybrid digital image watermarking technique for data hiding. In *2013 30th National Radio Science Conference (NRSC)* (pp. 220–227). IEEE.
45. Hemdan, E. E. D., El Fishawy, N., Attiya, G., & El-Samie, F. A. (2013). An efficient image watermarking approach based on wavelet fusion and singular value decomposition in wavelet domain. In *Proceeding of 3rd International Conference on Advanced Control Circuits and Systems (ACCS'013)* (pp. 1–10). Springer.
46. Jindal, H., Kasana, S. S., & Saxena, S. (2016). A novel image zooming technique using wavelet coefficients. In *Proceedings of the International Conference on Recent Cognizance in Wireless Communication & Image Processing* (pp. 1–7). Springer.
47. Mander, K., & Jindal, H. (2017). An improved image compression-decompression technique using block truncation and wavelets. *International Journal of Image, Graphics and Signal Processing, 9*(8), 17.
48. Kaur, S., & Jindal, H. (2017). Enhanced image watermarking technique using wavelets and interpolation. *International Journal of Image, Graphics and Signal Processing, 9*(7), 23.
49. Mittal, A., & Jindal, H. (2017). Novelty in image reconstruction using DWT and CLAHE. *International Journal of Image, Graphics and Signal Processing, 9*(5), 28.
50. Leng, L., Zhang, J., Xu, J., Khan, M. K., & Alghathbar, K. (2010). Dynamic weighted discrimination power analysis in DCT domain for face and palmprint recognition. In *2010 International Conference on Information and Communication Technology Convergence (ICTC)* (pp. 467–471). IEEE.
51. Leng, L., Li, M., Kim, C., & Bi, X. (2017). Dual-source discrimination power analysis for multi-instance contactless palmprint recognition. *Multimedia Tools and Applications, 76*(1), 333–354.
52. Leng, L., Li, M., & Teoh, A. B. J. (2013). Conjugate 2DPalmHash code for secure palm-print-vein verification. In *2013 6th International Congress on Image and Signal Processing (CISP)* (Vol. 3, pp. 1705–1710). IEEE.
53. Leng, L., Teoh, A. B. J., Li, M., & Khan, M. K. (2015). Orientation range of transposition for vertical correlation suppression of 2DPalmPhasor code. *Multimedia Tools and Applications, 74*(24), 11683–11701.
54. Thakkar, F. N., & Srivastava, V. K. (2017). A blind medical image watermarking: DWT-SVD based robust and secure approach for telemedicine applications. *Multimedia Tools and Applications, 76*(3), 3669–3697.
55. Mishra, A., Agarwal, C., Sharma, A., & Bedi, P. (2014). Optimized gray-scale image watermarking using DWT–SVD and firefly algorithm. *Expert Systems with Applications, 41*(17), 7858–7867.
56. Ali, M., & Ahn, C. W. (2014). An optimized watermarking technique based on self-adaptive DE in DWT–SVD transform domain. *Signal Processing, 94*, 545–556.

57. Panda, J., Uppal, A., Nair, A. S., & Agrawal, B. (2017). Genetic algorithm based optimized color image watermarking technique using SVD and DWT. In *2017 IEEE 7th International Advance Computing Conference (IACC)* (pp. 579–583). IEEE.
58. Ali, M., Ahn, C. W., Pant, M., & Siarry, P. (2015). An image watermarking scheme in wavelet domain with optimized compensation of singular value decomposition via artificial bee colony. *Information Sciences, 301*, 44–60.
59. Sharma, V., & Mir, R. N. (2019). *An enhanced time efficient technique for image watermarking using ant colony optimization and light gradient boosting algorithm*. Journal of King Saud University-Computer and Information Sciences.
60. Anand, A., & Singh, A. K. (2020). RDWT-SVD-firefly based dual watermarking technique for medical images (workshop paper). In *2020 IEEE Sixth International Conference on Multimedia Big Data (BigMM)* (pp. 366–372). IEEE.
61. Singh, R., Ashok, A., & Saraswat, M. (2020). Optimised robust watermarking technique using CKGSA in DCT-SVD domain. *IET Image Processing, 14*(10), 2052–2063.
62. Singh, R., & Ashok, A. (2021). An optimized robust watermarking technique using CKGSA in frequency domain. *Journal of Information Security and Applications, 58*, 102734.
63. Amrit, P., Anand, A., Kumar, S., & Singh, A. K. (2021). *Robust transmission of medical records using dual watermarking and optimization algorithm* (Journal of Physics: Conference Series) (Vol. 1767-1, p. 012060). IOP Publishing.
64. Selvaraj, P., & Varatharajan, R. (2018). Whirlpool algorithm with hash function based watermarking algorithm for the secured transmission of digital medical images. In *Mobile Networks and Applications* (pp. 1–14). Springer.
65. Rezaee, K., & Haddadnia, J. (2013). Designing an algorithm for cancerous tissue segmentation using adaptive k-means cluttering and discrete wavelet transform. *Journal of Biomedical Physics & Engineering, 3*(3), 93.
66. Bharati, S., Rahman, M. A., Mandal, S., & Podder, P. (2018). Analysis of DWT, DCT, BFO & PBFO algorithm for the purpose of medical image watermarking. In *2018 International Conference on Innovation in Engineering and Technology (ICIET)* (pp. 1–6). IEEE.
67. Kahlessenane, F., Khaldi, A., Kafi, R., & Euschi, S. (2021). A DWT based watermarking approach for medical image protection. *Journal of Ambient Intelligence and Humanized Computing, 12*(2), 2931–2938.

Chapter 18
Emergence of 3D Printing Technology in the Intelligent Healthcare Systems: A Brief Drug Delivery Approach

Pratik Chatterjee and Chinmay Chakraborty

Abstract Three-dimensional printing (3DP) is a modern phrase for three-dimensional objects created step by step on a software development platform. 3DP technology has been applied as a driving technological breakthrough in recent times, enhancing the industrial sector to develop and build advanced healthcare treatments and technology. In recent times, the effect of this technology has experienced effective development pointing to the increasing need for tailored medicines and healthcare implants. The ability to design generic drug delivery systems, artificial intelligence (AI) based drug dispersed devices and oral drug formulations for personalized treatment with rapid dosage is another benefit of 3DP. The evident advantages of this three-dimensional (3D) printing are highlighted, but a significant approach deriving from the risks of manufacturing and side effects is also presented. Additive manufacturing with fused deposition modeling and inkjet printing is among the diverse technological advancements for creating 3D objects having significant concern to the pharmaceutical products and medical implants modeling are explained briefly in this chapter. The relevance of 3DP as an exaggerated propitious technology is also analyzed in this chapter by exhibiting various scenarios as current modifications using supervised machine learning and deep learning and thus focusing on intelligent healthcare systems.

Keywords 3D printing technology · Personalized medicines · 3D medical implants · 3D based pharmaceutical products · Oral drug manufacturing · Supervised machine learning · AI-based drug delivery

P. Chatterjee (✉)
Department of Biotechnology, School of Bio Science and Technology, Vellore Institute of Technology (VIT), Vellore, India
e-mail: pratik.chatterjee2020@vitstudent.ac.in

C. Chakraborty
Department of Electronics & Communication Engineering, Birla Institute of Technology, Ranchi, India

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_18

18.1 Introduction

Three-dimensional printing (3DP) is a modern term used to refer to three-dimensional (3D) designs that are printed one layer at a time on a digital manufacturing platform. 3DP was created with industrial applications in mind and has evolved into a promising technology over the last few years [1]. The emergence of 3DP in healthcare companies has made a significant change in medical device production processes, allowing inanimate medical equipment to be converted into printed 3D products. In terms of operational advancement in the manufacture of bio-printed medical items, 3DP technology has been considered to be the most effective breakthrough in the last few decades in the field of healthcare companies [2]. The emerging ideas in a pharmaceutical model, a better knowledge of material characteristics, production technologies, and methods that ensure superior dosage forms are always being pursued. Through each step of research and development, different kinds of physicochemical and biological properties of active pharmaceutical ingredients (APIs) must be examined and analyzed. To create the required dosage form, auxiliary chemicals must also be evaluated. The major progress in personalized medicine is attributed to the increasing popularity of customizable devices associated with the advancement of technical advancement, as evidenced by the manufacture of a small succession of individual basis dosages and digitally made prosthetics that meet the anatomical needs of patients [3]. All 3DP technologies are built on the idea of layering materials to create things. The ability to create complicated structures, such as complex interior orifices or a mixture of various components in one phase, is a significant advantage of this method of object construction. However, because a huge number of layers are required to produce a satisfactory degree of the attribute, it is congenitally sluggish and difficult to scale up [4]. Although, because the amalgamation of material inside a layer differs from the way it consolidates linking coatings, the hardened object produced by 3DP frequently exhibits anisotropic instinctive features. The physical methods performed to condense substances into layers can then be used to characterize 3DP technology. Photochemical and thermal transformations along with binding and adhesion, are the major methods. Stereolithography (SLA), powder-based, and fused deposition modeling (FDM), including hot melted extrusion, too are prevalent 3DP methods [5]. The focus is on innovative methods in the composition of dosage forms for patient mediated therapy, although transdermal drug administration and medical devices of multiplicative printing technology, such as grafts, AI-based drug delivery, quality control by a deep neural network, machine learning-based (Support vector machine) control of 3DP bio-printed materials, and biorobots, are also discussed [6]. The concurrent growth of extrusion-based and powder-based modelling in drug delivery method and 3DP are discussed and contrasted, with an emphasis on bioprinting's progression.

There are several newly emerged technologies such as deep learning and machine learning, for producing 3DP goods that may be utilized in the medical sector and that relate to various usages of the products. The manner a layer accumulates on another

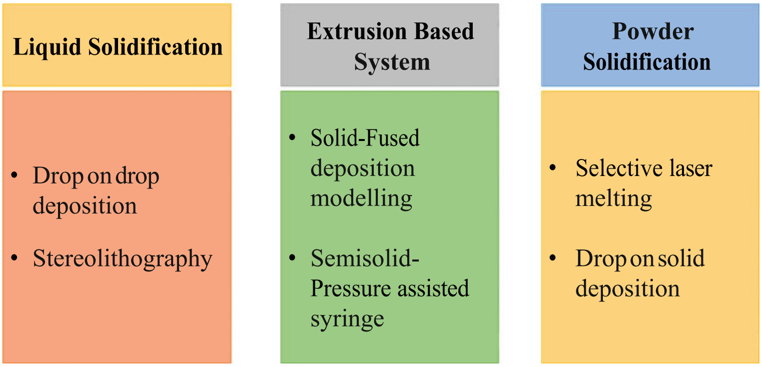


Fig. 18.1 Different methods of three-dimensional printing technology (3DP)

layer is symbolized between all these different techniques in terms of effectiveness and production. Furthermore, while choosing an appropriate technique for 3DP, speed, efficiency, reliability, and process parameters all should be assessed. A quick summary of the most significant 3DP processes used in the biomedical, such as fused deposition model, inkjet powder bed, and material jetting, is provided after examining certain literature (Fig. 18.1)

A 3D-basedpharmaceutical product can be made using a variety of techniques that substitute ink with the desired medication composition, which is then projected upon an adjustable substrate cumulatively. A palatable plate having a structure of specific hydrophilicity or hydrophobicity that works functionally along with porous nature, and penetrating property might be used as the substrate. The very first phase in fabricating a 3D object is to build a technical model of the anticipated 3D product using only a computer-aided design (CAD) program. The virtual design is then transferred to a format that can be read by the program, which is often a stereolithography (STL) file. Following that, a slicer (digital printing software) converts the STL file to a sequence of attenuated layers containing instructions specific to the 3D object [7]. The printer head rotates throughout printing, and the composing powdered ink spreads on the consecutive films on a constructed tray, forming the object's foundation. The operation is continued until the final 3D result is generated. Finally, in the post-printing operation, solvent remnants, residual powder, polishing, and sintering may be required for the 3D output [8]. While 3DP is commonly used to refer to materials that have been constructed layer by layer, additional terminology including process optimization, solid freeform construction, and additive manufacturing with alternative names for 3DP [9]. Figure 18.2 represents the different processes related to the building of 3DP materials.

In every country, healthcare is a critical management issue. Almost every healthcare system faces a fundamental problem: integrating the requirement to provide elevated treatment with the need to keep costs as low as possible and maintain the system's long-term viability. This research aims to investigate the complexities and potentialities of the use of 3DP in the production of personalized

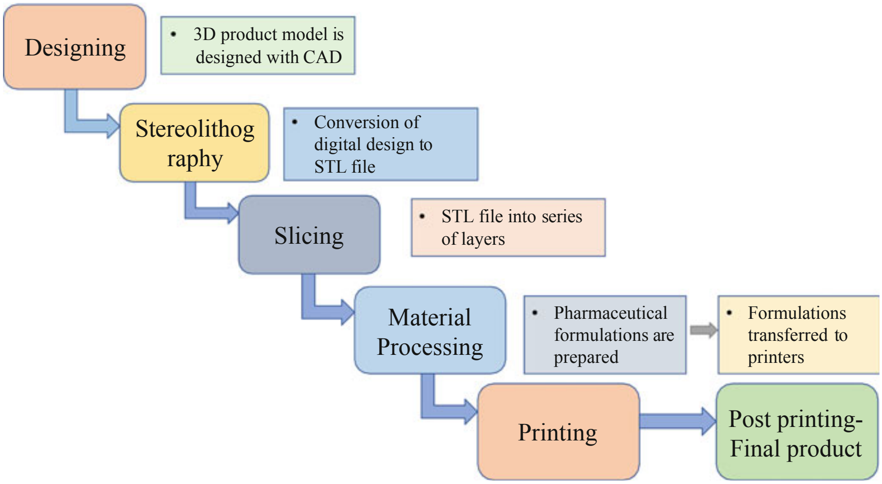


Fig. 18.2 Multiple steps involved in manufacturing 3D printed products

medication in order to find ways to reconcile efficiency and efficacy in healthcare management. Deep learning in 3DP can assist a machine learning system in identifying potential medicine [10]. Algorithms based on machine learning are anticipated to help, simplify, and speed up the creation of novel materials through simulations. In the table below (Table 18.1), comparative approaches of various newly emerged 3DP technologies have been elaborated for a better understanding.

18.2 3D Printing Methods Followed by Pharmaceutical Companies to Manufacture Products

The integration of 3DP into pharmaceutical technology seeks to produce tailored dosage forms based on structural design in particular. Because of the ability to quickly prepare tailor- made things that may be used in the tailored pharmacological intervention, 3DP technologies are gaining traction in the pharmaceutical and biomedical fields. Oral dosage forms are the target of much analysis since they are still the most common and preferred method of delivery [17]. Some studies are also looking at dose options for topical application. The physical methods utilized to condense materials into layers are being used to classify 3DP technology. Chemiluminescence and heat transformations, with fidelity and attachment, are the major methods.

Table 18.1 Various methods of 3DP technologies with a comparative analysis

Parameters	Different 3DP technologies				
	Extrusion based printer (Micro)	Inkjet printing	Laser associated printing	Stereolithography printing	References
Viability of the product	40 to 80 percent	Above 85 percent	Most. Above 95 percent	Above or equal to 85 percent	Derakhshanfar et al. [11]
Printing speed	Slow	Fast	Medium	Fast	Groll et al. [12]
Printing resolution	Moderate	Enhanced	High	Enhanced	Azad et al. [13]
Expense	Cheaper	Cheaper	Expensive	Cheaper	Huang et al. [14]
The density of the medicine	High	Low	Moderate	Moderate	Davoodi et al. [15]
Viscosity of the material	30 to 6×10^7 mPa/s	4 to 12.5 mPa/s	1 to 300 mPa/s	Not definitely mentioned	Huang et al. [14]
Cross-linking pattern	Thermal and chemical	Hardening by photo curing and chemical	Chemical and photo curing method	Mainly by chemical strategy and often by photo curing	Lim et al. [16]

18.2.1 Inkjet Printing Method

Inkjet printing is a 3DP technology in pharmaceutics. This method is especially useful when the initial ingredients are in a liquid condition. Depending on the orientation of drops, there are two different types of printing methods: the first one is dropped on demand (DOD) and other one is continuous inkjet printing (CIJ).

The droplets in CIJ are generated by a synthesizer or droplet loading equipment that produces a frequent flow of droplets. To attain the ideal charge, the spray molecules are steered to an ionic product. Eventually, the produced drop-like molecules reach the substrate and form the 3D object [18].

The concept of making objects by solidifying liquid is comparable to the granular phase transformation. Ink drips are sprayed on the attenuated layers and cured using high-energy radiation or evaporative refrigeration. DOD or Poly jet technique necessitates the involvement of other components to develop a base for the overhang model due to the lack of a powdery bed [19]. The pharmaceutical manufacture-based ink will be converted into a powder molecule form by putting a voltage to the polarised crystalline transducer to vortex the materials or heat the formulation to a temperature greater than the critical temperature. The molecules of the mixture are then delivered through the use of an opening to the nozzle of the printer head and solidified dropwise [3, 20]. The inject printing method's major benefit in the pharmaceutical industry is its great precision in manufacturing 3D medicinal items. The technique also allows for the use of novel active pharmacological components and customization in medication development. Inject printing has demonstrated promising uses for manufacturing oral dose forms such as poorly soluble and powerful medicines in experimental investigations.

18.2.2 *Extrusion-Based Printing Method*

There are two varieties of printing techniques in controlling extrusion printing which is fused deposition modeling (FDM) and hot-melt extrusion method (HME). A homogeneous solidified distribution of excipients for example synthetic polymers and polymeric chains are formed in a molten state of polymeric state using the HME procedure, and a drug component is injected into the polymeric composition. Following that, the formulation ink may be extruded straight through a dye at high temperature and high pressure, followed by soldering and consolidating after printing, which then further result in a 3D product with a symmetrical shape, high quality, and drug content [21]. FDM is a 3DP method highly focused on extrusion that is easily accessible, low-cost, flexible, and can fabricate single-unit dosage forms. It enables for variations in the active ingredient’s kind, dosage, and distribution, as well as the end product's size, shape, geometry, and density, ideally fitting the demands of bespoke medicine. FDM involves depositing molten/softened materials on a prepared surface from a heated printer extrusion head that travels along axes (Fig. 18.3) while reducing the construction platform allows the thing to develop from the bottom up.

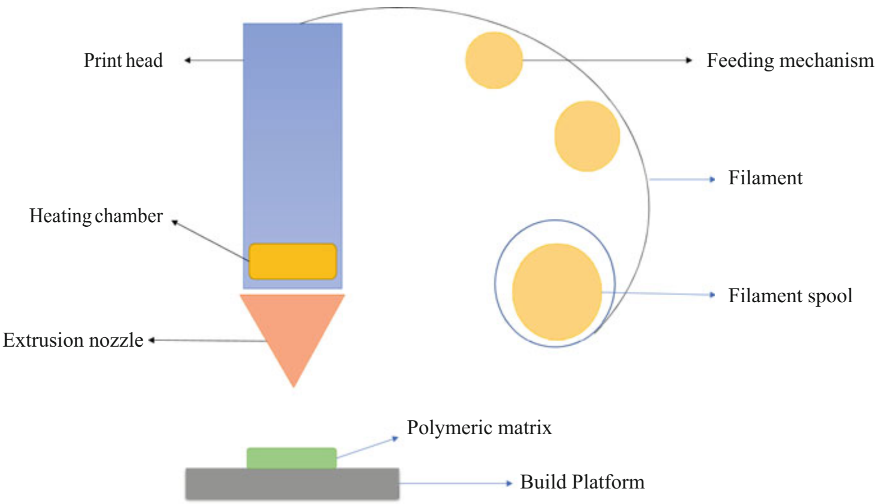


Fig. 18.3 Schematic representation of the extrusion-based 3DP process: Fused deposition modeling system (FDM)

The drug compound is loaded in a polymeric heat-labile filament i.e., through passively diffused from solutions, and exploited as precursor materials in the fused deposition technique. The material is then extruded frequently through the top of the printer with high temperature upon a surface, where it solidifies layer after layer as it exits the printer [22]. In the literature, the fused deposition method is referred to as fused filament (FF). The mechanical characteristics of 3D objects and the drug dosage are greater in hot melt extrusion printing in comparison with the fused deposition modeling.

In the realm of pharmaceutical technology, extrusion of colloidal suspension materials is already there with better acknowledgment. Dissemination of melted thermoplastic material is employed in fused deposition modeling. Conventional available commercial print heads are often used for filament dimensions of 1.75 mm and 2.85–3 mm. Thermoplastic polymers such as polylactic acid, polystyrene, polyethylene terephthalate glycol, acrylonitrile butadiene styrene, and nylon are used to make standard filaments. Although there are certain high- quality filaments produced from medically grade polymers, filaments created from graded polymers for medical purposes and incorporating APIs are not. The heat stability of impregnated API must be addressed while preparing drug-loaded filaments.

All these approaches have acquired favor in the pharmaceutical sector for constructing 3D pharmaceutical items. The major benefit of 3D extrusion printing is its great flexibility in developing innovative formulations of consolidating oral drug dosages forms with variable shape, size, and low structural product, along with the different dosage criteria, as well as the capacity to manufacture a variety of polymeric materials [23]. Extrusion is also a potential method for printing amorphous materials, which improves the dissolution rate and hence improves the bioavailability of poorly soluble medicines.

18.2.3 Powder-Based Binding Method for Printing

The pharmacological industry is heavily interested in additive manufacturing with a powder- based methodology since it has many similarities to existing production methods which can give away better effective long-range 3D printed products [7]. Composites of 3D printed materials are formed by the sprayed solution of therapeutics with extra excipients in minute droplets from a two-dimensional print head (Fig. 18.4) on a powder- based printing platform [24]. Then, based on the height of the layers, it is descended along the Z-axis until the next layer is built. In an aqueous solution form, the layers might be united via adherence or welding. Finally, in the right circumstances, the solvent residue and unbound powder are removed, allowing the 3D product to grow correctly in the post-printing process.

The powder bed is a type of 3DP technology which is efficient and can produce a variety of therapeutic ingredients. Furthermore, the quality of manufactured 3D goods is excellent, resulting in a significant decrease in production costs [25]. The

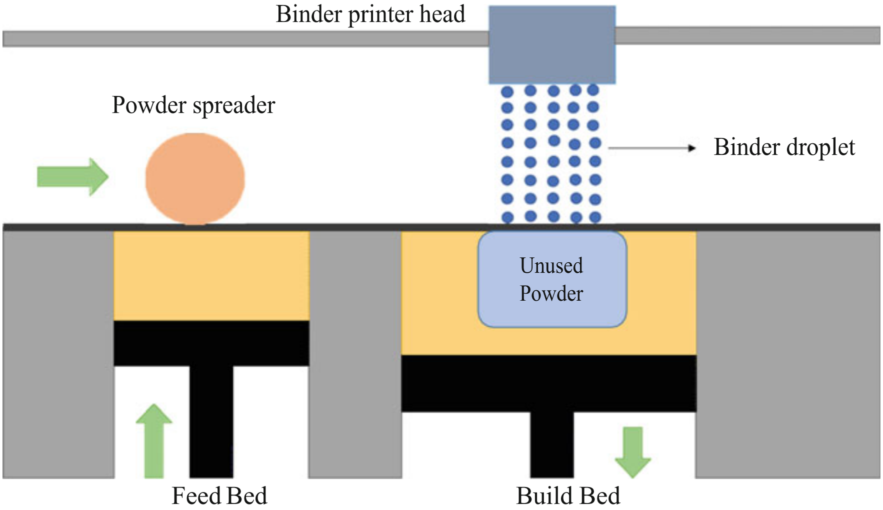


Fig. 18.4 Schematic methodological representation of power bed 3DP technology

approach offers a lot of opportunities for generating substantial pharmacological formulations, tailored and instantaneous release of drug formulations, and multilayer tablets with various and precise active ingredients. Because of these benefits, this method is widely used in pharmaceutical applications. Powder 3DP can print with a variety of materials, including metal and silica, that are less prevalent. In contrast, pure thermoplastics or thermoplastics mixed with additional materials are essentially only one material available for Fused deposition modeling (FDM) printing. Powder Bed Fusion 3D printers are also known to produce with much more reliability and can handle more complicated projects. This is because of small size of the laser, which allows it to produce greater detail than FDM printer nozzles [26].

The proper consistency of 3D printed manufactured materials can be maintained by determining the proper binder and intensity. Furthermore, the powder size distribution is another important aspect that influences the quality of the final 3D goods.

18.3 Scope of 3D Printing Methodology in the Drug Manufacturing Industry

The earliest printers used adhesive agents provided by commercially available thermal or piezoelectric print heads. Active pharmacological components and powdered ink or dust can disseminate several altering agents in a powder bed. This approach was chosen because it resembles traditional formulation methods such as wet granulation and allows for the use of active ingredients regularly utilized in pharmaceutical manufacturing, particularly in the formulation of tablet or capsule form [27]. One of the benefits of this approach is the ability to properly determine the appropriate dosage of medication or amend adjuvants inside the powdery bed to produce several compartments with varied compositions [28]. Powder and ink attributes have always influenced product proximate composition. The size of the particle and rate of flow of the granular particles, as well as a cohesive force among objects and parts of the printing technology or powder liquifying ability, all impact thickness of layers. Lowering the thickness of layers and applying successive layers results in more intricate and accurate production of structures with small mass and dosage changes. Ink components such as solvents, APIs, and manipulating excipients can alter viscosity, droplet size, and powder binding effectiveness. Solid oral drugs, like Chlorpheniramine tablets, are also formed with controlled-release profiles and acetaminophen like oral drug with linear surface functionalization. A powder can also be solidified by using a high-energy laser [29]. Layers are made by heating the polymeric or metallic powdered bed with a laser beam slightly below melting temperature, and the powdered bed is transmitted from one segment to another by a pull up mechanism. Oral dosage forms are the focus of much analysis as they're still the most common and preferred method of delivery. Some studies are also looking at dose options for topical application. The use of various 3DP methodologies (Table 18.2) to construct 3D printed pharmaceuticals reflects the increasing interest in medication design.

The initial attempts to use the DOD technique in the biopharmaceutical industry in the formulation field indicated that the evaluated matrix materials are appropriate for the creation of long-term dosage forms. The application of hydrophilic polymers or transforming the nature of the paraffin matrix can have a significant influence on dissolving characteristics. When using a UV light-based crystallization technique, the risk of API breakdown and stability issues must be considered. When this technique is used in therapeutic formulation, it is essential to highlight the postprocessing of the drug formulation, as well as the clearance and toxicity of unbounded monomeric compounds and photo-initiator.

Oral drugs with varied sizes and shapes, complicated characteristics like tablets with a planned porous structure, internal pore-forming gradients with channels, and several hollow systems such as poly-pills holding several APIs in single-dose form can be developed and manufactured using 3DP [37]. Goyanes et al. investigated the possibility of fabricating tablets of various sizes and shapes using a fused filament approach. They discovered that changing the printed shape of acetaminophen pills caused different release profiles of drugs, enabling for patient-tailored production [38]. The fastest release rate was shown by the pyramid- shaped acetaminophen tablet mostly with a maximum ratio between surface area and volume, although cylindrical-based tablet exhibited the lower rate of drug release with the minimum value. Their research found that tablets with varying shapes had a significant influence on in- vivo transit time, which might be useful for designing tailored medication delivery systems to a specific gastro-intestinal location. With several examples from current research, the next part extensively examines the influence of 3DP technology in several production processes, and in vitro and in vivo assessments are analyzed as to their outcome from 3D oral drug products (Table 18.3).

Table 18.2 Various methods of 3DP in manufacturing of 3D based pharmaceutical products

3DP method	Excipient	Dosage category	API	References
Powder solidification • Drop on solid • Laser sintering/ melting	*Powder:* Poly (l-lactic acid) (PLLA) *Ink:* Acetone, ethanol *Powder:* Maltodextrin *ink:* Polyvinylpyrroli done Polyvinylpyrroli done	Implant Tablets Oral dispersed tablets	Isoniazide Captopril Paracetamol	Gui et al. [6] Lee et al. [30] Fabrizio et al. [17]
Liquid solidification • Stereolithography	Salicylic acid with an amino group	Tablets	Paracetamol and 4-aminosalicylic acid (4-ASA)	Wang et al. [31]
Hot-melt extrusion- based methods • Fused deposition modeling (FDM)	Water-soluble synthetic polymer Sodium starch glycolate, Hydroxypropyl cellulose, Hydroxypropyl	Oral dispersible films Tablets Floating	Aripiprazole Theophylline	Jamróz et al. [32] Basel et al. [33]
• Extrusion at room temperature	Methylcellulose Lactose, Hydroxypropyl, methylcellulose, sodium starch glycolate, D-mannitol	Tablets Multi-compartm enttablet	Dipyridamole Captopril, glipizide	Li et al. [34] Khaled et al. [24]
Microneedles • Drop on drop	Insulin skin delivery Poly (ethylene glycol) diacrylate	Insulin Tablets	Xylitol, mannitol, Trehalose Hydrochloric acid (HCl)	Pere et al. [35] Clark et al. [36]

According to a recent literature study, the number of small-scale 3DP machines is low, and most of them are used for technical research. The low-quality result, high expense, and limited available resources are all aspects of why and how this approach is impractical for adoption at home or in other local settings [46]. One of the downsides that might cause concerns about product accountability is the biopharmaceutical company's approval of licenses of production for the desired medication product to pharmacies and patients who want to make the product locally [47].

18.4 3D Printing Technology and Patient-Tailored Medicines

3DP technologies offer a wide range of uses in medicine, such as generating perceptual systems utilized in tissue engineering and in pharmacy to create dosage forms due to the ability to employ a variety of materials. Tablets, as previously

Table 18.3 Drugs made via exclusive 3D printing methods

Drug product category	Printing methodology	Characteristics	References
Warfarin: The rapid disseminating oral drug	Powder bed printing	Constructed with a high number of orifices that dissipate quickly in the mouth	Tian et al. [39]
Aripiprazoleoro: Disintegrates in liquid	Fused filament printing technology	Amorphization of the drug material in a printed film having a porous structure	Jamróz et al. [32]
Theophylline: Long and short release rate	HME or FMD	Excipients are controlled digitally in a system that combines several release methods	Pietrzak et al. [40]
Prednisolone: Optimized drug release profile	Fused filament printing technology	Amorphous prednisolone in formulation or customized dosage medication	Skowyra et al. [41]
Deflazacort: Nanocapsule produced by printing technology	Fused deposition model	To produce a novel formulation, a combination of two technologies were used: 3DP and nanotechnology	Beck et al. [42]
Printed tablet fluorescein	Fused deposition model	For customized dose medicine and a precise release profile, a monolithic tablet can be used	Goyanes et al. [38]
Solid dosage manufactured ritonavir	Extrusion based method	To enhance solubility and bioavailability, hydrophilic polymer uses the solid dispersion method of the drug	Tan et al. [43]
Aminosalicylate: Targeted for colon	Extrusion based method	As a patient-tailored medication, a monolithic controlled release tablet is used	Goyaneset al. [44]
The optimized drug release profile of acetaminophen	HME or FMD	Varying densities inside the core and the thicknesses of the outer cover distinguish this 3D structure	Zhang et al. [45]

stated, are the most often manufactured dosage forms. While they can be made in a variety of geometries, there have only been few dosages for a single API accessible on an industrial scale [48]. The concept of personalized medicine has been established for a long time, but its significance has never been higher than where it is now. Since this diverse character of disease is a source of conventional rehabilitation challenges, the necessity for creating therapeutic interventions through the rational use of medications by patients in the correct dose is a topic of intense study [47]. Therapy failures or therapeutic effect limits are few drawbacks for adjusting the dosage form and dose of the active component, specifically for specific age groups. The optimal dose forms must be chosen based on not just physicochemical qualities, but also the target demographic and disease being treated. Because of the varied demands and characteristics of each clinical study, pharmaceutical product development for children and adult populations is highly suggested. Tablets are commonly divided into two or even four pieces in health care due to dosage flexibility and swallowing differences. Scored tablet issues have been documented in the literature. Overdosing or underdosing might originate from disproportionately splitting and loss of volume following division [49]. The scalability of the created items contributes to the ease of preparing medications with various dosages; hence, the dose may be regulated by calculating the consumption of the product during the scaling of the printed object while designing the platform. This technique of fabrication becomes very efficient in the manufacturing of pharmaceutical products for limited groups of patients. One of the key advantages in terms of short series of medical products is the relatively inexpensive cost of manufacture of pharmaceutical formulations with varying dosages.

The United States Food and Drug Administration (FDA) issued Technical Considerations for Additive Manufactured Medical Devices in December 2017 [50], which gives initial regulations into the needs of 3DP for healthcare systems. To ensure quality and consistency, all components of the printing process will need to be thoroughly evaluated for both pilot and lab-scale manufacturing of oral drug delivery systems including software, instruments, raw materials, training of the personnel, and quality controls. When utilizing 3DP on-demand in a hospital setting, for example, dosage forms may need to be developed based on clinical evaluations. As a result, it will be essential to thoroughly indicate clinically important design criteria involving shape and size with infill percentage as well as allowable parameter ranges [22]. Importantly, manufacturing alternative geometries might alter drug release, possibly raising research expenditures and attempts to better understand the effects of these factors. Furthermore, to design the dosage forms several types of 3DP methodologies with distinct factors are to be considered. Stereolithography (SLA), on the other hand, is reported to induce toxicity due to the use of nonpharmaceutical-grade excipients [51]. The existing commercialized 3D printers are not intended for good manufacturing practice (GMP) usage, rather they are a manufacturing environment that has been evaluated to ensure the final medicinal product is safe for human consumption [52]. As a result, the printer parts that come into contact with the formulation must not leach materials and must be easily cleaned.

From the collected resources it is obtained that the best model for 3DP technology has to be more creative in order to maintain the quality of the product. Primarily, this ideal printer would be inexpensive, create a variety of dose forms (Fig. 18.5) with acceptable cleanliness, accuracy, and consistency, have modest energy consumption, and ease of operation for newly emerging 3DP.

Even though 3DP incorporation into the healthcare system is still in a preliminary phase, regular enhancement and improvement are going on day by day. The resource data cultivated from academic researchers; the pharmaceutical sector has been shown to clarify each stakeholder's needs [53]. These legislative measures are expected to help 3DP could go from theoretical possibility to a practical and transformational production tool for the pharmaceutical sector.

By launching the initiative of generic drugs in the United States (US) in 2015, a greater idea took place emphasizing transition health care which was different from the overall approach of drugs, and it is known that rather than using a generic drug, customized medicine would be far better [54]. Previously tablets were produced in large quantities with less specificity which later depends on the dosage regulation as per the majority of the population and becomes the significant factor [55]. Depending

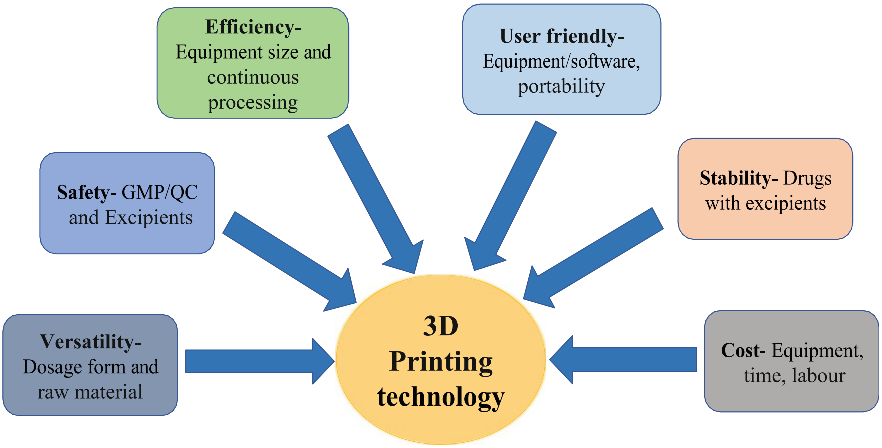


Fig. 18.5 Scope of 3DP technology in the field of pharmacogenomics

on the genetic profile of the patient including physiological and pathological conditions it is evident that one dose may not be suitable for all and hence the drug dosage can vary with population. Here comes the crucial technology, 3DP technology, using which patient-tailored drug products can be manufactured in a batch process directly at the point of treatment, enabling the advancement in the field of pharmacogenomics [56].

18.5 Implementation of 3D Printing in the Intelligent Healthcare System

In recent years, additive manufacturing (AM) has emerged as a promising production alternative. Because it can generate complicated geometrical shapes with the aid of design software, 3DP, as it is commonly called, provides for additional production possibilities. 3DP has already made a substantial contribution to several technological advancements in medicine and healthcare. Several 3DP lacks a way for surveillance and managing the printing process. Even if the filament runs out or there are any potential faults in the print, 3DP may continue to print the object until all layers have been completed. A technique for monitoring the 3DP process has been developed, which involves interrupting the printer at regular checkpoints to detect any potential flaws and taking appropriate remedial action [57]. Support Vector Machine (SVM) was the machine learning approach utilized in a study in which the final step of the quality assurance process is to use SVM classification.

18.5.1 Machine Learning-Based 3D Printed Medicines

The Support Vector Machine (SVM) is a supervised machine learning model that analyses data for regression and classification. The SVM training method takes a collection of neural networks, each of which belongs to different classifications, and develops a model that assigns any new models to one of the two categories. Machine learning (ML) may help pharmacological 3DP move towards the more deliberate, simplified, and quality-assured approach. ML program can be introduced for finding new drugs, and develop significant drug manufacturing pathways [58]. It was first used in the drug discovery area. Recently, in a study by Reker et al., it has been revealed that how machine learning may be used to speed up the identification of therapeutic nanoformulations, resulting in nanoparticles with increased bioavailability (94.9%) [59]. Instead of framing the input and output to build a proposed model, machine learning may be used to optimize processes directly. Various parts of the pharmaceutical workflow produce large amounts of multicollinearity in data, which is challenging to simulate using standard predictive models [60]. As a result, machine learning approaches such as artificial neural networks (ANNs) and decision trees have been used to start developing integrity within pharmaceutical drugs across the hot-melt extrusion and tableting process [61]. Drug manufacturing technologies have also thoroughly investigated advanced types of ML, such as ANNs, providing several achieved implementations that may be linked to medicinal 3DP. With low inaccuracy, ANNs could be used in a hypothetical tool to estimate the main pharmacokinetic parameters of indeterminate polymers, including moisture parameters, thermal stability, and solubility parameters [62]. The extraction process of prednisolone from the capsule can be varied with the concentration of the excipient and various other factors which can be simulated using an ANN method, with the error monitored unless a suitable value has been reached [63]. ANNs have also been used to assess HME process parameters for contraceptive drug formulation, with a lower inaccuracy value of the proposed result of the experiment [64]. Availability of data, output reproducibility, and the present demand for ML professionals are all obstacles that ML faces. Figure 18.6 gives an outline of the applicability of ML in the healthcare system using 3DP and illustrates the implementation and elaboration of ML for therapeutic purposes.

Considering 3DP design is already digital, machine learning is a perfect choice for this process. Generative adversarial networks (GANs) are a category of machine learning approaches that may be used to develop 3DP products [65]. The capability of GANs to overcome creative issues has been documented. GANs have also produced novel drug-like chemical structures in many other domains. GANs have also been used to augment data in regions where there aren't any, in order to expand the metadata and enhance the output of machine learning algorithms. GANs are recently used to increase the number of layer forming formulas to enable deep neural networks [66]. Printability, or the ability for formulations to be efficiently printed, provides another level of complexity to 3DP. Although a formulation may fulfill pharmaceutical criteria, it is still inadequate for 3DP if it is not printable.

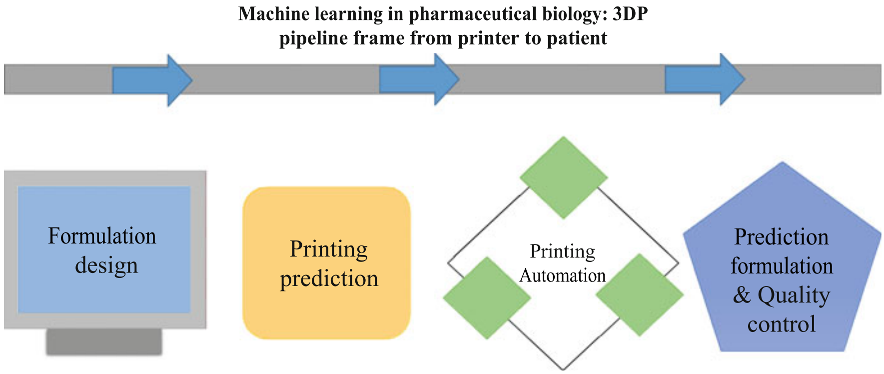


Fig. 18.6 In the drug development pipeline, significant steps of ML algorithm implemented for 3DP for therapeutic purposes

M3DISEEN, a program that uses machine learning to forecast the process of printing filaments with drug-attached compounds via FDM, has been recently published [67]. Depending only on the pharmaceutical excipient trade names, the online program allows 3DP formulation experts to estimate if a filament would be printed by FDM. An entirely automated manufacturing process is an intriguing objective in the 3DP of pharmaceuticals. Mechanization of 3DP can allow for the continuous selection of the best printing choices based on product requirements, greatly simplifying processes and eliminating operator error and subjectivity. Current 3D printers cannot anticipate ideal printing settings on their own, prompting the need for knowledge of 3DP experts to pick parameters based on their previous experience. In this case, machine learning may take the role of 3DP specialists by optimizing the algorithm to use according to the needs of the printed drug compound. Meanwhile, reinforcement learning (RL), a more sophisticated kind of machine learning algorithm, can revolutionize pharmaceutical 3DP self-regulation [68]. This algorithm solves issues by performing logical programming and rating their usefulness depending on how near it get the system near to its final objective. RL is belonging to a higher of ML that is still in its early stages, thus it might have been a few years before it is widely used in 3DP medications.

When dealing with large dimensional data, ML is superior to traditional optimization approaches such as second-order polynomial regression. For process optimization, ANN has been reported to be the most frequent and efficient ML method [69]. To obtain a 97% accuracy, a three-layered ANN is necessary. Due to its capacity to collect spatial information, the Convolutional neural network (CNN) outperforms ANN when working with two dimensional (2D) visuals and 3D models. That's why feature identification, feature suggestion, and anomaly detection are all used by CNN in 3D modeling and 3DP.

18.5.2 Current Scenario of AI-Based 3D Printing in Drug Delivery Aspect

History of production of two most documented oral solid dosage forms (OSDF) manufacturing 3DP technologies. Inkjet-powder bed techniques were systematically developed at the outset and became the first 3DP OSDF licensed by the FDA. There are currently, however, almost no commercially produced cost-effective inkjet 3D-bed printers, maybe it's because the technology required is inherently complicated, i.e., dependable ink jetting and powder management. By contrast, a great number of investigations involving 3DP OSDF have been stimulated by widespread, low-cost FDM systems which were mostly unfunded throughout their initial patent lifespan. However, because of their inherent restrictions on the diversity in medication formulations and production output, it is observed that FDM's economic potential is constrained. Therefore, dose-force and discharge characteristic plasticity (personalization), on-demand capability, and production capacity in decentralized locations are drivers for the 3DP of oral medicinal products [70]. The creation of such a capable technology requires resolving important administrative and regulatory concerns, including equipment conforming to GMPs, quality monitoring, product release, and traceability. It is expected that scalability will be a significant emphasis for research findings, given the fundamental limitations of most 3DP drug printing techniques lies in performance. Multiple print heads may be combined flexibly to deposit various materials or scale up production rates because the system is designed to be modular. Finally, a strong business case must translate essential 3DP characteristics, such as unique dose geometries, into concrete patient advantages. Spritam, for example, has a 3D printed porous system that allows for efficient oral dispersion. Although this is a benefit in this situation (emergency medicine), the effectiveness of the pharmacological therapy itself has been only considerably enhanced [71]. As a result, whether the increased value in terms of delivery translates into enough mean value and standard to repay the investments may ultimately determine the economic success of Spritam. Pharmacological compounds such as biological samples, pose significant therapeutic problems since they cannot be digested and given through traditional oral methods. The disruption in the balance of geometry and stability in gastrointestinal fluids is the primary cause of inadequate effectiveness and bioavailability.

Chai et al. represented an interesting enabling method for augmenting the solubility and bioavailability of the poorly soluble medicine "domperidone" using a 3DP technology [72]. Using fused disposition modeling, a 3D tablet has been created with an evolving idea as a gastro-intestinal drug regulatory system with a prolonged release profile. Domperidone is placed as a solid dispersion onto a hydrophilic filamentous carrier and developed into a tablet with a hollow structure. The number of shells and the infill percentage, which impact the contour and interior section of the 3D object, respectively, are used to regulate the shape of the hollow structure. The weight and strength of the pill will increase when the number of shells is increased. In many health services, 3DP may be employed starting from a community pharmacy or specialty clinics through care from hospital wards. Dispensing on demand in such environments would enhance access to medicine, decrease waste of drugs, and speed up discharge times. In timely and resource-compressed instances, one-off dosages can also be generated quickly, such as 3D printers being integrated into catastrophe regions, emergency departments, emergency unitoperations.3DP may readily be ventured with other advanced technologies of our generation, such as, and cloud-based computing and smart assistant-based health monitoring AI technology [73, 74]. Patients may now monitor their own health diagnosis (such as monitoring blood pressure and cardiac output) using publicly available apps on smartphones. In the upcoming world, the doctor might use the current internet infrastructure to obtain real-time data, allowing for easy evaluation and adjustment of therapies or doses [75]. The potential of AI-based techniques in drug research was universally acknowledged by mid-2010, a majority of big corporations had merged, bought, or partnered with AI-based computing corporations (Smalley, 2017). Early in the medication development process, AI-based algorithms may be used to reduce the number of compounds evaluated and to exclude medicines for which the algorithm predicts a high likelihood of adverse responses. With COVID-19, this tendency increased, and it now encompasses a broader range of the drug development process [76]. A scientist may create a printed output and transfer a prescription to a place with a 3D printer to be dispensed based on the feature of 3DP that it can be accessed virtually. Experienced patients might even be able to own their own drug dispensing 3D printers to make the therapy more autonomous.

18.5.3 Next-Generation 3D Printing Technology: Medical Model Manufacturing

Although picture-based surgery has been used extensively for decades, digital pictures have become more necessary. The use of additive model production makes it possible to diagnose the pathogenic modifications more accurately, to evaluate them better, and to analyze the architecture of the patient-specific organ. Before surgery, the quantity of information is considerably increased beyond particular organ characteristics, which lowers problems and loss of patients [77]. One of the most researched fields in 3DP technology is involving surgical modeling and educational parameter. The manufacturing of liver models becomes an illustration of employing 3D-printed medical models. The rising demand for transplants, along with a scarcity of cadaveric livers, raised the importance of utilizing organs from healthy donors. The vascular system and biliary tract are identified based on a type architecture in the way that it can enhance the safety of both the donor and the recipient before the surgery. Zein and colleagues described in silico models with adequate volume and color-coding arteries in 2013 [78]. They created six models of livers from six different individuals and found that the internal distribution and architectural characteristics of printed and natural organs were similar.

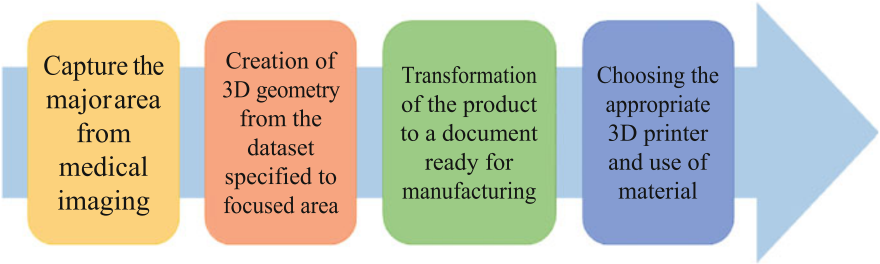


Fig. 18.7 Stepwise procedure in implementing medical model by implementing 3DP technology

3DP methods can be optimized for tailored pre-operative therapy and planning. This leads to a multi-stage process that determines the optimal treatment choice by combining clinical and imaging information. Several research studies have shown that pre-operative patient preparation is likely to minimize the time required for surgery and lead to fewer complications [78]. In addition, postoperative stays might be cut, reaction rates have decreased and healthcare expenses reduced. Custom implants or surgical guides and tools can be manufactured using 3DP. Therefore, additive manufacturing technology reduces the cost of customized surgical instruments and prostheses [79]. Safety management of the 3D printed model is the most preferred benefit in terms of 3DPfor education purposes in comparison with the ability to create various physiological morphology based on large metadata of images (Fig. 18.7) [80].

The application of 3DP allows for designing the tumor excision operations, as documented in a patient with colorectal liver metastases. Computed tomography (CT) images were utilized to create a 3D model of the liver, and organ specified components, systemic arteries, and the tumor was printed [81]. Due to printer restrictions, the model was thereafter split into four sections. A multi-layered structure was built and silicone was used to fill it.

18.6 Major Applications and Challenges

3DP of pharmacological drug delivery approach and prosthetic devices are indeed a useful technique for creating personalized products. The idea of 3D-printed medication formulation has rapidly advanced in recent years, with a focus on improving therapy through patient- centric medicine. After the first FDA clearance of a medication made with 3DP technology, studies on orally available, mucosal, and topical dosage forms greatly increased dramatically. This promising technique allows for formulation flexibility that is difficult to obtain using traditional technical methods [1]. The ability to design multimodal controlled drug delivery, multichannel drug devices, and drug formulations for customizable therapy with the accelerated release is another benefit of 3DP. To achieve the intended therapeutic impact, future studies should emphasize the development of infant and adult dose forms in customized dosing and patient-specified drug formulations. A growing number of medication research studies demonstrate the technology's clear benefits, but ultimate success will only come after pioneering the creation of novel dosage forms on a large scale. The fast spread of Covid-19 has put a challenge for healthcare systems all around the world, with a surge in demand for necessary medical equipment and supplies. The traditional medical device manufacturing line has been challenged by excessive worldwide demand, and the need for a simple, low-cost, and quick fabrication technique is felt more than ever. In order to cover the gap and boost the production line of medical equipment, manufacturers turned to additive manufacturing or 3DP [82]. In addition to providing a visual representation of patient-specific organ architecture, 3DP models provide new insights into disease alterations. Education and surgery planning are two of the most heavily invested sectors in the healthcare industry using 3DP. Collaboration and data sharing are two additional major advantages of 3DP, particularly in medicine and other disciplines. The National Institutes of Health (NIH) was a pioneer in this area, founding the shared 3DP data network 3D Print Exchange. Formerly it was deployed internally, where 3D printers are located around the institute's premises for data exchange of software and graphics for 3DP, but this is now a fully accessible site that allows anybody to share 3D print files for multiple devices.

Under the design criteria regulation, performance characteristics, improved bioavailability of printed material, and sterilization, additive manufacturing faces several challenges. Furthermore, the delicate nature of printed things, particularly cell-based objects, combined with the complexity of produced structures necessitates a well-thought-out method. However, the numerous benefits to patients and the whole healthcare system given by 3DP make the amount of study necessary to create a tailored product production method acceptable. The implementation of ML and 3DP has lots of limitations. For an optimum transfer to clinical research, software developers of ML-based 3DP technology can detect and remove these factors that affect the performance as early as possible [83]. Many of these issues are common to ML in general, with a subset that is unique to pharmaceutical 3DP. The accessibility of a big dataset for the training of algorithms is perhaps the most ubiquitous problem. Although the ML approach can moderate the little dataset are being developed, ML proposed models are typically more accurate when huge amounts of training data are provided [84]. Researchers may now create graphs and charts of various machine learning techniques, such as decision trees and biplots, to demonstrate how they work. The use of ML in 3DP medications raises a code of professional conduct concern. Before ML-guided 3DP may be utilized in hospitals, considerations on whether someone is accountable in the event of software failure or technological failure must be made. When many organization corporations employ 3DP and ML technologies, such constraints may get considerably more complicated.

18.7 Conclusion and Future Scope

Due to its high flexibility and its effective research and manufacturing of new medical devices, 3DP technology creates a substantial prospect of medication development, formulations, and administration. Furthermore, increasing the ability to modify high-grade deposition patterns to test diverse dosage forms, the adequacy of the technology as a tool for the personalization of drugs is enormous. The new technology enables a medicinal formulation to be reformulated and remanufactured to separate it from generic competitors on the market that can give additional advantages for patients and in the long run, reduce product costs. The evaluated studies showed improvement in the application of recent production for the manufacture of oral medicinal products. The majority of the time, hydrophobic (less soluble in water) medicines were included, indicating one of the major drawbacks in the drug developing industry. The research showed that by integrating an appropriate 3DP technology and established method for printing oral drugs, it is possible to enhance the bioavailability and solubility of poorly soluble medicines. The application of extrusion-based product manufacturing in an industry decreases the time and expense of health care while increasing surgical success rates. Emerging modified surgical methods can be evolved, particularly for hazardous and infrequently done operations. Furthermore, 3DP extremely realistic organ models for better exposure in the field of surgery can ease and minimize surgery time while reducing intra-operative problems. Despite these benefits, additive manufacturing has a broad range of limitations in terms of design parameter control, the performance of the device, biocompatibility, and cleanliness. This technology has the potential to transform formulation production, encouraging it to pivot away from mass production and toward the development of advanced versatile and customized drug molecules. Over the next decade, 3DP is prepared to remain substantially expanding. The implementation of 3DP into the healthcare systems will significantly improve tailored medicine and given unique formulations based on particular needs. With the use of machine learning, clinicians might be given recommendations on which medicine, dose, and formulation design according to different aspects of the patients. For a sustainable transmission to healthcare settings, 3DP as a unique technology would need the continual presence of experienced operators to manage and repair devices. The effort of physicians during evenings and weekends might be drastically reduced if reliable, automated 3DP of medications were available. Clinical studies, which frequently need to change formulation dosages on short notice, might profit greatly from such features. This high level of support is a good sign that ML-guided 3DP will be used in clinical settings. Since they have access to enormous amounts of digitalized patient data, big healthcare providers like the National Health Service of the United Kingdom (NHS) are highly suited for ML adoption. For 3DP of medicines, digital healthcare facilities provide trustworthy and consistent datasets that can be processed by machine learning. One of the advances in healthcare that is constantly being developed is the creation of medicines and precision medicine based on genomics and cloud computing. Drug development is expensive and takes a long time because of pharmaceutical failures, lack of efficacy, or toxicity; therefore, pharmacogenomics attempts to personalize therapies and medicines based on an individual's genetic structure and investigate rational drug development and repurposing drugs. In future hospitals, AI will be quicker and better than manual diagnostic methods in detecting diseases, thus there will be no need for laboratory or diagnostic units as we recognize things now. From medical equipment to human body parts like prosthetic ears, 3D printers will be able to create nearly anything. As a result, future hospitals will need to include room for scanning and 3DP.

In summary, AI-based 3DP technology gives the tools and ease of access to make the most of the clinical resources available to it for the sake of patient care. ML and deep learning can both simplify and quickly inspire novel formulation concepts in the pharmaceutical 3DP process, expediting its deeper and more comprehensive use and, in turn, improving patients' access to safe, customized required medications. In general, in pharmaceutical research and development printed techniques have established a strong appeal, but a total achievement to this field will be realized after getting illustrated innovative, industrially manufactured 3D dosage forms. The future of healthcare thus can be improved and enhanced by these emerging 3DP technologies along with AI-based drug delivery formulation.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Jamróz, W., Szafraniec, J., Kurek, M., & Jachowicz, R. (2018). 3D printing in pharmaceutical and medical applications. *Pharmaceutical Research, 35*(9), 176.
2. Hsiao, W. K., Lorber, B., Reitsamer, H., & Khinast, J. (2018). 3D printing of oral drugs: A new reality or hype? *Expert Opinion on Drug Delivery, 15*(1), 1–4. https://doi.org/10.1080/17425247.2017.1371698
3. Scoutaris, N., Ross, S., & Douroumis, D. (2016). Current trends on medical and pharmaceutical applications of inkjet printing technology. *Pharmaceutical Research, 33*(8), 1799–1816. https://doi.org/10.1007/s11095-016-1931-3
4. Zhang, J., Vo, A. Q., Feng, X., Bandari, S., & Repka, M. A. (2018). Pharmaceutical additive manufacturing: A novel tool for complex and personalized drug delivery systems. *AAPS PharmSciTech, 19*(8), 3388–3402. https://doi.org/10.1208/s12249-018-1097-x
5. Trenfield, S. J., Awad, A., Goyanes, A., Gaisford, S., & Basit, A. W. (2018). 3D printing pharmaceuticals: Drug development to frontline care. *Trends in Pharmacological Sciences, 39*(5), 440–451. https://doi.org/10.1016/j.tips.2018.02.006
6. Wu, G., Wu, W., Zheng, Q., Li, J., Zhou, J., & Hu, Z. (2014). *Experimental study of PLLA/INH slow release implant fabricated by three dimensional printing technique and drug release*

characteristics in vitro. BioMedical Engineering OnLine. Retrieved July 06, 2021, from http://www.biomedical-engineering-online.com/content/13/1/97
7. Goole, J., & Amighi, K. (2016). 3D printing in pharmaceutics: A new tool for designing customized drug delivery systems. *International Journal of Pharmaceutics, 499*(1–2) Elsevier B.V., 376–394. https://doi.org/10.1016/j.ijpharm.2015.12.071
8. Prasad, L. K., & Smyth, H. (2016). 3D printing technologies for drug delivery: A review. *Drug Development and Industrial Pharmacy, 42*(7), 1019–1031. https://doi.org/10.3109/03639045.2015.1120743
9. Khong Tan, D., Maniruzzaman, M., & Nokhodchi, A. (2018). Pharmaceutics advanced pharmaceutical applications of hot-melt extrusion coupled with Fused Deposition Modelling (FDM) 3D printing for personalised drug delivery. *Pharmaceutics, 10*(4), 203. https://doi.org/10.3390/pharmaceutics10040203
10. Ghilan, A., Chiriac, A. P., Nita, L. E., Rusu, A. G., Neamtu, I., & Chiriac, V. M. (2020). Trends in 3D printing processes for biomedical field: Opportunities and challenges. *Journal of Polymers and the Environment, 28*(5), 1345–1367. https://doi.org/10.1007/S10924-020-01722-X
11. Derakhshanfar, S., Mbeleck, R., Xu, K., Zhang, X., Zhong, W., & Xing, M. (2018). 3D bioprinting for biomedical devices and tissue engineering: A review of recent trends and advances. *Bioactive Materials, 3*(2), 144–156. https://doi.org/10.1016/J.BIOACTMAT.2017.11.008
12. Groll, J., et al. (2018). A definition of bioinks and their distinction from biomaterial inks. *Biofabrication, 11*(1), 013001. https://doi.org/10.1088/1758-5090/AAEC52
13. Azad, M. A., Olawuni, D., Kimbell, G., Badruddoza, A. Z. M., Hossain, M. S., & Sultana, T. (2020). Polymers for extrusion-based 3D printing of pharmaceuticals: A holistic materials–process perspective. *Pharmaceutics, 12*, 124. https://doi.org/10.3390/PHARMACEUTICS12020124
14. Huang, D. D., et al. (2020). Engineering liver microtissues for disease modeling and regenerative medicine. *Advanced Functional Materials, 30*(44), 1909553. https://doi.org/10.1002/ADFM.201909553
15. Davoodi, E., Sarikhani, E., Montazerian, H., Ahadian, S., Costantini, M., Swieszkowski, W., Willerth, S. M., Walus, K., Mofidfar, M., Toyserkani, E., Khademhosseini, A., & Ashammakhi, N. (2020). Extrusion and microfluidic-based bioprinting to fabricate biomimetic tissues and organs. *Advanced Materials Technologies, 5*, 1901044. https://doi.org/10.1002/admt.201901044
16. Lim, K. S., Galarraga, J. H., Cui, X., Lindberg, G. C. J., Burdick, J. A., & Woodfield, T. B. F. (2020). Fundamentals and applications of photo-cross-linking in bioprinting. *Chemical Reviews, 120*(19), 10662–10694. https://doi.org/10.1021/ACS.CHEMREV.9B00812
17. Fina, F., Madla, C. M., Goyanes, A., Zhang, J., Gaisford, S., & Basit, A. W. (2018). Fabricating 3D printed orally disintegrating printlets using selective laser sintering. *International Journal of Pharmaceutics, 541*(1–2), 101–107. https://doi.org/10.1016/J.IJPHARM.2018.02.015
18. Preis, M., Breitkreutz, J., & Sandler, N. (2015). Perspective: Concepts of printing technologies for oral film formulations. *International Journal of Pharmaceutics, 494*(2), 578–584. https://doi.org/10.1016/J.IJPHARM.2015.02.032
19. *3D inkjet printing of tablets exploiting bespoke complex geometries for controlled and tuneable drug release | Elsevier Enhanced Reader*. Retrieved July 7, 2021, from https://reader.elsevier.com/reader/sd/pii/S0168365917306892?token=946C354CAF7F33FC68BD862691AE191EA421FA564C578965AEB80EEE38040E4FF1BEC0BCF41E1E98F1A047C818DA66F3&originRegion=eu-west-1&originCreation=20210707113112.
20. Boehm, R. D., Miller, P. R., Daniels, J., Stafslien, S., & Narayan, R. J. (2014). Inkjet printing for pharmaceutical applications. *Materials Today, 17*(5), 247–252. https://doi.org/10.1016/J.MATTOD.2014.04.027
21. Nematollahi, B., Xia, M., & Sanjayan, J. (2017). *Current progress of 3D concrete printing technologies*. ISARC. https://doi.org/10.22260/ISARC2017/0035

22. Goyanes, A., Buanz, A. B. M., Basit, A. W., & Gaisford, S. (2014). Fused-filament 3D printing (3DP) for fabrication of tablets. *International Journal of Pharmaceutics, 476*(1–2), 88–92. https://doi.org/10.1016/J.IJPHARM.2014.09.044
23. Rahman, Z., Barakh Ali, S. F., Ozkan, T., Charoo, N. A., Reddy, I. K., & Khan, M. A. (2018). Additive manufacturing with 3D printing: Progress from bench to bedside. *The AAPS Journal, 20*(6), 101. https://doi.org/10.1208/s12248-018-0225-6
24. Khaled, S. A., Burley, J. C., Alexander, M. R., & Roberts, C. J. (2014). Desktop 3D printing of controlled release pharmaceutical bilayer tablets. *International Journal of Pharmaceutics, 461*(1–2), 105–111. https://doi.org/10.1016/J.IJPHARM.2013.11.021
25. Infanger, S., Haemmerli, A., Iliev, S., Baier, A., Stoyanov, E., & Quodbach, J. (2019). Powder bed 3D-printing of highly loaded drug delivery devices with hydroxypropyl cellulose as solid binder. *International Journal of Pharmaceutics, 555*, 198–206. https://doi.org/10.1016/J.IJPHARM.2018.11.048
26. Osouli-Bostanabad, K., & Adibkia, K. (2018). Made-on-demand, complex and personalized 3D-printed drug products. *BioImpacts: BI, 8*(2), 77. https://doi.org/10.15171/BI.2018.09
27. Brniak, W., Jachowicz, R., Krupa, A., Skorka, T., & Niwinski, K. (2013). Evaluation of co-processed excipients used for direct compression of orally disintegrating tablets (ODT) using novel disintegration apparatus. *Pharmaceutical Development and Technology, 18*(2), 464–474. https://doi.org/10.3109/10837450.2012.710238
28. Krupa, A., Jachowicz, R., Pędzich, Z., & Wodnicka, K. (2012). The influence of the API properties on the ODTs manufacturing from co-processed excipient systems. *AAPS PharmSciTech, 13*(4), 1120–1129. https://doi.org/10.1208/S12249-012-9831-2
29. Schultz-Knudsen, K., Sabaliauskaite, U., Hellsten, J., et al. (2021). New drug and biologics approvals in 2019: A systematic analysis of patient experience data in FDA drug approval packages and product labels. *Therapeutic Innovation & Regulatory Science, 55*, 503–513. https://doi.org/10.1007/s43441-020-00244-x
30. Lee, K. J., Kang, A., Delfino, J. J., West, T. G., Chetty, D., Monkhouse, D. C., & Yoo, J. (2003). Evaluation of critical formulation factors in the development of a rapidly dispersing captopril oral dosage form. *Drug Development and Industrial Pharmacy, 29*(9), 967–979. https://doi.org/10.1081/ddc-120025454
31. Wang, J., Goyanes, A., Gaisford, S., & Basit, A. W. (2016). Stereolithographic (SLA) 3D printing of oral modified-release dosage forms. *International Journal of Pharmaceutics, 503*(1–2), 207–212. https://doi.org/10.1016/j.ijpharm.2016.03.016
32. Jamróz, W., Kurek, M., Łyszczarz, E., Szafraniec, J., Knapik-Kowalczuk, J., Syrek, K., Paluch, M., & Jachowicz, R. (2017). 3D printed orodispersible films with aripiprazole. *International Journal of Pharmaceutics, 533*(2), 413–420. https://doi.org/10.1016/j.ijpharm.2017.05.052
33. Arafat, B. (2018). Tablet fragmentation without a disintegrant: A novel design approach for accelerating disintegration and drug release from 3D printed cellulosic tablets. *European Journal of Pharmaceutical Sciences, 118*, 191–199. https://doi.org/10.1016/J.EJPS.2018.03.019
34. Li, Q., Guan, X., Cui, M., Zhu, Z., Chen, K., Wen, H., Jia, D., Hou, J., Xu, W., Yang, X., & Pan, W. (2018). Preparation and investigation of novel gastro-floating tablets with 3D extrusion-based printing. *International Journal of Pharmaceutics, 535*(1–2), 325–332. https://doi.org/10.1016/j.ijpharm.2017.10.037
35. Pere, C. P. P., Economidou, S. N., Lall, G., Ziraud, C., Boateng, J. S., Alexander, B. D., Lamprou, D. A., & Douroumis, D. (2018). 3D printed microneedles for insulin skin delivery. *International Journal of Pharmaceutics, 544*(2), 425–432. https://doi.org/10.1016/j.ijpharm.2018.03.031
36. Clark, E. A., Alexander, M. R., Irvine, D. J., Roberts, C. J., Wallace, M. J., Sharpe, S., Yoo, J., Hague, R. J. M., Tuck, C. J., & Wildman, R. D. (2017). 3D printing of tablets using inkjet with UV photoinitiation. *International Journal of Pharmaceutics, 529*(1–2), 523–530. https://doi.org/10.1016/j.ijpharm.2017.06.085

37. Preis, M., & Öblom, H. (2017). 3D-printed drugs for children—Are we ready yet? *AAPS PharmSciTech, 18*(2), 303–308. https://doi.org/10.1208/S12249-016-0704-Y
38. Goyanes, A., Robles Martinez, P., Buanz, A., Basit, A. W., & Gaisford, S. (Oct. 2015). Effect of geometry on drug release from 3D printed tablets. *International Journal of Pharmaceutics, 494*(2), 657–663. https://doi.org/10.1016/J.IJPHARM.2015.04.069
39. Pan, T., Yang, F., Xu, Y., Lin, M.-M., Yu, L.-P., Lin, W., Lin, Q.-F., Lv, Z.-F., Huang, S.-Y., & Chen, Y.-Z. (2018). Oral disintegrating patient-tailored tablets of warfarin sodium produced by 3D printing. *Drug Development and Industrial Pharmacy, 44*(12), 1918–1923. https://doi.org/10.1080/03639045.2018.1503291
40. Pietrzak, K., Isreb, A., & Alhnan, M. A. (2015). A flexible-dose dispenser for immediate and extended release 3D printed tablets. *European Journal of Pharmaceutics and Biopharmaceutics, 96*, 380–387. https://doi.org/10.1016/J.EJPB.2015.07.027
41. Skowyra, J., Pietrzak, K., & Alhnan, M. A. (2015). Fabrication of extended-release patient-tailored prednisolone tablets via fused deposition modelling (FDM) 3D printing. *European Journal of Pharmaceutical Sciences, 68*, 11–17. https://doi.org/10.1016/J.EJPS.2014.11.009
42. Beck, R. C. R., Chaves, P. S., Goyanes, A., Vukosavljevic, B., Buanz, A., Windbergs, M., Basit, A. W., & Gaisford, S. (2017). 3D printed tablets loaded with polymeric nanocapsules: An innovative approach to produce customized drug delivery systems. *International Journal of Pharmaceutics, 528*(1–2), 268–279. https://doi.org/10.1016/j.ijpharm.2017.05.074
43. Tan, D. K., Maniruzzaman, M., & Nokhodchi, A. (Oct. 2018). Advanced pharmaceutical applications of hot-melt extrusion coupled with Fused Deposition Modelling (FDM) 3D printing for personalised drug delivery. *Pharmaceutics, 10*(4), 203. https://doi.org/10.3390/PHARMACEUTICS10040203
44. Goyanes, A., Buanz, A. B. M., Hatton, G. B., Gaisford, S., & Basit, A. W. (2015). 3D printing of modified-release aminosalicylate (4-ASA and 5-ASA) tablets. *European Journal of Pharmaceutics and Biopharmaceutics, 89*, 157–162. https://doi.org/10.1016/J.EJPB.2014.12.003
45. Zhang, J., Yang, W., Vo, A. Q., Feng, X., Ye, X., Kim, D. W., & Repka, M. A. (2017). Hydroxypropyl methylcellulose-based controlled release dosage by melt extrusion and 3D printing: Structure and drug release correlation. *Carbohydrate Polymers, 177*, 49. https://doi.org/10.1016/j.carbpol.2017.08.058
46. Pravin, S., & Sudhir, A. (2018). Integration of 3D printing with dosage forms: A new perspective for modern healthcare. *Biomedicine & Pharmacotherapy, 107*, 146–154. https://doi.org/10.1016/J.BIOPHA.2018.07.167
47. Sandler, N., & Preis, M. (2016). Printed drug-delivery systems for improved patient treatment. *Trends in Pharmacological Sciences, 37*(12), 1070–1080. https://doi.org/10.1016/j.tips.2016.10.002. Epub 2016 Oct 27.
48. Boetker, J., Water, J. J., Aho, J., Arnfast, L., Bohr, A., & Rantanen, J. (2016). Modifying release characteristics from 3D printed drug-eluting products. *European Journal of Pharmaceutical Sciences, 30*(90), 47–52. https://doi.org/10.1016/j.ejps.2016.03.013
49. Richey, R. H., Hughes, C., Craig, J. V., Shah, U. U., Ford, J. L., Barker, C. E., Peak, M., Nunn, A. J., & Turner, M. A. (2017). A systematic review of the use of dosage form manipulation to obtain required doses to inform use of manipulation in paediatric practice. *International Journal of Pharmaceutics, 518*(1–2), 155–166. https://doi.org/10.1016/j.ijpharm.2016.12.032
50. *Technical Considerations for Additive Manufactured Medical Devices | FDA*. Retrieved July 12, 2021, from https://www.fda.gov/regulatory-information/search-fda-guidance-documents/technical-considerations-additive-manufactured-medical-devices.
51. Ahearne, M., & Coyle, A. (2016). Application of UVA-riboflavin crosslinking to enhance the mechanical properties of extracellular matrix derived hydrogels. *Journal of the Mechanical Behavior of Biomedical Materials, 54*, 259–267. https://doi.org/10.1016/j.jmbbm.2015.09.035
52. *ICH Q7 Good manufacturing practice for active pharmaceutical ingredients | European Medicines Agency*. Retrieved July 12, 2021, from https://www.ema.europa.eu/en/ich-q7-good-manufacturing-practice-active-pharmaceutical-ingredients.

53. *FDA and the Emerging Technology of 3D Printing*. Retrieved July 12, 2021, from https://www.pharmtech.com/view/fda-and-emerging-technology-3d-printing.
54. Hamburg, M. A., & Collins, F. S. (2010). The path to personalized medicine. *The New England Journal of Medicine, 363*(4), 301–304. https://doi.org/10.1056/NEJMP1006304
55. Srivastava, S. C. (2012). Paving the way to personalized medicine: Production of some promising theragnostic radionuclides at Brookhaven National Laboratory. *Seminars in Nuclear Medicine, 42*(3), 151–163. https://doi.org/10.1053/J.SEMNUCLMED.2011.12.004
56. Florence, A. T., & Lee, V. H. L. (2011). Personalised medicines: More tailored drugs, more tailored delivery. *International Journal of Pharmaceutics, 415*(1–2), 29–33. https://doi.org/10.1016/J.IJPHARM.2011.04.047
57. Delli, U., & Chang, S. (2018). Automated process monitoring in 3D printing using supervised machine learning. *Procedia Manufacturing, 26*, 865–870. https://doi.org/10.1016/j.promfg.2018.07.111
58. Zoffmann, S., Vercruysse, M., Benmansour, F., et al. (2019). Machine learning-powered antibiotics phenotypic drug discovery. *Scientific Reports, 9*, 5013. https://doi.org/10.1038/s41598-019-39387-9
59. Reker, D., Rybakova, Y., Kirtane, A. R., et al. (2021). Computationally guided high- throughput design of self-assembling drug nanoparticles. *Nature Nanotechnology, 16*, 725–733. https://doi.org/10.1038/s41565-021-00870-y
60. Simões, M. F., Silva, G., Pinto, A. C., Fonseca, M., Silva, N. E., Pinto, R. M. A., & Simões, S. (2020). Artificial neural networks applied to quality-by-design: From formulation development to clinical outcome. *European Journal of Pharmaceutics and Biopharmaceutics, 152*, 282–295. https://doi.org/10.1016/j.ejpb.2020.05.012
61. Chakraborty, C., & Abougreen, A. N. (2021). Intelligent internet of things and advanced machine learning techniques for covid-19. *EAI Endorsed Transactions on Pervasive Health and Technology, 7*(26), e1. https://doi.org/10.4108/EAI.28-1-2021.168505
62. Ebube, N. K., Owusu-Ababio, G., & Adeyeye, C. M. (2000). Preformulation studies and characterization of the physicochemical properties of amorphous polymers using artificial neural networks. *International Journal of Pharmaceutics, 196*(1), 27–35. https://doi.org/10.1016/S0378-5173(99)00405-6
63. Manda, A., Walker, R., & Khamanga, S. M. M. (2019). An artificial neural network approach to predict the effects of formulation and process variables on prednisone release from a multipartite system. *Pharmaceutics, 11*(3), 109.," *mdpi.com*. https://doi.org/10.3390/pharmaceutics11030109
64. McKinley, D., Patel, S. K., Regev, G., Rohan, L. C., & Akil, A. (2019 Nov). Delineating the effects of hot- melt extrusion on the performance of a polymeric film using artificial neural networks and an evolutionary algorithm. *International Journal of Pharmaceutics, 25*(571), 118715. https://doi.org/10.1016/j.ijpharm.2019.118715
65. Hsu, Y.-C., Chi-Hua, Y., & Buehler, M. J. (2021). Tuning mechanical properties in polycrystalline solids using a deep generative framework. *Advanced Engineering Materials, 23*(4), 2001339. https://doi.org/10.1002/adem.202001339
66. Chakraborty, C., & Rathi, M. (2021). Smart healthcare systems using big data. In *Demystifying big data, machine learning, and deep learning for healthcare analytics* (pp. 17–32). ResearchGate GmbH. https://doi.org/10.1016/B978-0-12-821633-0.00009-X
67. Elbadawi, M., Muñiz Castro, B., Gavins, F. K. H., Ong, J. J., Gaisford, S., Pérez, G., Basit, A. W., Cabalar, P., & Goyanes, A. (2020 Nov). M3DISEEN: A novel machine learning approach for predicting the 3D printability of medicines. *International Journal of Pharmaceutics, 30*(590), 119837. https://doi.org/10.1016/j.ijpharm.2020.119837
68. Elbadawi, M., Gaisford, S., & Basit, A. W. (2021). Advanced machine-learning techniques in drug discovery. *Drug Discovery Today, 26*(3), 769–777. https://doi.org/10.1016/j.drudis.2020.12.003

69. Goh, G. D., Sing, S. L., & Yeong, W. Y. (2020). A review on machine learning in 3D printing: Applications, potential, and challenges. *Artificial Intelligence Review, 54*(1), 63–94. https://doi.org/10.1007/S10462-020-09876-9
70. Kyobula, M., Adedeji, A., Alexander, M. R., Saleh, E., Wildman, R., Ashcroft, I., Gellert, P. R., & Roberts, C. J. (2017). 3D inkjet printing of tablets exploiting bespoke complex geometries for controlled and tuneable drug release. *Journal of Controlled Release, 261*, 207–215. https://doi.org/10.1016/j.jconrel.2017.06.025
71. Sun, Y., & Soh, S. (2015). Printing tablets with fully customizable release profiles for personalized medicine. *Advanced Materials, 27*(47), 7847–7853. https://doi.org/10.1002/ADMA.201504122
72. Chai, X., Chai, H., Wang, X., et al. (2017). Fused deposition modeling (FDM) 3D printed tablets for Intragastric floating delivery of Domperidone. *Scientific Reports, 7*, 2829. https://doi.org/10.1038/s41598-017-03097-x
73. Garg, L., Chukwu, E., Nasser, N., Chakraborty, C., & Garg, G. (2020). Anonymity preserving IoT-based COVID-19 and other infectious disease contact tracing model. *IEEE Access, 8*, 159402–159414. https://doi.org/10.1109/ACCESS.2020.3020513
74. Norman, J., Madurawe, R. D., Moore, C. M. V., Khan, M. A., & Khairuzzaman, A. (2017). A new chapter in pharmaceutical manufacturing: 3D-printed drug products. *Advanced Drug Delivery Reviews, 108*, 39–50. https://doi.org/10.1016/j.addr.2016.03.001
75. Zanaboni, P., & Wootton, R. (2012). Adoption of telemedicine: From pilot stage to routine delivery. *BMC Medical Informatics and Decision Making, 12*(1), 1–9. https://doi.org/10.1186/1472-6947-12-1
76. Dwivedi, P., Sarkar, A. K., Chakraborty, C., Singha, M., & Rojwal, V. (2021). *Application of artificial intelligence on post pandemic situation and lesson learn for future prospects* (pp. 1–18). Taylor Francis. https://doi.org/10.1080/0952813X.2021.1958063
77. O'Brien, E. K., Wayne, D. B., Barsness, K. A., McGaghie, W. C., & Barsuk, J. H. (2016). Use of 3D printing for medical education models in transplantation medicine: A critical review. *Current Transplantation Reports, 3*(1), 109–119. https://doi.org/10.1007/S40472-016-0088-7
78. Sheth, U., Theodoropoulos, J., & Abouali, J. (2015). Use of 3-dimensional printing for preoperative planning in the treatment of recurrent anterior shoulder instability. *Arthroscopy Techniques, 4*(4), e311. https://doi.org/10.1016/J.EATS.2015.03.003
79. Garcia, J., Yang, Z., Mongrain, R., Leask, R. L., & Lachapelle, K. (2018). 3D printing materials and their use in medical education: A review of current technology and trends for the future. *BMJ Simulation & Technology Enhanced Learning, 4*(1), 27–40. https://doi.org/10.1136/bmjstel-2017-000234
80. Walker, V., & MLIS. (2017). Implementing a 3D printing service in a biomedical library. *Journal of the Medical Library Association, 105*(1), 55–60. Retrieved July 14, 2021, from *ncbi.nlm.nih.gov*, https://www.ncbi.nlm.nih.gov/pmc/articles/pmc5234447/
81. Witowski, J. S., Pędziwiatr, M., Major, P., & Budzyński, A. (2017). Cost-effective, personalized, 3D- printed liver model for preoperative planning before laparoscopic liver hemihepatectomy for colorectal cancer metastases. *International Journal of Computer Assisted Radiology and Surgery, 12*(12), 2047–2054. https://doi.org/10.1007/s11548-017-1527-3
82. Vasilescu, S. A., Bazaz, S. R., Jin, D., Shimoni, O., & Warkiani, M. E. (2020). 3D printing enables the rapid prototyping of modular microfluidic devices for particle conjugation. *Applied Materials Today, 20*, 100726. https://doi.org/10.1016/J.APMT.2020.100726
83. Elbadawi, M., McCoubrey, L. E., Gavins, F. K. H., Ong, J. J., Goyanes, A., Gaisford, S., & Basit, A. W. (2021). Disrupting 3D printing of medicines with machine learning. *Trends in Pharmacological Sciences, 42*(9), 745–757. https://doi.org/10.1016/j.tips.2021.06.002
84. Yamada, H., Liu, C., Wu, S., Koyama, Y., Ju, S., Shiomi, J., Morikawa, J., & Yoshida, R. (2019). Predicting materials properties with little data using shotgun transfer learning. *ACS Central Science, 5*(10), 1717–1730. https://doi.org/10.1021/acscentsci.9b00804

Part V
Management of Intelligent Healthcare

Chapter 19
Efficient Physical Layer Techniques for Healthcare Applications: Co-Operative Network Coding Algorithms and Modified Equalizers

Hani Attar

Abstract Medical health applications and the relevant techniques become more and more specific and limited in terms of the required system's parameters. Indeed, movable hospitals and ambulances, for example, are fully equipped with modern communication appliances that are in need of efficient and specific designs, such as wireless video calls, far distance demonization, high-quality image transmissions. . .etc. Accordingly, the major contribution for this chapter is proposing modern techniques based on improving data exchanging techniques over the Physical Layer (PL) to fulfill practical requirements of medical applications.

This chapter investigates the Network Coding (NC) technique that implemented to save the transmission power, improve the Bit Error Rate (BER) and Packet Error Rate (PER), and reduce the communication traffic. Moreover, the explicit and efficient design of equalizers that can fit the required parameters of the medical applications explored in this chapter. Indeed, applying the Orthogonal Frequency-Division Multiplexing (OFDM) system on the PL becomes such a well-recommended solution for the complexity resulted from the time-invariant multi-path channel effects, which requires sophisticated equalizers. So, this chapter proposes a simplified equalizer to apply over mobile medical systems such as the wireless communication systems implemented in ambulances or transportable hospitals.

Finally, the queuing algorithms for the Multi-Service Streams Network (MSSN) investigated in good detail, and hence the most applicable queuing algorithm for several medical applications was recommended.

The results of the research work show that PL efficient technique deigns significantly participates in improving mobile wireless communication for medical applications, such as in less power consumption, better BER and PER, and less time-invariant multi-path channel effects.

H. Attar (✉)
Factulty of Engineering, Department of Energy Engineering, Zarqa University, Zarqa, Jordan
e-mail: Hattar@zu.edu.jo

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_19

Keywords Physical layer · Network coding · Co-operative network · Orthogonal frequency-division multiplexing · Queuing algorithms · Bit error rate · Packet error rate

19.1 Introduction

In communication networks science, the physical Layer (PL) referred to the mechanism of processing the data in the form of bitstreams, through the communication between transmitters and receivers. The bitstreams are usually reconstructed to form what is called "code words" or "symbols". Then finally, the resulted code words are converted to a physical signal that is suitable to be transmitted in the physical transmission media (channel). For example, the transmission in wireless channels requires converting the code words to an electromagnetic (analogy) signal to broadcast in the air. As a result, working with the PL means dealing with the data in its bit forms (0 or 1).

Based on the above, the PL techniques deal with the data in its digital form, such as Network Coding (NC) [1–9], Orthogonal Frequency-Division Multiplexing (OFDM), Fractional Fourier Transform (FrFT), Discrete Fractional Fourier Transform (DFrFT), Discrete Fractional Fourier Transform Multi-Carrier Modulation (DFrFT-MCM), Discrete Fractional Fourier Transform Orthogonal Chirp-Division Multiplexing (DFrFT-OCDM) [10–13], equalizations that mitigate the time-invariant multi-path channel effects [12–14], Multi-Service Streams Network (MSSN) [15–18], queuing techniques [19], and others.

19.1.1 Co-Operative Network Coding for Healthcare Applications

Network Coding, in its most straightforward way of definition, is identified as combining the bitstreams at the PL before transmitting the resulted network-coded streams on the channel. The combination performed by XOR-ing($\bigoplus$) the bitstreams, so the resulted combined bitstream has no extra bitstream length. The resulted network coded code-words or symbols are converted to electromagnetic signals to transmit on wireless channels, instead of the usual code-words or symbols (uncombined bitstreams).

Figure 19.1 illustrates the entire processing steps performed over the PL that implements NC, where a client "A" transmits its data through a Base Station (BS) separately in Fig.19.1a, and after combining the stream of bits in the BS with a client "B" in Fig. 19.1b.

It is clear that the BS broadcasts just one combined bitstream rather than two separate single bitstreams. As a result, NC decreases the number of transmitted

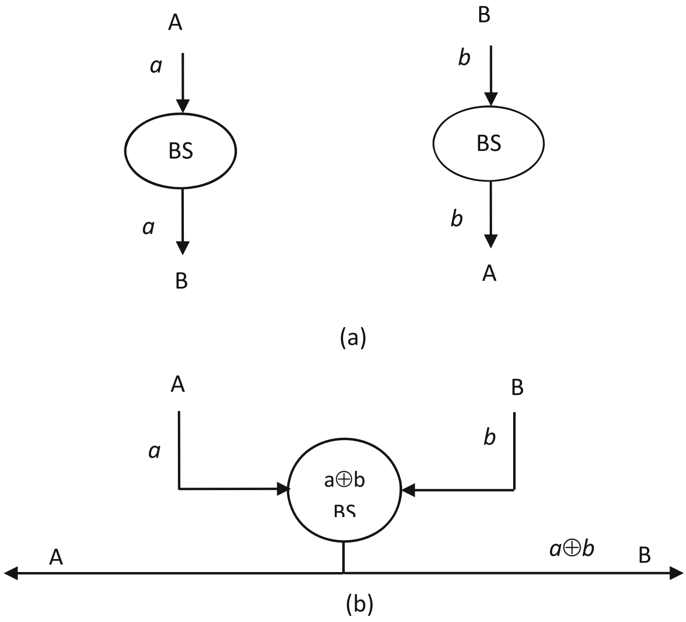


Fig. 19.1 (**a**) Base station without applying Network Coding, (**b**) Base station with applying NC

bitstreams that saves the consumption power, and improves the diversity and the communication traffic.

In wireless communication networks, NC usually implemented with another technique called Co-operation, resulting in Co-operative Network Code (CoNC) technique. When two users or more help each other to deliver the data to the destination, we can say that these nodes are in co-operation mode, in the other side, when the co-operation based on combining data, it becomes CoNC [1–5], as shown in Fig. 19.2 below:

If not receiving all bitstreams at the destination in the first transmission stage, the second stage follows, which is the stage where the co-operation with or without NC is applied.

When co-operation performed in a neighbor node with combining the bitstreams, the resulted system called CoNC, as shown in Fig. 19.2. In such a case, each client relays the received neighbor's bitstreams after combining its packet to the received ones. However, if the neighbor just retransmits the received bitstreams without combination, the system is called only a co-operative (co-operative but not network coded).

Based on Fig. 19.2, the destination, in this case will be receiving the transmitted bit streams in an uncombined from in the first stage at the first time slot. The redirected bitstreams received to enable the destination to receive the wanted bitstreams correctly, which is transmitted in the second time slot.

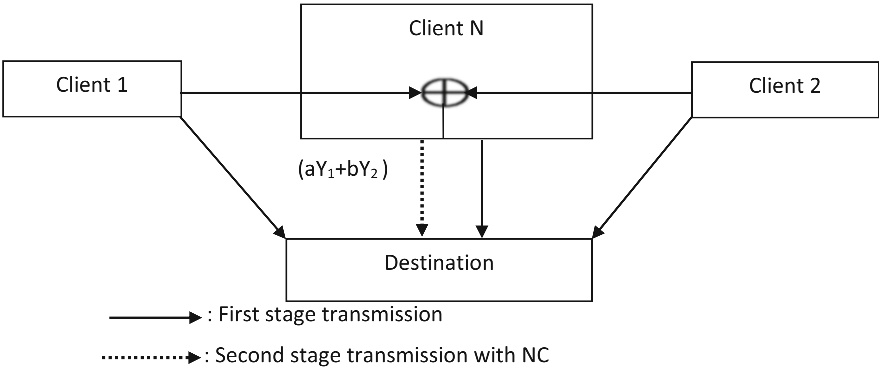


Fig. 19.2 Two stages of communications

Accordingly, CoNC improves wireless communication significantly by decreasing the consumed power, improving the directivity, and improving the network traffic. Indeed, the good advantages of the CoNC enable this technique to be such practical solution that could suit the required specific application designs needed for the healthcare systems, such as the healthcare applications that may suffer from shortage in transmission power or high-speed mobility in the case of ambulances [19].

19.1.2 Equalization for OFDM, DFrFT, DFrFT-MCM, and DFrFT-OCDM

OFDM has been recently considered as an excellent technique to implement in fast mobile communication scenarios with rapid time and Frequency fading channel variations (doubly selective channel) [20–23]. Examples for Flash-OFDM, ambulances wireless communication systems, and mobile reception of Digital Video Broadcasting-Terrestrial (DVB-T). In these channel scenarios, the DFT cannot diagonalize the channel matrix anymore, and Inter-Carrier Interference (ICI) appears.

The effect of the substantial ICI produced from significant Doppler shifts could be mitigated by implementing the pulse shaping technique [24]. To minimize the remaining effect of ICI, several researches proposed methods that are based on complex equalization for various frequency-domains, which includes Minimum Mean-Square Error (MMSE) schemes, and Zero-Forcing (ZF) [25, 26]. Complicated equalizers use the inverse of the estimated channel matrix to mitigate the channel effect, which is a very computationally expensive process related directly to the number of subcarriers. Multimedia services that adapt OFDM as a physical layer for its communication systems always use many subcarriers. For example, DVB-T subcarriers can reach up to 8000 subcarriers,

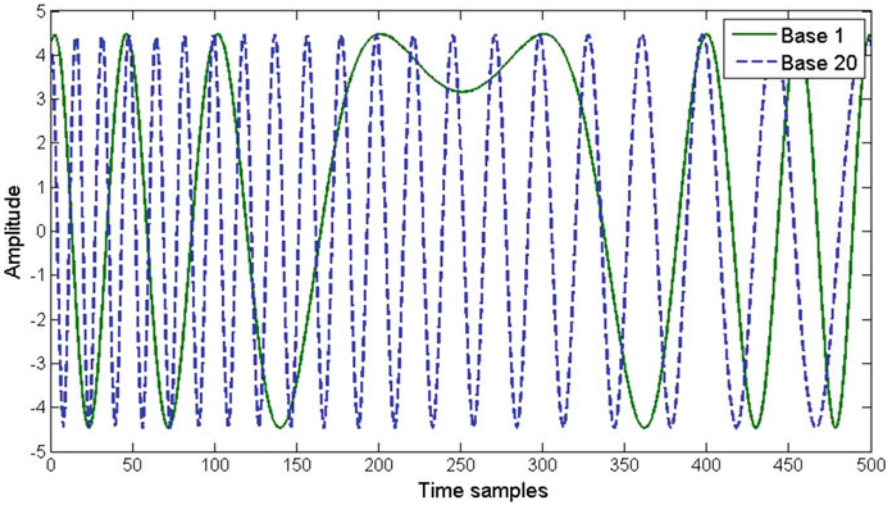


Fig. 19.3 1st and 20th basis signals of DFrFT-OCDM when $\alpha = 0.7$ (source: Attar et al. [12])

and DVB-T the second generation can reach up to 32,000 subcarriers. Hence, there is a great demand for low complexity equalizers. Based on [27–30], the complexity of equalizers decreased when exploiting advantages of the frequency-domain channel matrix (approximate) band structure.

The research work in 1929 [31] introduced FrFT as a generalization idea of the Fourier transform. Later on, Namias reintroduced FrFT in a mathematic form for applications in quantum mechanics in 1980 [32]. In [33–36], several researches reinvented the Discrete Fractional Fourier Transform (DFrFT) transformation. Later, in [31, 37–40], the complexity of the equalizer representation discussed, resulted in improving complexity representations, applications, and computational cost for the DFrFT. Now DFrFT implemented in various applications, such as quantum optics, optical diffraction theory, optical beam propagation [34, 37, 41], signal recovery, detectors, encryption and compression, correlation, convolution, pattern recognition, beamforming speech processing, digital watermarking, multiplexing, tomography, blind source separation and energy localization problems, high-resolution trigonometric interpolation, and securing information in digital holography [40–44].

In DFrFT-MCM systems, the subcarriers are orthogonal chirp signals represented in a block transfer system, which is the reason to name it as DFrFT-Orthogonal Chirp Division Multiplexing DFrFT-OCDM. Figure 19.3 illustrates DFrFT-OCDM two bases systems, where in Fig. 19.4, revealed the DFrFT-OCDM Spectral Energy Distribution (SED) for the first and the 20th basis signals.

Moreover, Fig. 19.3 shows the properties of DFrFT time and frequency domain winger distribution for the signals with the 1st and the 20th basis, when α set at 0.7; indeed, the frequency varies with the time for DFrFT transformation.

OFDM System Implementation on actual Digital Signal Processing (DSP) board is emplaned as an example for the usual hardware implementations, where the

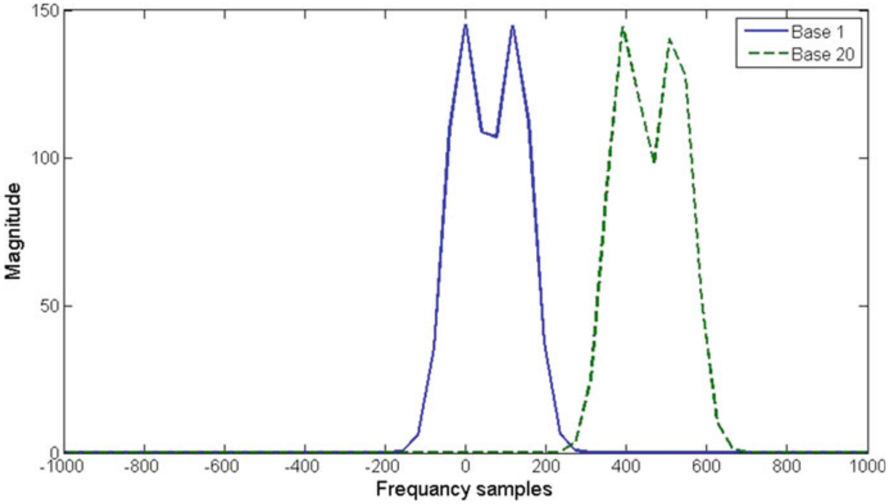


Fig. 19.4 1st and the 20th basis signals SED for DFrFT-OCDM (source: Attar et al. [12])

fundamental building blocks of an OFDM Modem designed and implemented. The functionality of the modem verified with the real system using the TI C6713 DSK board. Consequently, the required hardware is two PCs and two Texas Instruments C6713 DSP boards, where the required software is MATLAB R2007a and Code Composer Studio 6713 DSK V3.1.

19.1.2.1 Communication Channel Equalization

In single carrier modulation systems, the estimation of the transmitted signal with the minimum number of errors is the receiver's responsibility, which has to be performed effectively and with the minimum computation cost. The primary source for errors on the receiver side is channel distortion, which requires implementing effective equalizers to recompense channel distortion.

The aim of equalization is to compensate channel effect to renovate the correct shape (undistorted) of the signal [45, 46]. Filters acknowledged as a simple and basic method (equalization) to recompense frequency selectivity of radio channel fully, which achieved by selecting the proper impulse response for the receiver filter that accomplishes with Eq. (19.1) below:

$$\boldsymbol{W} \bigotimes h = 1 \tag{19.1}$$

where the equalizer and the channel impulse responses are $\boldsymbol{W}$and h respectively.

The equalizer based on Eq. (19.1) is named ZF equalizer and widely investigated in [45–47] that showed that the ZF equalizers are able to recompense for the radio channel frequency selectivity fully, resulting in removing the full suppression of the

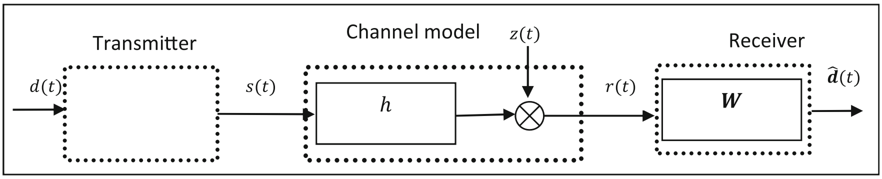


Fig. 19.5 An example of time-domain linear equalizer (source: Attar et al. [12])

related signal corruption, such as the equalizer shown in Fig. 19.5, taking into consideration that ZF equalizers badly increase the level of the noise as a result of amplification the noise signals through the filtering processes, which for sure decreases the performance of the system.

Based on above, the trade-off between the improvement in signal corruption and the related produced noise is regarded as the main equalization design factor. A proper trade-off achieved by selecting a filter that manages to minimize the Mean-Square Error (MSE) denoted by ε, between the transmitted signal and the equalizer output, which is shown in Eq. (19.2):

$$\varepsilon = E\left\{ \left| \widehat{d}(t) - d(t) \right|^2 \right\} \tag{19.2}$$

where the actual transmitted signal is $d(t)$, and the estimated signal is$\widehat{d}(t)$.

The equalizer that satisfies Eq. (19.2) is called as a Minimum Mean-Square Error (MMSE) equalizer.

The time equalization complexity is regarded as inefficient when implemented in frequency fading channels, mainly for single carrier modulation systems; consequently, the OFDM systems are introduced to solve this problem because they provide an instant solution by implementing a single tap equalizer in the frequency domain. However, OFDM is confirmed to be unable to match up with the doubly dispersive channels, resulting in implementing DFrFT and DFrFT-OCDM instead, because of their superior performances; however they require complicated equalizers to compensate the effects of channels.

Accordingly, implementing proper equalizers in healthcare applications requires a practical and simple equalizer design, which is regarded as a key factor to improve the PL healthcare communication.

So, if it is desired to obtain a practical and efficient healthcare PL communication system, it is important to decrease the communication consumed power, and come up with simplified equalizer to mitigate the effect of the high-speed mobility when existed, such as in ambulances, so, both Co-NC and simplified equalization techniques are needed.

19.1.3 Wireless Multimedia Service Mechanism of IFO, PQ, CQ, FQ, and WFQ Algorithms

The queuing algorithms of the bitstreams over the PL are considered important when choosing the proper queuing algorithm for the proposed healthcare applications. Accordingly, in this chapter, the First-In First-Out (FIFO), Priority Queue (PQ), Custom Queue (CQ), Fair Queuing (FQ), and Weighted Fair Queuing (WFQ) algorithms discussed to propose the proper queuing algorithm recommended for the healthcare application [18, 19], based on the most significant communication parameters such as, packet loss probability, average time delay, and the jitter time.

FIFO queuing algorithm regarded as the most basic and straightforward algorithm; it simply allows the bit streams on the PL to process according to the 'first come, first served,' which means that all the received bitstreams have the same priority, i.e., no bitstream has a better priority over others.

In the medical healthcare application, it is not wise to consider that all the data have the same priority. Accordingly, FIFO queuing algorithm rarely recommended for healthcare wireless communication.

The PQ algorithm gives different levels of priority for the received bitstreams on the PL; accordingly, the better priority bitstream is processed quicker and given better transmission power. As a result, the better packet loss probability dedicated to the bitstreams that are given higher level of priority, resulting in more minor time delay, and better jitter.

The improvement achieved in the higher priority streams is, in fact, resulted in decreasing the performance of the low-priority bitstreams, such as higher loss probability, longer delay time, and worse jitter.

In the algorithm of CQ, a certain weight dedicated for each queue, where the queuing weight calculated based on the bitstreams' size, i. e., the bigger the bit stream, the heavier the weight, taking into consideration that the queue weight average found by dividing the queue weight over the bitstreams' average size. Consequently, CQ is recommended in identical size of bitstreams, and when the bitstreams' size is known in advance.

The FQ is typically recommended for resource-constrained networks mainly to avoid large bitstreams from overwhelming the throughput or CPU time, on the cost of other bitstreams, i.e., it is an algorithm implemented to reach the equity in sharing of the network resources. In [48], it is shown that FQ has the lowest bitstreams' loss probability among all other queuing algorithms, which makes FQ to be highly recommended for healthcare applications that require a high multimedia traffic compatibility mechanism.

In WFQ, the flow is provided by a certain fraction of capacity, which is the reason that WFQ regarded as an extension to FQ. In [49], the results of all type of services provided, which showed that WFQ prevents any parameter to exceed the already set boundary conditions.

Many techniques recently applied to improve the healthcare services, such as in [48], where a home-base rehabilitation sensing system evaluated based on standardized clinical tests. In [49], the stroke self-rehabilitation techniques usage contributing factors investigated. Artificial Intelligence (AI) introduced for home-based rehabilitation explained in [50]. A specific application technique to develop the edge processing solution for vessel monitoring suggested in [51]. Similarly, various work recently presented in [48–50, 52–57], considering that the recent healthcare researches mainly directed to improve the applications that tend to facilitate self-care and far distance home-communications, of curse at the highest safety conditions.

The rest of the chapter organized as follows: Sec. II explains a practical CoNC to decrease the transmission power. Sec. III presents a simplified equalizer recommended to be applied in mobile health care systems. Sec. IV explains the queuing algorithm to know how to choose the proper queuing for the current applications. Finally, Sec. V and Sec. VI illustrate the results and conclude the chapter, respectively.

19.2 Co-Operative Network Coding in Healthcare Services

One of the most critical parameters in healthcare applications is power consumption, mainly when the communication carried out in power limited systems, such as ambulances or mobile hospitals; so, for these particular applications, CoNC proposed to support such communication systems.

19.2.1 Network Coded Amplify-Forward, and Decode- Forward Schemes

The proposed schemes for healthcare applications based on applying NC over the PL in a deterministic manner, before broadcasting the combined y_i bitstreams to the BS. Indeed, if N clients co-operate with using NC, this results in improving the data rate, and increasing the network reliability.

Conventionally, exchanging information between N clients through a BS needs a total of $N(N-1)$ separate DL conductions when no broadcast mode existing, or N conductions when the broadcast mode existed through a BS that connects all clients. Taking into consideration that a BS can "handles" multiple streams by applying either data mixing methods (such as NC), or time-sharing [58]. The suggested CoNC implements the two methods by first combining y_i for a certain number of bitstreams, where y_i is the code word (x_i) received at the BS, which is the code word with UL channel noise. The resulted in combined bitstreams then broadcast in a separate time slot for each combined bitstream. The proposed combination for healthcare applications is simplified to be at the BS as follows:

$$y_1 + y_2, y_2 + y_3, \ldots, y_{(N-1)} + y_N$$

When CoNC applied on Amplify and Forward (*AFp*) system, the resulted in combined bitstream received at the BS (after passing the UL channel) at the j^{th} time slot is:

$$\widehat{y}_j = A_{AFp}\left(x_i + z_i^{UL} + x_{i+1} + z_{i+1}^{UL}\right) + z_j^{DL}, \quad i = 1, \ldots, N-1, \ j = 1, \qquad (19.3)$$

where z_i^{UL} is the Additive White Gaussian Noise (AWGN)resulted from the noise through the UL transmission from the i^{th} client, z_j^{DL} DL is the AWGN resulted from the noise through the DL transmission at the j^{th} time slot, and $A_{AFp} \geq 1$ is the gain assigned by the BS before forwarding the combined bitstreams of i and i + 1.

As shown in Eq. (19.3), the BS broadcasts the sum of the first two y_is in the first time slots. Consequently, each client must receive the same number of the $N - 1$ combined bitstreams for recovering all partners' bitstreams. Moreover, the capacity for the AF_P scheme in the suggested system shown in Eq. (19.4), where C_{AFpi} is the same for all i.

$$C_{AFpi} = \frac{1}{2}\log\left(1 + \frac{A_{AFb}^2 P_i}{2A_{AFb}^2 + 1}\right) \qquad (19.4)$$

Equation 19.4 shows that the channel capacity decreases significantly as a result from combining two noisy bitstreams. To improve the channel capacity, Decode-Re-encode Amplify and Forward scheme (DF_p) proposed, where an encoder implemented before the modulation, resulting in Eq. (19.4). Taking into consideration that $A_{DFp} \geq 1$ is the gain. The proposed forward error detection and correction code is the Partial Unit Memory Turbo Code (PUMTC). The reason PUMTC suggested is that PUMTC is less complicated than the usual Turbo Code, and it consumes less processing time and power [7–9].

Moreover, the capacity of DF_p almost equals to the capacity of DF_b (when NC not applied), simply because the added noise through the UL channel is removed by the decoding and re-encoding process. Accordingly, only $N - 1$ DL transmitted bitstreams are needed instead of N ones, as shown in Eq. (19.5):

$$\widehat{y}_{(i,i+1)_{DFp}} = A_{DFp}(\widehat{x}_i + \widehat{x}_{i+1}) + z_j^{DL}, \quad i = 1, \ldots, N-1, \ j = i. \qquad (19.5)$$

Though saving one bitstream in the transmission seems to be insignificant, mainly when increasing the clients' number, but the effect of the saved bitstream is essential for a small number of clients, which is expected in special design applications for healthcare wireless networks.

Figure 19.6a, b illustrate an example of $N = 4$ as a suggested AF_p and DF_p example.

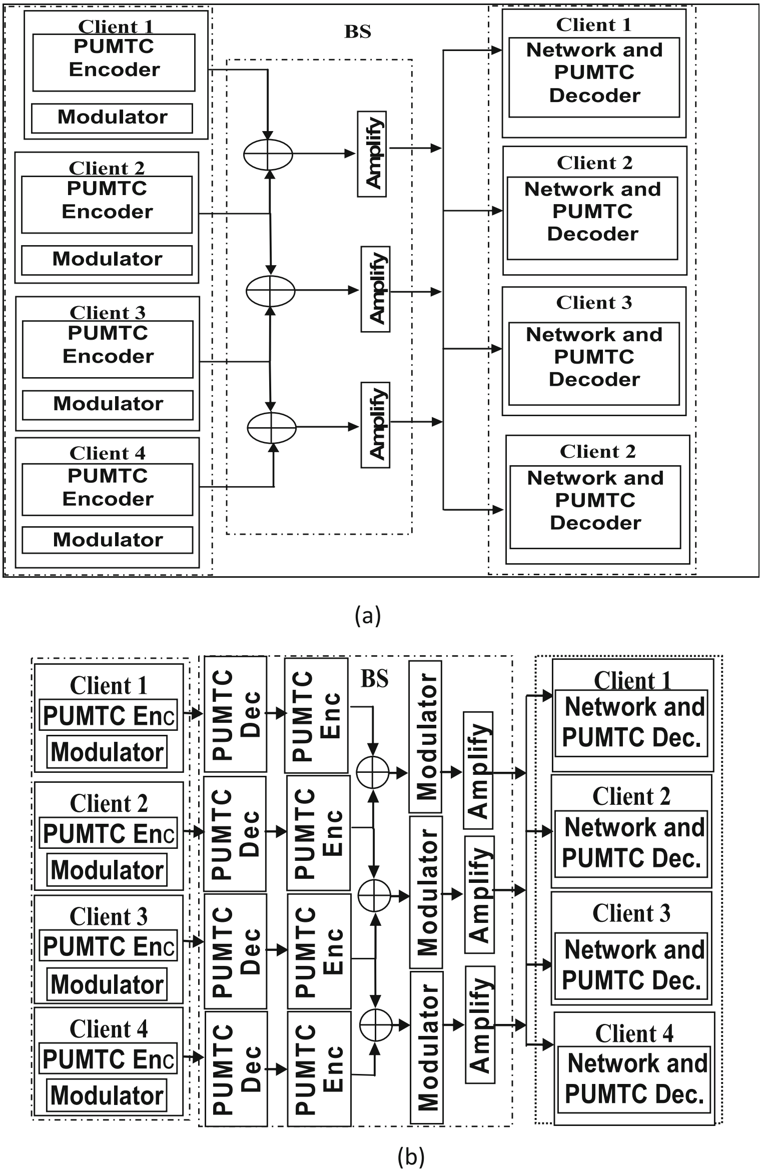


Fig. 19.6 An example of four client connected via a BS, where the BS applies AF_p(**a**), DF_p(**b**) relaying strategies (source: Attar et al. [3])

Figure 19.6 shows that less transmitted bitstreams needed, which saves the transmission power.

Moreover, it is important to notice that when decode and re-encode performed in the BS, the channel capacity will not change because eliminating the noise through the decoding process.

19.2.2 Message Recovery for the Proposed Schemes

At the end of the BS transmission, each client i intentions to retrieve all other neighbors bitstreams $\widehat{x}_k$, where $k = 1,2,\ldots,N$ and $k \neq i$. Indeed, each client can retrieve the entire bitstreams when correctly decode the received combined bitstreams, which broadcasted by the BS, as shown in Eqs. 19.6 and 19.7 for AF_p and DF_p systems, respectively.

When considering that each receiver knows its original bitstream, i.e., client i knows x_i, accordingly, the client i starts the processing from the known bitstream (x_i) with the co-operation with the $N - 1$ received network coded bitstreams, as in Eq. (19.6) for AF_P and Eq. (19.7) for DF_P, respectively.

$$\begin{aligned} x'_K &= A_{AFp}\left(x_i + z_i^{UL} + x_{i+1} + z_{i+1}^{UL}\right) + z_J^{DL} - A_{AFp}x_i \\ &= A_{AFp}x_{i+1} = A_{AFp}\left(z_i^{UL} + z_{i+1}^{DL}\right) + z_j^{DL}, \end{aligned} \tag{19.6}$$

$$x'_k = A_{DFp}(\widehat{x}_i + \widehat{x}_{i+1}) + z^{DL} - A_{DFp}x_i \tag{19.7}$$

The processes starts by 'subtracting' the receiver's bitstreams from the upper ($k = i + 1$) and lower ($k = i - 1$) combined bitstreams simultaneously.

For AF_p, the subtraction results in a noisy recovered bitstream because of the noise aggregation resulted from the UL AWGN. To remove the accumulated noise, DF_p tends to decode and then re-encode the bitstreams before starting the retrieving processes. Moreover, in the DF_P, the receiver just needs to XOR its bitstreams with the upper and lower combined packets, resulting in retrieving them as shown in the Gauss-Jordan Elimination (GJE) steps in Fig. 19.7a, where Fig.19.7b shows the decoding process steps.

Based on Fig. 19.7a, each row of the GJE matrix has only two pivots (just two combined bitstreams); and the processing starts from the receiver's raw, unlike the usual GJE where the processes starts from first pivot at the first top row.

The example for retrieving all received bitstreams at the third client shows that the retrieving process performed simultaneously. Moreover, it is important to notice that the third clients knows its bitstreams (x_3), hence its pivot set to zero in the GJE processing matrix (Fig. 19.7a).

The retrieving steps at client k can be explained by Eq. (19.8) for AF_p and Eq. (19.9) for DF_P, where A_p refers to the gain A_{AFp} or A_{DFp}, for AF_P or DF_P, respectively.

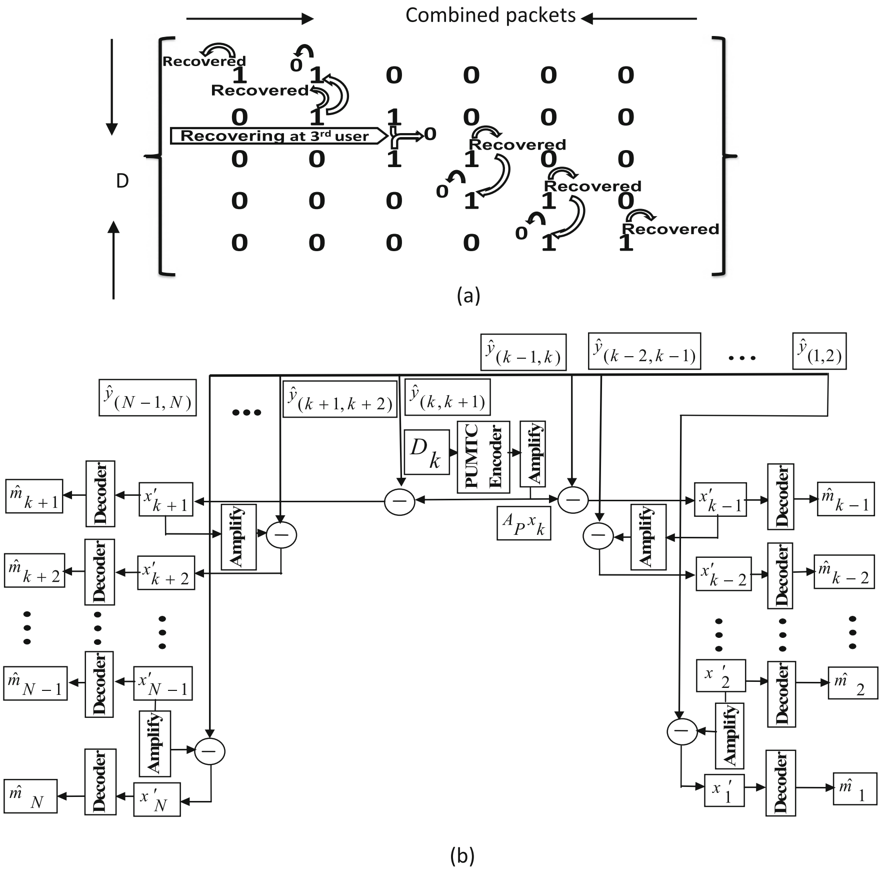


Fig. 19.7 (**a**) GJE steps to retrieve 6 bit streams from the received five combined ones as an example, at the third node. (**b**) Network decoding processes (source: Attar et al. [12]).

$$x'_{k+i} = \widehat{y}_{k+i-1,k+i} - A_p x'_{k+i-1}, \tag{19.8}$$

Where

$$x'_{k-i} = \widehat{y}_{k-i,k-i+1} - A_p x'_{k-i+1} \tag{19.9}$$

According to Fig. 19.7a, b, and Eqs. 19.8 and 19.9, the retrieving steps increase according to the number of connected clients, resulting in higher error probability and longer processing time.

To reduce the number of processing steps, the BS can broadcast more combined bitstreams C_T, as recommended in Eqs. 19.10 and 19.11 for AF_p and DF_p, respectively.

$$C_{T(k,k+i+1)} = A_{DFp}(\widehat{x}_k + \widehat{x}_{k+i+1}), \quad i = 1, 2, \ldots, N - K - 1, \tag{19.10}$$

$$C_{T(k,k-i-1)} = A_{DFp}(\widehat{x}_k + \widehat{x}_{k-i-1}), \quad i = 1, 2, \ldots, N - K - 2. \tag{19.11}$$

To make Eqs. 19.10 and 19.11 clearer, assume that the clients one and four aim to exchange the data in the example of four clients shown in Fig. 19.6; in such scenario, each client needs to retrieve x_4 and x_1, respectively.

According to Eqs. 19.10 or 19.11, the client one needs to retrieve x_2' and x_3' to extract thee data of client four x_4', ending up with three processing steps, and it is the same number of processing steps when client four aims to retrieve the information of client one (x_1'). So, as the error aggregates when more processing steps needed, the retrieved bitstreams (x_1' or x_4') is expected to be noisy (mainly when AF_p is implemented at the BS), resulting in worse BER for $\widehat{m}_1$ and $\widehat{m}_4$, where $\widehat{m}_1$ and $\widehat{m}_4$ are the retrieved data (correctly decoded) for client one at client four, and client four at client one, respectively.

Based on above, sending an extra combined bitstream, such as $C_{T(1,4)}$makes both clients one and four exchange the information without the need to retrieve both x_2' and x_3' at client one first. Moreover, the extra transmitted combined bitstreams C_T improves the ARQ significantly as well. The saved ARQ resulted from using Co-NC is shown in Ref. [3].

19.3 Efficient and Simplified Equalizer Proposed for Healthcare Applications

The OFDM system data flow $\boldsymbol{x}_n = [x_0, x_1 \ldots x_{N_a-1}]^T$ presented in Fig. 19.8, where n^{th} is the vector of the data transmitted in OFDM symbol, and T is the time sampling period. The OFDM samples permuted in the frequency domain by the binary matrix $\boldsymbol{P} \in \mathbb{Z}^{N \times N_a}$, where $\boldsymbol{P}$ is the permutation matrix, resulting in assigning the data vector $\boldsymbol{x}_n \in \mathbb{C}^{N_a}$ to N subcarriers, with N_a actives as shown in Eq. (19.12):

$$\boldsymbol{P} = \left[0_{N_a \times (N-N_a)/2} \boldsymbol{I}_{N_a} 0_{N_a \times (N-N_a)/2}\right] \tag{19.12}$$

where $0_{N_a \times (N-N_a)/2}$ is an $N_a \times (N - N_a)/2$ matrix withzero entries, and $\boldsymbol{I}_{N_a}$is the identity matrix that has the dimension of $N_a \times N_a$.

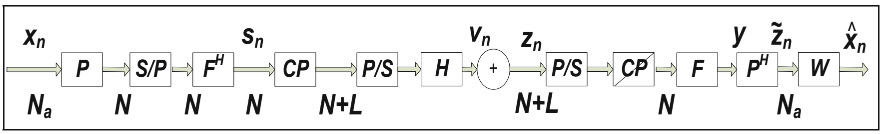


Fig. 19.8 The Block Diagram that shows the data flow of OFDM (source: Attar et al. [12])

The transmitted vector in the n^{th} OFDM symbol $\boldsymbol{s}_n = [s_0 s_1 \ldots . . s_N]^T$, found from Eq. (19.13)

$$\boldsymbol{s}_n = \boldsymbol{F}^H \boldsymbol{P} \boldsymbol{x}_n \tag{19.13}$$

where $\boldsymbol{F}^H$ is matrix's N-point IDFT, and H is the doubly dispersive channel convolution matrix.

In [20, 21, 59], the justification of demonstrating the frequency and time fading channels by time-variant discrete impulse response $h(n, u)$ presented with more detail, where n and u are the time instant and time delay, respectively.

Consequently, the formula of the convolutional matrix for the double dispersive channel (time-variant, or circular) given by Eq. (19.14):

$$[H]_{n,u} := h\left(n, \langle n-u \rangle_N\right) \tag{19.14}$$

In the case when the maximum delay spread N_h and causal channel CP was shorter than the time index $L(\text{CP}N_h \le L)$, and with supposing of eliminating the CP, the received symbol of the n^{th} OFDM determined by Eq. 19.15:

$$\boldsymbol{z}_n = \boldsymbol{H}_n \boldsymbol{x}_n + \boldsymbol{v}_n \tag{19.15}$$

where $\boldsymbol{z}_n$is the AWGN in the time domain, and $\mathbf{v}_n$ are the samples of the AWGN when the variance equals σ^2.

In static setting, $\boldsymbol{H}_n$ becomes circulant, when decoupling the DFT matrix, consequently, the subcarriers that received after the DFT demodulation $\boldsymbol{y}$ shown in Eq. (19.16):

$$\boldsymbol{y} = \boldsymbol{F} \boldsymbol{z}_n \tag{19.16}$$

where $\boldsymbol{F}$ refers to the DFT matrix.

On the other hand, the equalizer matrix $\boldsymbol{W}_n \in \mathbb{C}^{N_a \times N_a}$ applied over the input shown in Eq. (19.17):

$$\widetilde{\boldsymbol{z}}_n = \boldsymbol{P}^H \boldsymbol{F} \boldsymbol{H}_n \boldsymbol{F} \boldsymbol{b}^H \boldsymbol{P} \boldsymbol{x}_n + \boldsymbol{P}^H \boldsymbol{F} \boldsymbol{v} = \boldsymbol{U}_n \boldsymbol{x}_n + \widetilde{\boldsymbol{v}}_n \tag{19.17}$$

where $\widetilde{\boldsymbol{z}}_n$ and $\widetilde{\boldsymbol{v}}_n$ represented in the frequency domain, with a system matrix of $\boldsymbol{U}_\text{n} \in \mathbb{C}^{\text{N}_\text{a} \times \text{N}_\text{a}}$, where $\boldsymbol{U}_n = \boldsymbol{P}^H \boldsymbol{F} \boldsymbol{H}_n \boldsymbol{F}^H \boldsymbol{P}$.

To remove upper and lower corner components that may appear in U_n, the binary matrix $\boldsymbol{P}$ applied according to [60], besides reducing the emissions of the out-of-band.

Based on above, the data vector estimation specifications resulted from the applied equalizer shown in Eqs. 19.18 and 19.19:

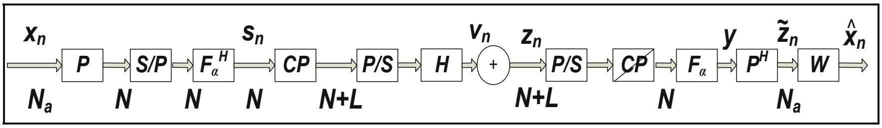


Fig. 19.9 The Block Diagram that shows the data flow of DFrFT-OCDM (source: Attar et al. [12])

$$\widehat{\boldsymbol{x}}_n = \boldsymbol{W}\widetilde{\boldsymbol{z}}_n \tag{19.18}$$

$$\left[\widetilde{H}\right]_{m,k} = \widetilde{h}(m-k,k), \tag{19.19}$$

where $\widetilde{h}(m,k) = \frac{1}{N}\sum_{n=0}^{N-1}\sum_{u=0}^{N-1} h(n,u)e^{-j2\pi(uk+mn)/N}$

Equation 19.19 shows that $\left\{\widetilde{h}(0,\ :)\right\}$ is on the main diagonal of $\left[\widetilde{H}\right]_{m,k}$, where $\left\{\widetilde{h}(1,\ :)\right\}$ is on the first sub-diagonal, and $\left\{\widetilde{h}(-1,\ :)\right\}$ is on the first super-diagonal. Moreover $\widetilde{h}(m,k)$ regarded as the response of the frequency-domain for a subcarrier $k + m$ to the frequency-domain impulse centered at the subcarrier k, where k is the frequency index and m is the Doppler index.

Figure 19.9 illustrates the data flow diagram of the DFrFT-OCDM. Comparing Figs. 19.8 and 19.9, the difference from the OFDM system (Fig. 19.8) and DFrFT-OCDM (Fig. 19.9) becomes clear. Indeed, Fig. 19.9 shows that DFrFT-OCDM applies the Inverse Fractional Fourier Transform (IDFrFT) for the modulation, where the DFrFT applied for the demodulation. When assuming that the transmitter and the receiver apply matching sequences, and the data vector, the equalizer $\boldsymbol{W}_n \in \mathbb{C}^{N_a \times N_a}$ function plays the rule of estimating the transmitted data, as shown in Eq. (19.20), which is modified accordingly, to Eq. (19.20):

$$\widetilde{\boldsymbol{z}}_n = \boldsymbol{P}^H\boldsymbol{F}_\alpha\boldsymbol{H}_n\boldsymbol{F}_{-\alpha}\boldsymbol{P}\boldsymbol{x}_n + \boldsymbol{P}^H\boldsymbol{F}_\alpha\boldsymbol{v} = \boldsymbol{U}_{n,\alpha}\boldsymbol{x}_n + \widetilde{\boldsymbol{v}}_n \tag{19.20}$$

where $\boldsymbol{F}_\alpha$ is the DFrFT matrix, $\boldsymbol{F}_{-\alpha}$ is the DFrFT matrix, and α is the fractional angel. Taking into consideration that the channel matrix $\widetilde{\boldsymbol{H}}_\alpha$ and the noise vector in the fractional domain $\widetilde{\boldsymbol{v}}$, determined by $\widetilde{\boldsymbol{H}}_\alpha = \boldsymbol{F}_\alpha\boldsymbol{H}\boldsymbol{F}_{-\alpha}$ and $\widetilde{\boldsymbol{v}} = \boldsymbol{F}_\alpha\boldsymbol{v}$, respectively.

As $\widetilde{\boldsymbol{H}}$ and $\widetilde{\boldsymbol{H}}_\alpha$ are non-diagonal subcarrier channel matrixes; consequently, ICI is then produced in the same manner of the doubly dispersive fading channel, resulting in complicating the equalizer mission to estimate the symbol.

19.3.1 Zero Forcing and MMSE Block Equalizers

According to Ref. [60], ZF and MMSE equalizers can estimate the transmitted data by minimizing $E\{\|\boldsymbol{x}_n - \boldsymbol{W}\widetilde{\boldsymbol{z}}_n\|\}$ as shown in Eqs. 19.21 and 19.22:

$$\widehat{\boldsymbol{x}}_{ZF} = \widetilde{\boldsymbol{H}}_{\alpha}^{+}\widetilde{z}_n = \widetilde{\boldsymbol{H}}_{\alpha}^{H}\left(\widetilde{\boldsymbol{H}}_{\alpha}\widetilde{\boldsymbol{H}}_{\alpha}^{H}\right)^{-1}\widetilde{z}_n \tag{19.21}$$

where γ is Signal-to-Noise Ratio (SNR), $\widetilde{\boldsymbol{H}}_{\alpha}$ is the fractional domain channel matrix, $\widehat{\boldsymbol{x}}_{ZF}$ is the estimated data using the ZF, $\widehat{\boldsymbol{x}}_{MMSE}$ is the MMSE equalizers respectively, and $\widetilde{\boldsymbol{H}}_{\alpha}^{+}$ is the fractional domain Moore-Penrose pseudo-inverse of the channel matrix introduced in Ref. [61].

$$\widehat{\boldsymbol{x}}_{MMSE} = \widetilde{\boldsymbol{H}}_{\alpha}^{H}\left(\widetilde{\boldsymbol{H}}_{\alpha}\widetilde{\boldsymbol{H}}_{\alpha}^{H} + \gamma^{-1}\boldsymbol{I}_{N_a}\right)^{-1}\widetilde{z}_n \tag{19.22}$$

when $\alpha = \pi/2$, $\widetilde{\boldsymbol{H}}_{\alpha}$ reduced to the frequency domain channel matrix $\widetilde{\boldsymbol{H}}$.

According to Eqs. 19.21 and 19.22, the channel estimation participates significantly to obtain all the needed channel matrix $\boldsymbol{H}_{\alpha}$ information, even without using the guard subcarriers by the equalizer. Furthermore, it is supposed that: $E\{\boldsymbol{x}_n\} = E\{\widetilde{\boldsymbol{v}}_n\} = 0, E\{\boldsymbol{x}_n\boldsymbol{x}_n^H\} = \boldsymbol{I}, E\{\boldsymbol{d}_n\widetilde{\boldsymbol{v}}_n^H\} = 0,$ and $E\{\widetilde{\boldsymbol{v}}_n\widetilde{\boldsymbol{v}}_n^H\} = \sigma^2\boldsymbol{I}$.

Finally, it is important to remind that the ZF equalizer escalations the noise, consequently; its performance regarded as poor when compared to the performance of the MMSE equalizer [62]. Though MMSE equalizer provides the best performance [62], but it is considered the most complicated one as a result of implementing the channel matrix inversion, which involves $O(N_a{}^3)$ complex processes [63]. As a result, implementing MMSE equalizer for a large value of N_a healthcare applications, such as DVB-T, DVB-H and WiMAX, regarded as unreasonable and impractical.

19.4 Wireless Multimedia Service Mechanism Recommended for Wireless Healthcare Network

The parameters that regarded as essential for medical healthcare, which adopted in this chapter to be the criteria of evaluation and comparison between the queuing algorithms are as following: the number of loss packets, the packet loss probability, the time average delay time, and the time of jitter.

Based on the above mentioned parameters, and for FIFO, PQ, CQ, FQ, and WFQ algorithms in service mapping, the traffic types that widely implemented in healthcare applications are evaluated and then compared, such as IPTV-Multicast, Video Conference, Video-on-Demand, Web Traffic, and IP-Telephony.

The evaluation and comparison can clearly show which queuing algorithm is most suitable for each healthcare traffic type, which is imperative to take into account when implementing the wireless healthcare system.

19.4.1 Methods and Modelling

In PL, the transmission and receiving information have different queuing algorithms, depending on the data size, data priority, communication channel types…etc. Moreover, each queuing algorithm has different behavior that results in different parameter's values.

To recommend a queuing algorithm for a particular healthcare application, the queuing algorithms should be evaluated and then their parameters compared. Consequently, an estimation parameter needed to play the rule of the overall comparison factor, besides comparing all parameters separately, so, the evaluating method followed in this paper is the integral criterion formula shown in Eq. (19.23) below, where the compared queuing algorithms are FIFO, PQ, CQ, FQ, and WFQ:

$$K_{Alg} = \frac{1}{m}\sum_i \frac{A_{p-i}}{A_i} \cdot k_i \tag{19.23}$$

where K_{Alg} is the algorithm quality parameter's enhancement estimation, $A_{p\text{-}i}$ is the initial value of quality for the i^{th} parameter, A_i is the i^{th} parameter's present value, k_i is the quality value of the i^{th} parameter importance coefficient, and m is the number of the compared parameters.

Based on Eq. (19.24), each parameter has its quality factor. The overall quality factor K_{Alg} is simply the summation of the quality factor for each parameter divided by the number of the adopted parameters m, taking into consideration that the evaluated parameters in this chapter are three (packet loss probability, delay time, and jitter), and the compared algorithms are FIFO, CQ, PQ, FQ, and WFQ.

The performed simulation results for the multi-service queuing algorithms based on the data priority proposed in [19].

Finally, it is considered that the packets amount, and the buffer size are crucial values when comparing the algorithms' parameters; consequently, the packet arrival intensity file for each algorithm assumed to be specified when setting the observation interval time, which is1S.

19.4.2 Evaluation Parameters

When the packet is confirmed to be handled, the processing algorithm then set and the parameters calculated accordingly.

Based on the best QoS presented in [19, 20], the packet loss probability shown below:

$$P_{\text{loss}} = \frac{1}{N}\sum\nolimits_{k} n_k \tag{19.24}$$

where P_{loss} is the packet loss probability, N is the number of the handled packets, and the n_k is the number of lost packets during the K-period.

The confirmed jitter parameter adopted in this chapter is the average jitters T_{ave} when N packets assumed to be received in various jitter times, where the jitter time T_i identified by the different amid the received packet's real time delay and its anticipated specific time delay. Eq. (19.25) shows the average jitter value T_j:

$$T_j = \frac{1}{N}\sum\nolimits_{i} |T_{ave} - T_i| \tag{19.25}$$

The delay time is the time form the packet arriving till it is completely processed, which depends on the packet length R_{pack} and the packet processing duration T_p, accordingly, it consists of several parts, starting from the waiting time in the buffer T_b for service, the time needed to process the packet, and the time the packet needs to inter the bus and leave it after completing the process, which is depends on the speed of interring and leaving the bus V_{bus}. Accordingly, to have a fair comparison, it assumed that all the above mentioned time delay parts are the same for all compared queuing algorithms. The service duration i. e., the total service duration T_S (delay time) is shown in Eq. (19.26):

$$T_S = T_b + 2\frac{R_{\text{pack}}}{V_{\text{bus}}} + T_p, \tag{19.26}$$

19.4.3 FIFO Algorithm Modelling

The outcome of the data flow for the FIFO algorithm is shown in Table 19.1. The collected results show that the packet loss for FIFO regarded as high. Accordingly, for crucial traffic types for healthcare applications, mainly when the high-quality resolution is essential, FIFO not recommended for the multi-services data flow, telephony, and video communication. Moreover, the jitter time and average delay considered as high as well. As a result, FIFO not recommended for real-time transmission healthcare applications.

The results shown in Table 19.1 agree with the results published in [5].

A critical observation from Table 19.1 is that all traffic types have almost the same parameters' values, which is regarded as a significant behavior for FIFO because it qualifies FIFO to be such an ideal Benchmark system to be compared with in this chapter.

Table 19.1 The FIFO QoS parameters for several traffic types

Traffic type	Jitter (ms)	Average delay value (ms)	Lost packets number	Packet losses, probability (%)
Video conference	0.07	0.567	5472	0.0264
IPTV-multicast	0.07	0.567	9401	0.0263
Web-traffic	0.07	0.567	12.107	0.0263
IP-telephony	0.07	0.567	1567	0.0262
Video-on-demand	0.07	0.567	7417	0.0263
Service data	0.07	0.567	558	0.0265
General flow	**0.07**	**0.56,702**	**36.524**	**0.0264**

Table 19.2 The PQ QoS parameters for several traffic types

Traffic type	Jitter (ms)	Average delay value (ms)	Lost packets number	Packet losses, probability (%)
Video conference	0.0105	0.162	2963	0.014489
IPTV-multicast	0.0210	0.343	122.721	0.261,248
Web-traffic	0.0258	0.523	236.128	0.34,577
IP-telephony	0.0075	0.255	0	0
Video-on-demand	0.0144	0.433	0	0
Service data	0.0009	0.084	0	0
General flow	**0.0120**	**0.386**	**361.812**	**0.211644**

19.4.4 PQ Algorithm Modelling

In PQ, a specific priority factor located for each data service through the queuing process; accordingly, the queuing time is inversely related to the priority, making the service with the highest priority to be processed first.

The collected results for PQ in this chapter based on four different queuing priorities as in [18]; accordingly, the highest priority packet will go first, resulting in four different waiting times (time delay).

For healthcare applications, it is agreed that video-conference and telephony regarded as the most essential applications; accordingly, the highest priority located for them in this chapter. The IPTV application is then given the average priority, where Web-traffic regarded as the lowest priority.

Table 19.2 shows the collected results for the traffic types with the different priorities. It is clear that the application with the higher priority has better packet loss probability, better jitter, and shortest delay times.

Table 19.3 The CQ QoS parameters for several traffic types

Traffic type	Jitter (ms)	Average delay value (ms)	Lost packets number	Probable packet losses (%)
Video conference	0.010	0.162	947	0.004677
IPTV-multicast	0.019	0.341	6990	0.019745
Web-traffic	0.025	0.520	5443	0.012036
IP-telephony	0.007	0.255	263	0.004499
Video-on-demand	0.014	0.431	0	0
Service data	0.001	0.084	0	0
General flow	**13.643**	**0.384**	**0.010022**	**0.011**

The significant released results in Table 19.2 show that PQ regarded as such practical algorithm for the healthcare applications, because healthcare services are not equally important, which justifies the reason for different priority levels.

Finally, It is essential to acknowledge that the enhancement of the packet loss probability and delay times for the highest priority are not for free; indeed, when linking FIFO and PQ outcomes (Tables 19.1 and 19.2), it is obvious that the less priority parameters become worse in PQ, i. e., the lowest priority services paid the price of improving the higher level priority services.

19.4.5 CQ Algorithm Modelling

The QoS in CQ algorithm based on locating the better packet loss probability for the smaller packet size, hence, service data, and video-on-demand assumed to have the non-loss of flows. Similarly, the packets with large size given the worse packet loss probability, hence IPTV-Multicast, and web-traffic have the worse packet loss probabilities.

19.4.6 FQ Algorithm Modelling

The algorithm of FQ in this chapter performed as in [45]. The collected results shown in Table 19.4 declare that FQ has the lowest packet losses for all flows; as a result, this algorithm highly recommended for healthcare applications. However, the jitter and delay times in FQ are around 15% worse than CQ. Moreover, the delay time for all traffic types very high, mainly for video conferences, and video-on-demand. Though the vast delay is, for sure, a severe limitation; in fact, this disadvantage has a significant practical benefit, which is protecting the network resources from unfair usage. Accordingly, the FQ algorithm recommended for healthcare, as

Table 19.4 The FQ QoS parameters for several traffic types

Traffic type	Jitter (ms)	Average delay value (ms)	Lost packets number	Probable packet losses (%)
Video conference	0.035	0.259	0	0
IPTV-multicast	0.054	0.391	0	0
Web-traffic	0.060	0.452	34	0.000,076,09
IP-telephony	0.039	0.111	0	0
Video-on-demand	0.080	0.515	0	0
Service data	0.054	0.060	0	0
General flow	**0.048**	**0.399**	**34**	**0.000025**

Table 19.5 The WFQ QoS parameters for several traffic types

Traffic type	Jitter (ms)	Average delay value (ms)	Lost packets number	Probable packet losses (%)
Video conference	0.0105	0.075	739	0.003653
IPTV-multicast	0.0225	0.131	1334	0.003,829
Web-traffic	0.0265	0.170	3161	0.007025
IP-telephony	0.0075	0.022	24	0.000,412
Video-on-demand	0.0146	0.101	0	0
Service data	0.0009	0.008	0	0
General flow	**0.0124**	**0.123**	**5258**	**0.003,886**

long as fair downloads and usage of the network resources required by the service providers.

Table 19.4 reveals a significant result that is the improvement in the probability of the packet losses is, in fact, at the cost of the average delay and the jitter.

19.4.7 WFQ Algorithm Modelling

WFQ simply divides the network capacity into specific fractions, resulting in controlling the network resources, and that is why WFQ regarded as a natural extension of the FQ.

The main advantage of the WFQ that all the traffic types' parameters considered as satisfied for all service shown in [46], unlike the FQ, where the delay time was beyond the limit.

Table 19.5 shows that the WFQ algorithm holds an intermediate position in term of QoS parameters, i. e., there is neither any parameter over performs the other

Table 19.6 Comparing the five investigated algorithms

	FIFO	PQ	CQ	FQ	WFQ
Number of lost packet	36.524	36.812	13.643	34	5258
Loss (%)	0.0264	0.213	0.01	0.000025	0.00389
Delay time (ms)	0.567	0.386	0.384	0.399	0.123
Jitter (ms)	0.0701	0.012	0.0114	0.048	0.0124

Table 19.7 The enhancement quality parameters value for the queuing algorithms

	K_{PQ}	K_{FQ}	K_{CQ}	K_{WFQ}
Losses (%)	0.12	1045.91	2.63	6.79
Delay (times)	1.46	1.42	1.47	4.62
Jitter (times)	5.85	1.46	6.15	5.68
Total (times)	**0.33**	**2.16**	**2.45**	**5.56**

queuing algorithms, nor any parameter regarded the worst. Consequently WFQ has an acceptable parameter's values, which is the reason makes this algorithm to be the widest applied one among the other algorithms. Consequently, the WFQ recommended for heavy public healthcare applications, where all traffic types are equally important, such as public hospitals.

Table 19.6 compares the five presented algorithms in term of the number of lost packets, loss percentage, delay time, and jitter:

19.4.8 Quality Parameter Comparison

Table 19.7 shows a comparison between the investigated queuing algorithms when taking each parameter separately, according to Eq. (19.23).

19.5 Simulation Results

In this part, the results for the PL techniques illustrated to show the impact of the proposed techniques on the BER over the PL.

19.5.1 Co-Network Coding Bit Error Rate

When combining more than one bitstreams, the aggregated noise resulted from the UL channel causes more noisy bitstreams.

When the combination (Co-NC) performed in AF BS, the resulted combined bitstreams become more and more noisy, in fact, results show that when combined a

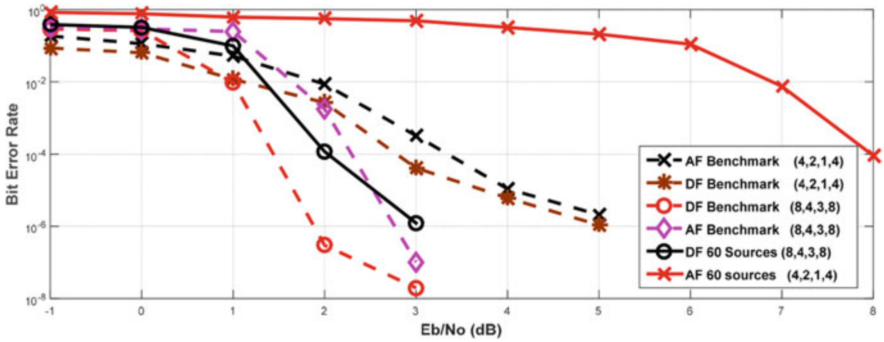


Fig. 19.10 BER for the AF_b and DF_b, AF_p, and DF_P systems based on (8,4,3,8) and (4,2,1,4) PUMTC for $N = 2$

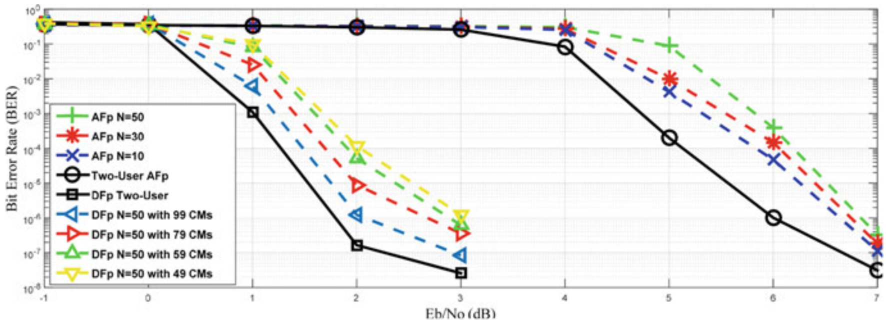


Fig. 19.11 AF_p and DF_p systems based on (8,4,3,8) PUMTC for $N = 10$, 30 and 50

large number of bitstreams, such as ten, the resulted combined bitstream become extremely noisy, which decrease the channel capacity C_{AFc} significantly, as shown in Eq. (19.27).

$$C_{AFc} = \frac{1}{2}\log\left(1 + \frac{AF_b^{P_i}}{(N-1)AF_b + 1}\right) \tag{19.27}$$

When the BS performs the decode-re-encode and amplification, the noise resulted from the UL channels will be eliminated resulting in making the total channel capacity for N combined bit stream equals the uncombined bit stream [64].

Figure 19.10 shows the BER for AF_b, AF_P, DF_b, and DF_P, i.e., with and without applying CoNC over two nodes for PUMTC (8,43,8), and PUMTC (4,2,1,4).

Figure 19.10 shows that applying the Co-NC resulted in a drop on the BER, however, when implementing DF_p, the BER becomes much less than AF_p, moreover, Fig. 19.10 shows that PUMTC (8,4,3,8) well out performs PUMTC (4,2,1,4), which agrees with the results in [65].

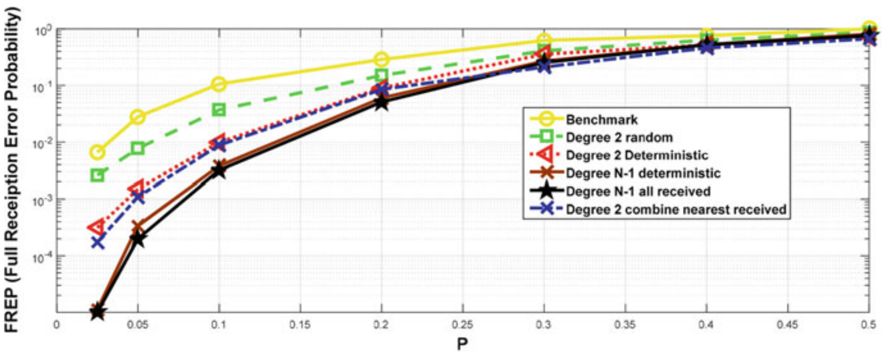


Fig. 19.12 The probability when full communication is not obtained for several combination strategies

Figure 19.12 exemplifies the consequence of changing the amount of nodes from 10 to 50 for AF_p and DF_p systems, and then compare the results with AF_b and DF_b systems to evaluate the loss in BER resulted from combining bitstreams. As anticipated, the BER performance regarded as satisfactory, mainly because the loss of BER for the PUMTC (8,4,3,8) code, is just around 0.2 dB for DF_p and 0.3 dB for AF_p, respectively. The minimum BER is justified by the strong behavior of the implemented PUMTC (8,4,3,8) [65].

The deteriorating in BER over the PL resulted from combining the bitstreams, has such excellent and significant impact on the PER (upper layers), as shown in Fig. 19.12 below:

Figure 19.12 shows that the probability for not retrieving the N combined bit streams, the figure shows that the PEP is improving when more bitstreams are combined; indeed, when the BS combines all the received bit streams, the probability of not retrieving all bit streams drops from around 3×10^{-2} to around 1×10^{-4}, which shows that the lost in BER compensated by improving the PER.

The reliability of the wireless communication systems and the gained benefits when use the Co-NC in hypred ring-mish network presented in [1], which shows how Co-NC can even work in very bad channels conditions.

19.5.2 Bit Error Rate for Equalization

The uncoded BER performance for the conventional OFDM and DFrFT-OCDM systems considered for the time-variant and invariant channels.

The investigated QPSK modulated OFDM system has: $L = 8$ (the number of a cyclic prefixes), $N = 128$ (the number of subcarriers), and $N_a = 96$ (number of active subcarriers). The channel under investigation is the Rayleigh fading channel, where the chosen Carrier Frequency ($F_C = 10$GH) is Ultra-High Frequency (UHF) because it is the frequency applied in most of healthcare applications, the channel exponential power delay profile and, a root-mean-square delay spread are assumed to be 3. The subcarrier spacing Δfassumed to be 20 kHz, which is usual value for mobile healthcare applications. The Doppler Frequency (f_d) is chosen for high speed, such as V = 324 Km/h, resulting inf_d=20 Hz. The number of the simulated bits is $10^5 * 96 * 4$ bits, which resulted from choosing a10^5 continuous channels and different OFDM symbols.

In time-invariant channels environment, f_d=0, OFDM applied equalizer is single tap, and the DFrFT-OCDM applied equalizer is MMSE.

The obtained results in [12] match the results in [66] that show that the BER of DFrFT-OCDM out performs OFDM system when single tap equalizer is applied, though implementing much less complicated equalizer. Consequently, OFDM is recommended to apply in healthcare application with single tap equalizer, even for such high-speed of 324 Km/h that makes the proposed equalizer to be well-recommended in ambulance medical communications.

In addition, the results in [12] show that the BER for DFrFT-OCDM with MMSE well out performs the conventional OFDM single tab equalzer.

In the time-variant channels environment, the f_d is no more equals to zero, so, according to the proposed healthcare applications, f_d assumed 0.15 ΔfHz.

On the other hand, the results in [12] confirm that the DFrFT-OCDM system again outperforms OFDM system when the same equalizer type and complexity implemented (same MMSE equalizer); consequently, the DFrFT-OCDM in time-invariant channels more recommended to be applied, which is unlike time-variant.

19.5.3 Traffic Services Queuing Parameters Results

The Tables 19.1 to 19.6 show that CQ and FQ enhance the service quality twice, where WFQ does so fivefold when compared to the FIFO.

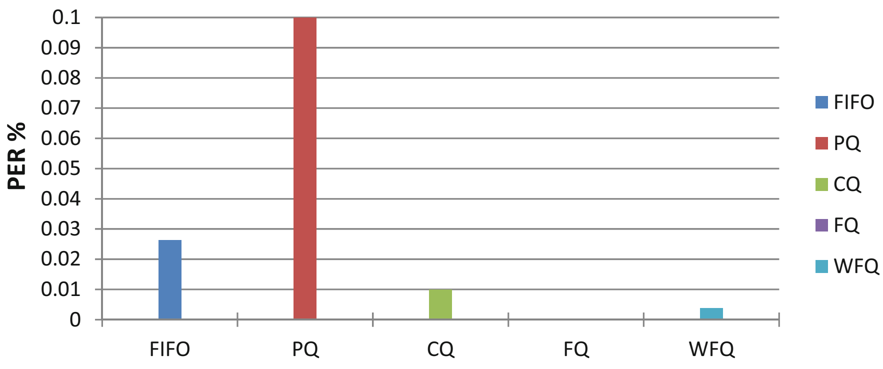


Fig. 19.13 The general flow of the packet losses probability for the corresponding service algorithm (source: Attar et al. [18])

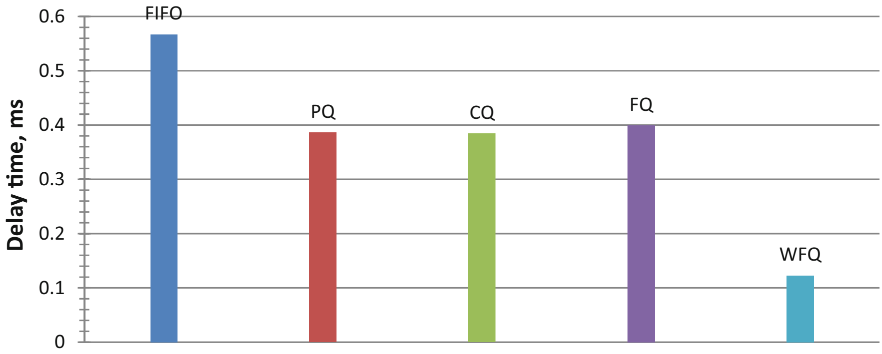


Fig. 19.14 The general flow of the average time for the corresponding service algorithm [18]

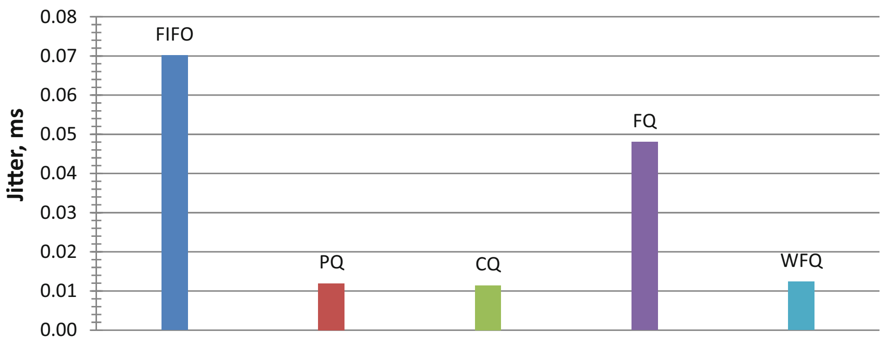


Fig. 19.15 The general flow of the average jitter value for the corresponding service algorithm (source: Attar et al. [18])

Figures 19.13, 19.14, and 19.15 show that the FQ over-performs the other algorithms in term of packet losses probability, where the WQF does so in term of the best delay time, on the other hand, the FQ is regarded as the worse in term of the jitter time.

19.6 Conclusion

In this chapter, three Physical Layer (PL) techniques proposed as valuable solutions for wireless healthcare applications.

Co-operative Network Coding (Co-NC) technique showed that better Packet Error Rate (PER) could be achieved when combining the bitstreams over the PL with an acceptable loss of BER, mainly for Decode-Re-encode-Forward (DF) Base Station (BS).

For high-speed mobile healthcare applications, such as ambulances, the proposed PL technique is a simpler equalizer (single tap equalizer) that gives competitive BER as MMME complicated equalizers.

Finally, the queuing algorithms for different traffic services investigated for several traffic parameters.

The investigated traffic services are the video-conference, IPTV multicast, Web-traffic, IP Telephony, and Video-on-demand, where the investigated parameters are the packet loss probability, the delay time, and the jitter time.

The Quality of Service (QoS) for the above-mentioned traffic services based on the mentioned parameters found for the queuing service data algorithms of FIFO, PQ, CQ, FQ, and WFQ algorithms.

The results declare that the FIFO algorithm has no acceptable parameter to be implemented in healthcare applications; however, the FIFO is adopted in this chapter as a Benchmark Scenario. Moreover, the WFQ algorithm proved to have the best average modeling outcomes; accordingly, the WFQ parameters are within the boundary conditions that makes it recommended to be applied in general healthcare systems, such as public hospitals or medical centers.

When healthcare application is implemented in high packet erasure probability, then the FQ is recommended as it has best behavior, where the PQ is the worst. However, FQ is regarded as the algorithm of the worst jitter time behavior.

Finally, WFQ is the algorithm with the less delay time that qualifies it to be the best algorithm for real-time healthcare applications.

The future work is directed to be implementing CoNC over the PL for big data in various fields of the health services such as forecasting COVID-19 [67], moreover, implementing the work presented in [1] over a full health system is under consideration.

19.7 Acknowledgments

The author of this chapter Dr. Hani Attar would like to thank Dr. Ahmad Amin, Istanbul Gelisim University, Turkeyor Dr. Ioannis vourganas from Abertay University, Dundee, UK, and Dr. Annalito Michala from Glasgow university, UK, for their well support in finishing this chapter; indeed their contribution was a key point in this work, and totally appreciated by the author.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Attar, H. H., Solyman, A. A. A., Alrosan, A., Chinmay, C., & Mohammad, R. K. (2021). Deterministic cooperative hybrid ring-mesh network coding for big data transmission over lossy channels in 5G networks. *EURASIP Journal on Wireless Communications and Networking, 2021*, 159. https://doi.org/10.1186/s13638-021-02032-z
2. Attar, H. H., Vukobratovic, D., Stankovic, L., & Stankovic, V. (2011). Performance analysis of node cooperation with network coding in wireless sensor networks. In *2011 4th IFIP International Conference on New Technologies, Mobility and Security, Paris* (pp. 1–4). IEEE. https://doi.org/10.1109/NTMS.2011.5721048
3. Attar, H., Stankovic, L., & Stankovic, V. (2012). Cooperative network-coding system for wireless sensor networks. *IET Communications, 6*(3), 344–352.
4. El-M, M., Attar, H., Solyman, A. A. A., & Stankovic, L. (2016). Network coding cooperation performance analysis in wireless network over a lossy channel, M users and a destination scenario. *Communications and Network, 8*, 257–280. https://doi.org/10.4236/cn.2016.84023
5. Nazir, S., Stankovic, V., Attar, H., Stankovic, L., & Cheng, S. (2013). Relay-assisted rateless layered multiple description video delivery. *IEEE Journal on Selected Areas in Communications, 31*(8), 1629–1637.
6. Attar, H., Stankovic, L., Alhihi, M., & Ameen, A. (2014). Deterministic network coding over long term evaluation advance communication system. In *Proceedings of 4th International Conference on Digital Information and Communication Technology and its Application (DICTAP)* (pp. 56–61). IEEE.
7. Attar, H. H., Solyman, A. A., Khosravi, M. R., Qi, L., Alhihi, M., & Tavallali, P. (2021). Bit and packet error rate evaluations for half-cycle stage cooperation on 6G wireless networks. *Physical Communication, 44*, 101249. https://doi.org/10.1016/j.phycom.2020.101249
8. Attar, H., Alhihi, M., Zhao, B., & Stankovic, L. (2018). Network coding hard and soft decision behavior over the physical payer using PUMTC. In *2018 International Conference on Advances in Computing and Communication Engineering (ICACCE), Paris* (pp. 471–474). IEEE. https://doi.org/10.1109/ICACCE.2018.8441742
9. Attar, H. (2016). Physical layer deterministic network coding using PUM turbo codes over AWGN channel, N nodes through a base station scenario. *Communications and Network, 8*, 241–256.
10. Attar, H. (2016). Peak-to-average power ratio performance analysis for orthogonal chirp division multiplexing multicarrier systems based on discrete fractional cosine transform. *International Journal of Communications, Network and System Sciences, 9*, 545–562. https://doi.org/10.4236/ijcns.2016.912043
11. Attar, H., & Solyman, A. (2017). A proposed orthogonal chirp division multiplexing (OCDM) multicarrier transceiver based on the discrete fractional cosine transform. *Journal of Computer and Communications, 5*, 34–47. https://doi.org/10.4236/jcc.2017.52005
12. Attar, H. H., Solyman, A. A. A., Mohamed, A. E. F., Khosravi, M. R., Menon, V. G., Bashir, A. K., & Tavallali, P. (2020). Efficient equalisers for OFDM and DFrFT-OCDM multicarrier

systems in mobile E-health video broadcasting with machine learning perspectives. *Physical Communication, 42*, 101173.
13. Solyman, A. A., Attar, H., Khosravi, M. R., & Koyuncu, B. (2020). MIMO-OFDM/OCDM low-complexity equalization under a doubly dispersive channel in wireless sensor networks. *International Journal of Distributed Sensor Networks, 16*(6), 1–16. https://doi.org/10.1177/1550147720912950
14. Solyman, A. A. A., et al. (2020). A low-complexity equalizer for video broadcasting in cyber-physical social systems through handheld mobile devices. *IEEE Access, 8*, 67591–67602. https://doi.org/10.1109/ACCESS.2020.2982001
15. Attar, H. (2017). Multipath routing mathematical model to solve the traffic engineering in multi-protocol label switching network. *Journal of Computer and Communications, 5*, 113–122.
16. Attar, H., Alhihi, M., Samour, M., Solyman, A. A. A., Igorovich, S. S., Georgievna, K. N., & Khalil, F. (2018). A mathematical model for managing the distribution of information fows for MPLS-TE networks under critical conditions. *Communications and Network, 10*, 31–42.
17. Alhihi, M., Khosravi, M., Attar, H., & Samour, M. (2017). Determining the optimum number of paths for realization of multi-path routing in MPLS-TE networks. *Telkomnika, 15*(4), 1701–1709. https://doi.org/10.12928/TELKOMNIKA.v15i4.6597
18. Attar, H., Khosravi, M. R., Igorovich, S. S., Georgievan, K. N., & Alhihi, M. (2020). Review and performance evaluation of FIFO, PQ, CQ, FQ, and WFQ algorithms in multimedia wireless sensor networks. *International Journal of Distributed Sensor Networks, 16*(6), 155014772091323. https://doi.org/10.1177/1550147720913233
19. Attar, H., Khosravi, M. R., Igorovich, S. S., Georgievan, K. N., & Alhihi, M. (2021). E-health communication system with multiservice data traffic evaluation based on a G/G/1 analysis method. *Current Signal Transduction Therapy, 16*(2), e050521179644. https://doi.org/10.2174/1574362415666200224094706
20. Xiaodong, C., & Giannakis, G. B. (2003). Bounding performance and suppressing intercarrier interference in wireless mobile OFDM. *Communications, IEEE Transactions on, 51*, 2047–2056.
21. Tiejun, W., et al. (2006). Performance degradation of OFDM systems due to Doppler spreading. *Wireless Communications, IEEE Transactions on, 5*, 1422–1432.
22. Das, S., & Schniter, P. (2007). Max-SINR ISI/ICI-shaping multicarrier communication over the doubly Dispersive Channel. *Signal Processing, IEEE Transactions on, 55*, 5782–5795.
23. Won Gi, J., et al. (1999). An equalization technique for orthogonal frequency-division multiplexing systems in time-variant multipath channels. *Communications, IEEE Transactions on, 47*, 27–32.
24. Rugini, L., & Banelli, P. (2007). Performance analysis of banded equalizers for OFDM systems in time-varying channels. In *Signal Processing Advances in Wireless Communications, 2007. SPAWC 2007. IEEE 8th Workshop on* (pp. 1–5). IEEE.
25. Solyman, A., & Wise, J. J. S. S. (2011). *"Low-complexity LSMR equalisation of FrFT-based multicarrier Systems in Doubly Dispersive Channels," presented at the ISSPIT 2011*. Bilbao.
26. Taubock, G., et al. (2007). LSQR-based ICI equalization for multicarrier communications in strongly dispersive and highly mobile environments. In *Signal Processing Advances in Wireless Communications, 2007. SPAWC 2007. IEEE 8th Workshop on* (pp. 1–5).
27. Luca Rugini, P. B., & Leus, G. (2006). Low-complexity banded equalizers for OFDM systems in doppler spread channels. *EURASIP Journal on Applied Signal Processing, 2006*, 67404. p. 13.
28. Rugini, L., et al. (2005). Simple equalization of time-varying channels for OFDM. *Communications Letters, IEEE, 9*, 619–621.
29. Saxena, R., & Singh, K. (2005). Fractional Fourier transform: A novel tool for signal processing. *Journal of Indian Institute of Science, 58*, 11–26.
30. Namias, V. (1980). The fractional order fourier transform and its application to quantum mechanics. *IMA Journal of Applied Mathematics, 25*, 241–265.

31. Almeida, L. B. (1994). The fractional Fourier transform and time-frequency representations. *Signal Processing, IEEE Transactions on, 42*, 3084–3091.
32. Ozaktas, H. M., & Mendlovic, D. (1993). Fourier transforms of fractional order and their optical interpretation. *Optics Communications, 101*, 163–169.
33. Mendlovic, D., & Ozaktas, H. M. (1993). Fractional Fourier transforms and their optical implementation: I. *Journal of the Optical Society of America A, 10*, 1875–1881.
34. Mendlovic, D., et al. (1996). Signal spatial-filtering using the localized fractional Fourier transform. *Optics Communications, 126*, 14–18.
35. Ozaktas, H. M., et al. (2001). *The fractional Fourier transform: With applications in optics and signal processing*. John Wiley & Sons Ltd.
36. Bultheel, A., & Martìnez Sulbaran, H. (2003). *A shattered survey of the fractional Fourier transform*. http://www.cs.kuleuven.be/_nalag/papers/ade/frft/index.html,
37. A. Bultheel and H. E. Sulbaran, "Computation of the fractional Fourier transform," Applied and Computational Harmonic Analysis, vol. 16, pp. 182–202, February 2004.
38. Yeung, D. S., et al. (2004). Complete way to fractionalize Fourier transform. *Optics Communications, 230*, 55–57.
39. Leith, E. (1972). Review of 'Systems and transforms with applications to optics'. *Information Theory, IEEE Transactions on, 18*, 451–452.
40. Shankar, S., & Srivastav, N. (2011). Power play: On the notion of fractional quantum Fourier transform. *Potentials, IEEE, 30*, 29–32.
41. Santhanam, B., & Hayat, M. (2011). On a pseudo-subspace framework for discrete fractional Fourier transform based chirp parameter estimation. In *Digital signal processing workshop and IEEE signal processing education workshop (DSP/SPE)* (Vol. 2011, pp. 360–363). IEEE.
42. Shi, R., et al. A novel SAR signal reconstruction method from non-uniform sampling associated with fractional Fourier transform. In *Measuring technology and mechatronics automation (ICMTMA), 2011 Third International Conference on 2011* (pp. 210–213). IEEE.
43. Jianjun, G., & Fulin, S. (2010). A new cross-range scaling algorithm based on FrFT. In *Signal Processing (ICSP), 2010 IEEE 10th International Conference on* (pp. 2043–2046). IEEE.
44. Xiaolong, C., & Jian, G. (2010). A fast FRFT based detection algorithm of multiple moving targets in sea clutter. In *Radar Conference, 2010* (pp. 402–406). IEEE.
45. Schmidt, D. P., & Rutland, C. J. (2000). A new droplet collision algorithm. *Journal of Computational Physics, 164*(1), 62–80.
46. Balogh, T., & Medvecky´ M. (2012). Average bandwidth allocation model of WFQ. *Modelling and Simulation in Engineering, 2012*, 301012.
47. RAPPAPORT. (1996). Wireless Communication Systems.
48. Vourganas, I., Stankovic, V., Stankovic, L., & Michala, A. L. (2020). Evaluation of home-based rehabilitation sensing systems with respect to standardised clinical tests. *Sensors, 20*, 26. https://doi.org/10.3390/s20010026
49. Vourganas, I., Stankovic, V., Stankovic, L., & Kerr, A. (2019). Factors that contribute to the use of stroke self-rehabilitation technologies: A review. *JMIR Biomedical Engineering, 4*, e13732. https://doi.org/10.2196/13732
50. Vourganas, I., Stankovic, V., & Stankovic, L. (2021). Individualised responsible artificial intelligence for home-based rehabilitation. *Sensors, 21*, 2. https://doi.org/10.3390/s21010002
51. Michala, A. L. (2018). *An edge processing solution development for vessel condition monitoring*. Ph.D., University of Strathclyde.
52. Michala, A. L., & Vourganas, I. (2017). A smart modular wireless system for condition monitoring data acquisition. In V. Bertram (Ed.), Hamburg, p. 14 p. Research output: Chapter in Book/Report/Conference proceeding › Conference contribution *Compit'17* (pp. 212–225). Volker Bertram.
53. Michala, A. L., Barltrop, N., Amirafshari, P., Lazakis, I., & Theotokatos, G. (2016). *An intelligent system for vessels structural reliability evaluation* (pp. 171–179). University of Strathclyde, GBR.

54. Dikis K, Lazakis I, Michala AL, Raptodimos Y, Theotokatos G (2016) Dynamic risk and reliability assessment for ship machinery decision making. In: Walls L, Revie M, Bedford T (eds). CRC/Taylor & Francis Group, GBR, pp. 685–692
55. Lazakis, I., Dikis, K., & Michala, A. L. (2016). *Condition monitoring for enhanced inspection, maintenance and decision making in ship operations*. Technical University of Denmark.
56. Michala, A. L., Lazakis, I., Theotokatos, G., & Varelas, T. (2016). *Wireless condition monitoring for ship applications* (pp. 59–66). The Royal Institution of Naval Architects.
57. Michala, A. L., Lazakis, I., & Theotokatos, G. (2015). *Predictive maintenance decision support system for enhanced energy efficiency of ship machinery* (pp. 195–205). International Conference on Shipping in Changing Climates. GBR.
58. Katti, S., Maric, I., Katabi, D., Goldsmith, A., & Medard, M. (2007). *Joint relaying and network coding in wireless networks*. Proceedings in IEEE ISIT.
59. Prasad, R. (2004). *Ofdm for wireless communications systems*. Artech House.
60. Russell, M., & Stuber, G. L. (1995). Interchannel interference analysis of OFDM in a mobile environment. In *Vehicular Technology Conference, 1995 IEEE 45th* (Vol. 2, pp. 820–824). IEEE.
61. Negash, B. G., & Nikookar, H. (2000). Wavelet-based multicarrier transmission over multipath wireless channels. *Electronics Letters, 36*, 1787–1788.
62. Darlington, S. (1970). On digital single-sideband modulators. *Circuit Theory, IEEE Transactions on, 17*, 409–414.
63. Negash, B. G., & Nikookar, H. (2001). Wavelet based OFDM for wireless channels. In *Vehicular Technology Conference, 2001. VTC 2001 Spring. IEEE VTS 53rd* (Vol. 1, pp. 688–691). IEEE.
64. Attar, H.. (2011). *Cooperative network coding for wireless networks*. Ph.D thesis, the University of Strathclyde, UK.
65. Nelson, C., & Fagoonee, L. (2007). EXIT charts for PUM woven turbo codes. In *2007 Fourth International Symposium on Wireless Communication Systems* (pp. 11–15). IEEE. https://doi.org/10.1109/ISWCS.2007.4392292
66. Rugini, L., Banelli, P., & Leus, G. (2005). Simple equalization of time-varying channels for OFDM. *IEEE Communications Letters, 9*(7), 619–621. https://doi.org/10.1109/LCOMM.2005.1461683
67. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). *BIFM: Big-data driven intelligent forecasting model for COVID-19* (pp. 1–13). IEEE Access. https://doi.org/10.1109/ACCESS.2021.3094658

Chapter 20
Emerging Paradigm of Smart Healthcare in the Management of COVID-19 Pandemic and Future Health Crisis

Soumik Gangopadhyay, Amitava Ukil, and Somnath Chatterjee

Abstract Remote patient oriented healthcare is an effort to ensure "Health for all". Smart health options such as e-Health, m-Health, Telemedicine is a by-product of policy implementation of health administration of nations with compromised health status as it functions at the intersections of 'health', 'healthcare' and 'health policy'. Effective implementation of such technique depends on availability of uninterrupted high speed network, access to affordable gadget, awareness of public and wishful thinking of the policy administrators. In consonance with sustainable development goals, many underdeveloped nations implemented telemedicine to reduce heath inequality among the residents. M-Health is a parallel option to manage scarce resource better. Cost, distance or time of travelling influence perceived importance of individuals to adopt telemedicine for self-treatment. In India it was initiated as a trial and error method to reduce the patient burden on public clinical establishments. Poor awareness and access are the major concerns of growth of e-health in India. But, during COVID-19 pandemic, embargo on free travel and nationwide lockdown to avoid infections, telemedicine became an option of treatment. Compulsion rather than choice has fuelled the necessity of telemedicine as a viable and trusted alternative of treatment. But Resurge in capacity development is possible only in case of ample support from the associated areas.

Keywords Smart healthcare · COVID-19 Pandemic · Value addition · Telemedicine · Tele-density · Remote location · Record · Report · Resurge · Replace · m-Health · e-Health · West Bengal · India

S. Gangopadhyay (✉)
Institute of Engineering and Management, Kolkata, India
e-mail: soumik.gangopadhyay@iemcal.com

A. Ukil
Eminent College of Management and Technology, Kolkata, India

S. Chatterjee
Aliah University, Kolkata, India

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_20

20.1 Introduction

Silent emergence, unwarranted therapeutic option and inestimable death have left no option other than 'lock down' to break the highly contagious infection chain of COVID-19 [1, 2]. Lock down is very effective to restrict the intensity of spread of the disease but has immense power to halt the growth of a nation. Significant economic changes as evidenced are compromised manufacturing of fast moving consumer goods, interruption in supply of convenience goods, loss of commercial value of corporates, inadequate cash flow due to restricted commercial activity in the market, steep fall in the growth of revenue [3]. Non-functioning of service sector, cancellation or postponement of formal outdoor sports, restriction in travel, disruption of services, cancellation of celebration of religious, festive and cultural rituals, burning stress among individuals, social distancing among people, embargo in entry of places for entertainment services such as the hospitality and tourism service delivery premises, postponement of offline classes at educational institutes are some of the major social changes as compelled by COVID pandemic [4]. Under such backdrop, perceived dissatisfaction of individuals has shifted from the issues of growth mind-set to self-existence or sustenance. Even during COVID-19 pandemic, students developed Post Traumatic Stress Disorder [5]. Global corona virus death toll crosses record number every day and shows zero signs to stop. To control the abrupt increase in cases of COVID-19, tertiary care facility, infrastructure and behavioural changes are the existing options to increase morbidity and reduce mortality [6]. Moreover, uncontrolled escalation in number of COVID-19 victims has already created a mismatch between current provision of available occupancy and skilled care demand. In the war against Novel Corona virus, few outcome of healthcare are wrong diagnosis, home quarantine & treatment of suspected or victims; challenges of the delivery of the existing clinical service; halt in health service delivery to non COVID-19 patients; unpredictable overload on medical and Para-medical professionals; high health risk of medical professionals; overloading of pharmacies; disruption of supply chain of medical products [7]. Therefore, a radical change of healthcare service was imminent.

The organization of this chapter is as follows. After the introductory part, the concept of smart healthcare is discussed in the second section. The third section deals with the discussion on era before COVID-19 (BC). In the fourth section, the healthcare scenario of West Bengal is presented. The smart healthcare in management of COVID-19 pandemic is analyzed in the fifth section of the chapter. The concluding remarks have been presented in the sixth section.

20.2 Concept of Smart Healthcare

Accessibility and affordability are the two important pillars of effective healthcare. On the face of change, such necessities are more felt during COVID-19 pandemic. In support of diversity, inclusion and equality new methods were adopted by health administration of several nations. It opens a new platform for future policy making to assess the disease based or need based healthcare facilities [8]. Smart health options such as e-Health, m-Health, and telemedicine are innovative policy implementation of health administration of nations with compromised health status as it functions at the intersections of health planning and healthcare delivery [9]. Over the last two decade, hospital and health service sector has passed through a paradigm of revolution. Shifting trend in pattern of diseases dominance has impacted the pattern of management of healthcare. Modern hospitals function as a wellness centre rather than a hub of medical treatment. The concept of a clinical establishment now explores as health restoration centres, home care services, day care centres, healing centres and night hospitals. Research has revealed the comparative escalation in information seeking behavior among current patients regarding facility, process, treatment, staff care, doctors, diseases, and the status of health crisis from clinical establishments during emergency [10]. Individuals are interested to receive information from authentic sources [11]. With the easy access of internet based knowledge, patients are increasingly mining diseases and health related information [12]. Pew Internet report June, 2012 has also revealed the sustained dominance of information seekers (66%) using the internet to research on specific diseases or medical problems compared to 56% users who searched for doctors or related health professionals whereas, 36% enquired regarding hospitals or other medical facilities.

Partial shift from manpower to machine power can help to cope up with the rapid pace of change. Machines are more commit-mental than human being as it does not have emotion that makes them comparatively consistence. In such a scenario, dependency on technology-based system and devices becomes relatively more reliable, cost effective and a progressive step for healthcare institutions [13]. The considerable progress in the computing domain leads to the appearance of ‘Internet of Things’ which is now considered as a vital ICT (information, communication, technology) as it has profound power to unite devices like cameras, robots, smart thermostats etc. used for monitoring the health status of patients. The efficiency of health data collected through these smart objects is indispensable and essential to develop the domain of health during current pandemic to achieve expected care of patients [14]. These smart IOTs are being proved as a tool of hope to manage the propagation of the COVID virus by allowing a contemporary access to healthcare service in real time turns it valuable for the clinical and paramedical personnel and patient [15]. Technological innovation in the part of IoT expertise, the smart home mechanization, healthcare arrangement and contact-based visits to the healthcare institution are presently considered as non-obligatory. At this point, SMHCS (Smart home Healthcare Support) and HAC (Hyperspace Analogue to Context) systems are anticipated for ‘monitoring patient‘s health condition and getting doctor’s advice

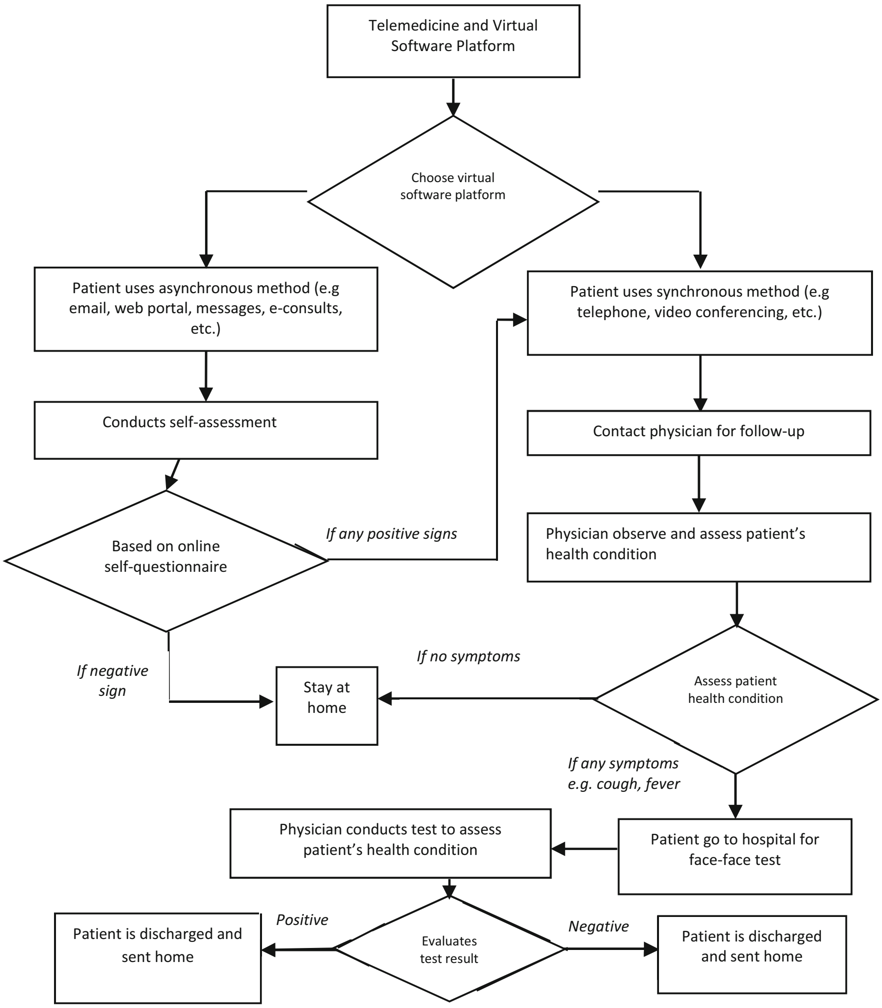


Fig. 20.1 Flow chart of application of telemedicine

while being at home and also towards precise data of the physiological variables and enhanced system functionality (Fig. 20.1).

Doctors can also remotely accomplish the analysis of illness by means of the data composed from the concerned patients. A modern mobile phone, configured with Android application interacts with a virtual platform (web backed) is executed for proficient real-time patients-doctors interface [16]. Thus, a mobile phone based automated remotely driven system were appreciated during COVID-19 treatment [17]. Identical health crisis is sure to arrive in future and dependency on human capital may not be guaranteed (Fig. 20.2).

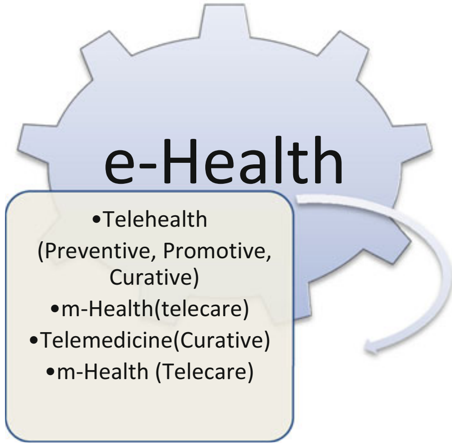


Fig. 20.2 Pattern of e-Health platforms

Telemedicine as an option of treatment to provide home treatment as initiated by the national administration through a state governed centralized centre was a successful model of management [18]. It gives an option of faster data processing, easy access to information, effective remote operation [19]. Since the outbreak of this pandemic, introduction of 'AROGYA SETU', a made in India APP was a path breaking step to control such a mammoth problem in India. Current health crisis prevailing with the arrival of COVID-19 was massively benefitted as evidence from data [20]. Outdoor treatment of both COVID and non-COVID were primarily shifted to online mode by many health providers. Home quarantine and people with comorbidity availed the facilities as a compulsive option, but not as a choice. Thus, monitoring and surveillance becomes easy through sustenance and nurturing the creation for target area and situation in respect to health crisis. Virtual, augmented reality & robotics will consolidate health system more resilient for future [13]. But, it is necessary to examine whether it is complementary or a substitute from the consumer point of view. This can be a strategy to attain better national health.

20.2.1 Transformation of Indian Healthcare Service

Healthcare service market of India is estimated to reach US$372 billion by the end of 2022 with a major share of private players through out of pocket (OOP) payments [21, 22]. With the evolution of mobile, internet, analytics and cloud based system, an easy access to technology and data is no more a dream and rather a hard reality [23]. Integrating health information system with the help of technology is an effective step to upgrade the state of health [24]. In consonance with sustainable development goals, many underdeveloped nations implemented telemedicine to reduce heath inequality among the residents. m-Health is a parallel option to manage scarce resource better [25]. Cost, distance or time of travelling influence perceived value (utility and ease of handling) of individuals to adopt telemedicine for self -treatment [26]. In India, it was initiated as a trial and error method to reduce the patient burden on public clinical establishments [20]. Effective implementation of such technique depends on availability of uninterrupted high speed network, access to affordable gadget, awareness of public and wishful thinking of the policy administrators [27]. Indian healthcare industry has considered paperless prescription with the introduction of digital health in early 2005. In 2015, with the objective of digital maintenance of health records and information, the department of Health and Family Welfare, Government of India developed National e-Health Authority (NeHA) [20]. Since its formation, NeHA functioned to create a centralized e-Health platform which is affordable, efficient and accessible to every Indian. NeHA engaged in health capacity enhancement and spread health awareness in collaboration with other stakeholders of health sector. Digital Information Security in Healthcare Act (DISHA) is a brainchild of such effort enabled India to enact on privacy, security and confidentiality of digital information to utilize data of patients securely in programmes [20]. COVID-19 has restricted the free movement of Indian residents due to lockdown or quarantine, but treatment cannot wait. Due to maximum exploitation of offline treatment, poor access to desired healthcare and capacity constraints of hospitals, telemedicine was chosen as an alternative by Indians. To arrest the progress of COVID-19, introduction of telemedicine was a quick fix strategy adopted by many nations. Telemedicine provides remote access to healthcare facilities i.e. Tele-consultation, Tele-counselling for clinical diagnosis and treatment of a patient by a doctor [28]. Telemedicine market of the globe is estimated to touch US$171.81 bn. by 2026 with a CAGR of 37.2% [29]. Global telemedicine market has been segmented (a) based on type of Product: Tele-hospital, Tele-home, (b) Based on Component- health products, health services, (c) Based on Application- Tele-counselling, (d) Based on Technology- real time, (e) Based on model of Delivery Model: mobile/web, call centres and (f) Based on End-user - Providers, Payers, Patients, Others [30]. Global players include companies like SANOFI, MERK & CO., INC., ROMVAC Company S.A., HESTER BIOSCIENCES LIMITED, INDOVAX among many [30].

20.2.2 Smart healthcare in West Bengal

Telemedicine facilitates virtual interaction between health service provider and patients through software, email or internet [31]. Teleconferencing initiatives to serve remote patients with best health consultancy started long back in the year 1996 by the Health administration of West Bengal. Since 2001, the School of Tropical Medicine (STM), Kolkata is the telemedicine referral centre, whereas, ‘Siliguri district hospital’ (SDH) and ‘Bankura Sammilani Hospital’ (BSMCH) functions as nodal centres. Many effective partnership with BSMCH & SDH; Asia Heart Foundation & RTIICS-Kolkata, the state health hospitals have successfully handled diagnosis and treatment of life threatening critical clinical cases for the rural patients [32]. The successive telemedicine referral centres Burdwan Medical College and NRS Medical College, Kolkata along with four nodal centres namely, Midnapore (west), Suri, Behrampur and Purulia district hospitals were implemented by WEBEL in 2004. The project used 512 kbps leased line and West Bengal State Wide Area Net Work (2 Mbps fibre optic link) for mutual networking [33]. More hospitals were also covered under the telemedicine facilities gradually.

Health Management Information System (HMIS) was implemented in the year 2008 as part of National Rural Health Mission (NHRM). It records health related activities and information at the level of primary, secondary health services for effective public health outcome. Information, Communication and Technologies (ICT) has been widely used in healthcare sector. Some technology based techniques used currently include electronic health record, hospital information system, picture archiving and communication system, digital imaging and bar coding etc. West Bengal Electronics Industry Development Corporation Ltd. (WEBEL) is working in this area as a state nodal agency and they have rolled out the optic fibre network as part of National Optic Fibre Network (NOFN) project till the Gram Panchayat level (rural West Bengal) with huge bandwidth and network for better telemedicine and Tele-health. Thus, the network between medical institutions is equipped for better e-health service of the state. These options were working as a hospital to hospital connectivity through POTS & ISDN. Such outcome fetched few national and international recognition for the state government namely “National e-Governance Award-2004”, “Outstanding Performance in Service Delivery”, ‘Skoch Challenger Award-2005’, Manthan – American India Foundation Award, 2006 under “e-Health” Category [32].

Department of Computer Science & Engineering of IIT-Kharagpur have launched ‘iMedix’, software based telemedicine system on 2nd October, 2020. It integrates home-care with healthcare services and facilitates support to patients for critical health issues at their door steps through remote consultation by a physician. Only basic internet browser and mobile device are required to avail such services. The home quarantine or aged patients can consult as per their choice or, upload necessary medical record; fix an appointment with the doctor through email or SMS or video conference. A pilot model was tested at ‘Swasthya Bhawan’ (State Health Administrative Building), Govt. of West Bengal on trial basis prior to roll out.

20.2.3 Role of e-Health during COVID-19

Telemedicine offers limitless possibilities. COVID-19 induced unpredictable increasing rate of infection, abnormal mortality rate has turned daily routine of human life into a pause. During the fight against COVID-19, the victims and the healthcare providers have developed a stigma and social discrimination that is an important obstruction of treating such communicable diseases [34]. Some Indian states such as Assam, Bihar, Chhattisgarh, Orissa, Madhya Pradesh with poor average health infrastructure facilities (lowest number of beds, doctors etc.) were more vulnerable to COVID-19 pandemic. Neogi et al. [7] observed that even with a less than average Global Health Security Score (46.5), India has given an encouraging fight against Corona virus as compared to many developed nations. Telemedicine emerged to explore the scale and reach of healthcare services during COVID-19 pandemic [35]. Globally, patients have opted virtual appointment to avoid health risk [36]. To pace with the situation, West Bengal health administration initiated teleconferencing facilities for the COVID-19 patients officially from 1st July 2020.

During this pandemic situation non COVID-19 patients prefer to stay away from COVID-19 patients. Therefore, few private tertiary care hospitals have initiated helpline number for long-distance patient counselling service. Many doctors started using Whatsapp or email for receiving the pathological test report from their patients for their follow up during private consultation. In search of safety, non COVID patients used the virtual platforms like helpline, email, Whatsapp, Skype Call etc. to discuss their physical problem with the doctors for treatment. Tele-consulting has accelerated more than ten times in USA during the COVID pandemic [37].

20.3 Era Before COVID-19 (BC)

India has successfully reduced the maternal mortality ratio (MMR) by 77% between 1990 and 2015 (Ministry of Health and Family Affair, Govt. of India). Before COVID-19 pandemic, National country profile 2019 accounts 53% of all Indian deaths were claimed due to Non communicable diseases. Before COVID-19 pandemic, the share of diseases is largely dominated by communicable diseases, maternal problems, neonatal complications, and nutritional deficiency diseases which have escalated from 30% to 55% within a span of 10 years [38]. The variance in disease dominance among Indian states ranged between 48–75% for non-communicable diseases, 14–43% for infectious and allied diseases; and 9–14% due to injuries. These problems have resulted in steep fall of Disability-adjusted life years (DALYs) to 33% in 2010 as compared to 61% in 1990 [39].

Between 1995 and 2004, a sharp rise in footfall of outpatient consultations (8%) and a vastly elevated (13%) hospitalization rates caused by Non-communicable diseases related tertiary care. This has led to a catastrophic increase in out-of-pocket expenditure that directly adds to impoverishment among urban Indians [40]. A few other by-product outcomes of Non-communicable diseases are escalated ALS (average length of hospital stay) and a 5–10% additional burden on GDP that have multiplied the potential threat to national economy and jeopardized the very fundamental basis of sustainable health [41]. Moreover, the magnitude of significant loss in disability adjusted life years (DALYs), among the segment of under-70 aged Indians, is comparatively higher than developing countries. This argues the necessity of a robust intervention based Non-communicable diseases related Indian health policy [42]. So, the Indian community has been compelled to pause and ponder on this current, burgeoning health crisis.

Moreover, in the battle against Non-communicable diseases, circumstances leave zero options for the individual other than to pay for costly tertiary healthcare, without any predictable guarantee of cure. As a result, the horrifying—and often long term—ramifications of Non-communicable diseases has fuelled the mushrooming of innumerable tertiary private health care establishments in tier I and tier II Indian cities. This, in turn, is propelling the growing commercial value of Indian healthcare industry. Ischemic heart diseases (IHD), Chronic Obstructive Pulmonary Diseases (COPD) and stroke are becoming enduring concerns to be immediately taken care of to mitigate their leading, increasing contribution to the Indian death toll [43]. A Calcutta (Kolkata) based Indian study has revealed an increasing interest among patients to prevent or treat Non-communicable diseases (Lifestyle related diseases) as they are beginning to perceive these as a threat to their physical existence and well-being [44]. Moreover, the overcrowded and out-dated infrastructure of the government tertiary clinical establishment, blended with the accompanying stench of an unhealthy environment, gives goose bumps [45].

Currently, West Bengal has 110/lakh and 475/lakh mortality rate respectively for communicable and non-communicable diseases. All India average for the same is 192 and 455/lakh population. Age standardised mortality rate is also higher than all India average [43].

In essence, even the improved emotional responses to Non-communicable diseases, combined with the latest medical technology currently available and accessible in private tertiary care have failed to effectively combat this deadly trend. So, private hospitals seem to have a pivotal role to play in the mediation and / or moderation of the individual psyche and to persuade the average person to adopt a healthy lifestyle to prevent Non-communicable diseases (primordial / primary / secondary / tertiary prevention) as a justifiable change / step – from the perspective of the patients. But, epidemiological transitions across the states have fuelled the mushroom growth of tertiary care hospitals and West Bengal has majorly evidenced it.

20.4 Healthcare of West Bengal

West Bengal is the residents of more than nine crores people (population density of 904/square km) among which 72% is staying at rural areas. 24.7% of the state population represent below poverty line (Indian national average is 27.5%). The state is marching with some other states of India at the bottom of the health development list. In India, it has been found that there is a significant association between the access of public healthcare and the financing of health Infrastructure. Healthcare financing is an influential associate of the access to healthcare of the population. So, a supply driven move towards the healthcare services by means of financing of healthcare infrastructural development is accepted to concentrate on the difficulties of outreaching healthcare services to the population. West Bengal is considered at the lower-middle categories in this analytics [46]. A financially crippled population of West Bengal accessing dilapidated health structure by compulsion, not by choice. Surveys of NFHS 1 and 2 have indicated two reasons for that i.e. lack of infrastructure or facility and non-utilization of available health services. Apart from these, social factors like living conditions, privileges, obligations and cultural traditions are also being identified as the influencer of health risk [47]. Although the infant mortality rate, child death rate, maternal mortality rate of West Bengal are showing a lower trend as compared to India's average but, still holistic development of health of the state population is yet to be achieved. Moreover, due to poor public health facilities, healthcare of the state is increasingly being dominated by private service providers which are fundamentally based on mounted trust of people on their corresponding success of treatment. According to IHDS 2005, untrained private providers, pharmacies and Dais (trained lady worker for delivery of rural mothers) are the most reliable source of primary and secondary care in West Bengal. Only 2% of sub-centres and 80% PHCs open daily as compared to 80% and 97% of rest of India. As observed by NCAER, 16% of short term illness required hospitalization with a 6.3 days average length of stay (ALS) whereas, 25% of long term illnesses required ALS of 13.3 days of hospitalization. Observations through NHFS and IHDS data survey confirmed that 14% respondents of West Bengal (18% rest of India) blames monetary constraints as the prime reason of not seeking care for short term illness, 3% blames the accessibility of health service and 80% opines that treatment is not necessary. For both the cases, 12% residents didn't seek treatment even during sickness. However, residents of Bengal are relatively least interested to seek treatment during their sickness with respect to rest of India. Even for a long term sickness 60% Bengalis blames their financial obligation as a prime cause of their reluctance of treatment and 40% thinks that treatment is not necessary. But, urban Bengal is 40–50% more likely to seek care during their sickness compared to rural Bengal. Interestingly, 69% dwellers of Bengal would like to seek treatment for long term illness in private facilities and only 9% trust public facilities. Further, a higher percentage of West Bengal are inclined to receive treatment from informal private sources such as "traditional healers" and 97% of those belong to rural Bengal. A majority of urban Bengal expressed their dependence on self-treatment through pharmacies [48]. Curative 'health-seeking behaviour' is often driven by 'perceived ill health' [48]. Labour and migratory workers staying at urban slums and high income group of urban areas of West Bengal have higher probability of getting hospitalized. Moreover, compromised education and poor affordability drives the poor towards public healthcare premises of west Bengal [49]. In West Bengal, it is experienced that patient's financial prominence, status of education and conditional factors of decision have significant impact on the preference to access of healthcare services [50]. In rural West Bengal, due to poor accessibility of doctors, quack doctors ('self-practitioners') with limited knowledge of science treat people and offer affordable treatment to people. Thus they run a parallel option of healthcare [51]. Other reasons of poor 'health-seeking behaviour' among the residents of this state province of India pertains to media exposure of the subject, cultural belief, decisional dominance of the head of the family, social structure, cultural belief [52]. Overcrowding is the fundamental problem of Indian

Table 20.1 West Bengal Health on the March 2016–17 & 2017–18 as on 31.12.2018

Type of Medical Institution	Number	Total no. of beds
Medical College Hospital	17	18,703
Other Teaching Hospitals	6	2366
District Hospital	18	8526
Multi / Super Speciality Hospitals	42	13,800
Sub divisional Hospital	36	7840
State General Hospital	24	2778
Other Hospitals (Leprosy, Mental, Dental, etc.)	34	7232
SNCU (established at different hospitals)	70	2523
SNSU (established at different hospitals)	307	680
CCU (established at different hospitals)	37	572
HDU (established at different hospitals)	21	126
PICU (at 12 MCH & Teaching Hospitals)	–	208
MCH Hubs (at 9 Hospitals including MCH & Teaching Hospital)	–	2250
Rural Hospitals	273	9596
Block Primary Health Centre	75	1470
Primary Health Centre	913	7191
Sub Centres	10,369	–
Total Beds in Govt. Hospitals	–	84,911
Hospitals under other Departments of State Govt.	67	5672
Hospitals under Local Body	30	1083
Hospitals under Government of India	57	8146
Hospitals under NGO/Private	2139	53,992
Total beds		153,804

Source: Ref. [55]

healthcare as evidenced from West Bengal and Assam [53]. Chronic health problem is a burning health issue of the state as it has resulted to catastrophe induced by out of pocket (OOP) health expenditure [40]. Private hospitals patients of West Bengal relatively give importance to staff and overall care rather than treatment, quality and cost [54]. So, the private hospitals of West Bengal should emphasize on quality of treatment, expected patient care and quality of paramedical service rendered on top priority.

The perceived service gap prevails in private clinical establishment is mismanagement due to poor ergonomic reasons as revealed and implied by the patient [54]. Stringent adherence with standard practices in healthcare service through accreditation of JCI, NABH, ISO, and NABL can ensure high quality patient care service. Review of new ergonomics is the need of the hour (Table 20.1).

Every associated aspects of healthcare need to be revisited to achieve highest precision in service performance. Extensive strategy oriented staff training must be arranged to develop better version of clinical and paramedical staff. Hospitals must upgrade their services in adherence with patient feedback system. To minimize the mismatch between promise and performance, expectation of customer should be considered on top priority.

20.4.1 Factors affecting the growth of e-Health in West Bengal

e-Health is an effective option provided it is supported by internet speed and Tele-density of the focused geography. IoT (Internet of things) based network has fuelled digital shift in Indian healthcare. But, growth by leveraging the benefit will depend on homogeneous digital reach across the population [56]. Hence, digital footprint is nonhomogeneous in the state and thus digital footprint is a question. Growth of telemedicine in India is at a pace of 22.7% (CAGR) as compared to 7.4% in USA and 7.9% in China. West Bengal has good internet support but functions with below all India average Tele-density which reveals an obstruction in smooth performance of Tele-counseling service at this geography (Fig. 20.3).

More than 60+ age group and comorbidity turns a person more vulnerable to be a victim of COVID-19. It directly affects the increasing case fatality rate of COVID-19. Even, it increases the crisis due to its un-estimated effect on hospital occupancy. As evidenced from the secondary data, West Bengal has registered an alarming state of uncertainty due to its higher degree of comorbidity among the residents. These prospective victims neither can escape doctor's consultation nor can reach to hospital to get victimized. In such cases, tele consultation is a huge relief and only alternative available before them. With Rs.988 per capita health expenditure, West Bengal was comparatively less prepared than other states of India (average is Rs.1482). With less than all India average number of hospital beds, it was forced to depend on an alternative option of health facilities as the escalation of COVID-19

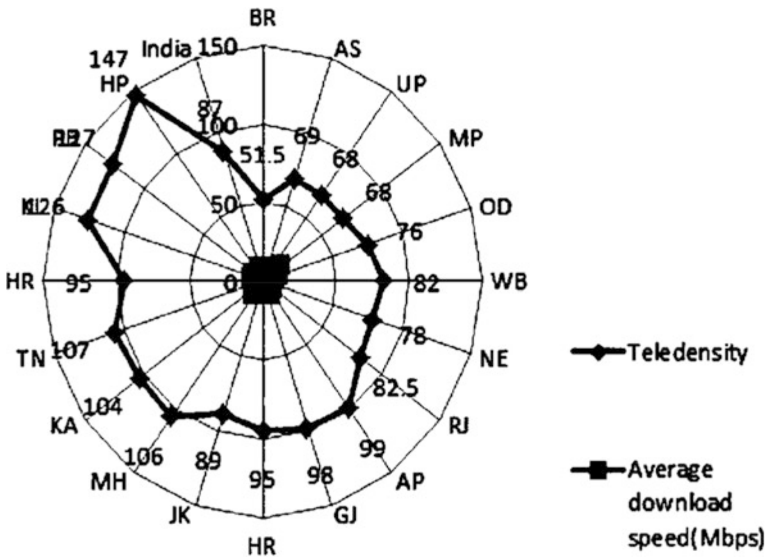


Fig. 20.3 Internet speed & Tele-density of India

victims was unexpectedly unpredictable. E-Health facility is one of such suitable alternative was depended.

Less than average affordability to avail healthcare expenditure with more out of pocket dependence, the residents are in a very financially compromised condition and bound to reach penury in the fight against COVID pandemic. During early months of COVID-19 pandemic, several countries were competing to be the epicenter of Corona. India was one among them. Disparity in state health expenditure is a prime concern to sustain or cope up with such health emergencies. Gross domestic product of West Bengal is Rs.119637 which is lower than all India average of Rs. 145491 (Table 20.2).

With less than all India average doctors versus population ratio (7 per 10,000 populations) the state compromise in treatment of the residents of the geography. With below average health warrior, the crisis got potentiated further. Moreover, attrition of approximately 500+ nurses from several private hospitals of Kolkata made the journey tough. All these indicate an alternative option to be generated. Eventually, telemedicine was being identified as a fruitful option for the inadequate health facility prevails [16].

20.5 Smart Healthcare in Management of COVID-19 pandemic

Dynamics of healthcare has changed with the unprecedented attack of COVID virus. Telemedicine is an effective option for treating chronic ailment and behavioral health [58]. During latest pandemic situation patients are naturally preferring to stay away from COVID patients. Digital consultation is very useful for the patients to follow-up on their treatment [59]. Many physician use WhatsApp or email for getting the report from their patients for their follow up. Non COVID patients can use this platform like helpline, email, WhatsApp call, Skype calls etc. to consult with the doctors for their treatment. West Bengal health administration was initially not prepared to handle the first wave of COVID-19 management and as a result of which, people were not aware regarding e-health services. The telemedicine consultation for COVID treatment was started from June 2020 and Tele-psychological counseling from Aug 2020. Prior to that, only general quarries service was available. COVID positive patients can consult with the qualified doctors in free of cost before admission in hospital. With the gradual increase of the COVID patient more e-health services like real time updated information on bed occupancy status in COVID hospitals, direct telemedicine line, ambulance service help line, COVID-19 live audio visual telemedicine service, COVID-19 telemedicine WB app, Know your COVID-19 patient status, active COVID-19 vaccination center list, etc. were added in the web portal of Health & Family Welfare Department, Govt. of West Bengal for public [55]. It provides real-time updated status related to vacancy and admission to different COVID facilities, ambulance, oxygen, etc. Information are provided

Table 20.2 Demographic transition across Indian states

State	GSDP Per Capita (2018–2019)	Share of population in 60+ age Cohort (2021)	Prevalence of COVID-19 risk conditions (2017)				COVID-19 impact (as on 30.09.20)		
			Diabetes Mellitus	Chronic respiratory diseases	Cardio Vascular Diseases	Cancer	Cases	Deaths	Case fertility rate
Unit	INR	Per cent	Per 1lakh population				Per one million population		
Delhi	394,216	9.3	4995	5598	4596	377	14,949	287	2.1
Haryana	260,286	9.8	4922	6314	4216	270	4559	49	1.2
Karnataka	232,874	11.5	6137	5797	4606	410	8907	122	1.7
Kerala	225,484	16.5	6894	6642	6955	606	5493	21	0.6
Telangana	225,047	11.0	5400	5081	4392	236	4849	29	0.7
Gujarat	224,896	10.2	4695	5610	4348	268	2151	54	2.9
Uttarakhand	220,257	10.6	5204	6581	4336	250	4355	54	1.5
Maharashtra	216,169	11.7	5287	5711	5117	312	11,242	298	3.3
Tamil Nadu	215,049	13.6	8429	4775	5225	356	7677	122	1.7
Himachal Pradesh	211,325	13.1	5105	7043	5237	323	2010	24	1.6
Punjab	172,149	12.6	6537	5107	5338	293	3778	113	3.5
Andhra Pradesh	168,083	12.4	5638	6149	5048	266	12,865	108	0.9
NE States (excluding Assam)	127,334	8.8	3915	4706	3569	233	3861	28	0.7
Rajasthan	123,343	8.6	3727	6498	3691	204	1670	18	1.3
West Bengal	119,637	11.3	4673	6202	5367	269	2581	50	2.1
Jammu & Kashmir	109,769	9.5	4082	5515	4087	169	5517	87	2.0
Orissa	109,416	11.8	5004	5296	4594	221	4727	19	0.5
Chhattisgarh	108,458	8.8	5198	5003	3995	279	3859	33	1.2

Madhya Pradesh	99,025	8.5	4276	5333	3720	246	1500	27	2.2
Assam	94,385	8.2	4254	5033	3695	206	5075	20	0.5
Jharkhand	82,430	8.4	4280	4512	3439	201	2167	18	1.0
Uttar Pradesh	74,402	8.1	4186	6057	3367	214	1678	24	1.7
Bihar	47,541	7.7	3327	4899	3258	155	1466	7	0.5

Source: Ref. [57]

through various modes like phone call, online and Whatsapp chat. WBICMS also provide information related to COVID sample testing, Burial & Cremation, Nodal officers for Burial and cremation, Oxygen Cylinder Retailers etc. across the state of West Bengal [60]. The portal also includes e-Hospital, a digital platform created by the National informatics Centre (NIC) with a vision to upgrade the quality of healthcare services to integrate doctors, patient, and hospitals.

It is a web enabled and workflow-based application hosted at NIC's Cloud, built on a decentralized multi-instance architecture used by over 268 hospitals across the country. It provides online appointment booking, access to lab reports, online blood availability etc. The modules were used in the e–Hospital application for out-patient and in-patient registration, admission, discharge, transfer, billing, laboratory information system, radiology information system, clinics, dietary, laundry, store & pharmacy and OT Management [55].

Further, Many corporate hospitals have allotted helpline number for long-distance advice and counseling, home monitoring packages for COVID-19 patients with mild symptoms to escalate their reach artificially. The package includes online and telephonic consultation, monitoring of health parameters like temperature, pulse rate, oxygen saturation etc. though instruments provided by hospitals and according to the gravity of the situation, the doctor may attend the patient at home or refer hospitalization. Apollo Gleneagles, AMRI Group of hospital, MEDICA super specialty hospital is pioneer in this field. Other corporate hospitals like RTIICS, Peerless Hospital etc. have gradually followed the path of remote monitoring services for mild COVID patients (Tables 20.3 and 20.4).

Up to 31st May 2021 Kolkata and its surrounding districts like 24 Parganas (North and South), Howrah are badly affected during this pandemic. Nadia, Darjeeling, Medinipur (East and West), Burdwan (East and West), Jalpaiguri and Bankura districts of West Bengal have sustainably dominated by number of active patients (Fig. 20.4).

Trend of usage of telemedicine in managing COVID-19 clearly signals a new option of treatment. Moreover it opens a new option to support existing facilities. As revealed from the data that during COVID-19 pandemic, home quarantine was an outcome of shortage in hospital beds at the concerned state. Total COVID cases & COVID-19 related general quarries shows a high correlation (value = 0.71). Even correlation between number of home quarantine and number of total COVID-19 treatment done by patients is also high (Value = 0.72), but no association among them has been observed (chi square = 132.00, $P = 0.233 > 0.05$). Two way ANOVA test value has indicated positive association between total no. of home quarantine, telemedicine consultation for COVID-19 treatment and total number of Telepsychological counseling (F statistic = 5.62, $P = 0.01 < 0.5$).

The statistical test done indicate that observed effect is random and reflects only a trending pattern among the real or prospective victims. Telemedicine became more imperative as crisis increased and due to poor accessibility/ reach. So, it can be mentioned that centralized telemedicine options created by the health administration was successfully used as an option of enquiry.

Table 20.3 District wise Covid-19 Case status up to 31.05.2021 in West Bengal

Sl. No.	District	Total cases	Total discharged	Total death	Active cases as on 31.05.21
1	Alipurduar	11,984	10,919	94	971
2	Coochbehar	21,391	19,469	84	1838
3	Darjeeling	42,751	38,670	368	3713
4	Kalimpong	4672	4117	35	520
5	Jalpaiguri	30,684	26,925	374	3385
6	Uttar Dinajpur	17,401	15,952	191	1258
7	Dakshin Dinajpur	15,189	14,066	143	980
8	Malda	31,256	29,989	179	1088
9	Murshidabad	32,232	30,569	276	1387
10	Nadia	60,407	54,803	476	5128
11	Birbhum	38,425	37,541	252	632
12	Purulia	18,533	17,857	106	570
13	Bankura	29,444	26,620	219	2605
14	Jhargram	8184	6992	23	1169
15	West Medinipur	42,280	38,293	406	3581
16	East Medinipur	49,281	45,193	324	3764
17	East Bardhaman	35,829	33,410	125	2294
18	West Bardhaman	52,695	48,573	296	3826
19	Howrah	85,043	77,249	1345	6449
20	Hooghly	72,600	66,874	749	4977
21	24 Paraganas (North)	294,106	272,137	3919	18,050
22	24 Paraganas (South)	86,478	78,621	1098	6759
23	Kolkata	295,446	278,886	4456	12,104
24	Others	66	63	3	0
	Total	1,376,377	1,273,788	15,541	87,048

Source: Ref. [55]

20.6 Proposed Model

In the context of Corona pandemic, focus of the healthcare service has been shifted from general health service to COVID-19 treatment. Existing facilities were applied to increase surge capacity during the crisis. Inorganic reach of health facilities was explored to deal with the crisis and it was partially successful. Principal of COVID-19 pandemic management in India is 'Trace-Track-Treat' which has been broadly supported by e-Health provisions [61]. This focused approach can be managed better by a 3R model i.e. Record, Report, and Resurge. Telemedicine facilitates and compliments descriptive, diagnostic, prescriptive and predictive analysis [62]. Thus, data can be recorded for real and on time analysis of situation. Easy and fast reporting of cases enables better response and can ensure efficient

Table 20.4 Use of telemedicine by the COVID-19 patients of West Bengal

Month	Total no. of COVID-19 cases	Total no. of Hospitalized COVID-19 cases	Total no. of earmarked COVID-19 beds	Total no. of safe home	Total no. of beds in safe home	Total no. of home quarantine	Number of Telemedicine consultation	Tele-psychological counseling	Total Number General quarries
Jun-20	13,058	78	10,479	106	6908	88,361	NA	NA	NA
July-20	51,629	83	11,299	106	6908	94,861	32,165	NA	NA
Aug-20	92,590	87	12,045	200	11,507	112,871	117,221	44,403	126,960
Sep-20	94,271	92	12,715	200	11,507	180,018	125,981	37,005	114,434
Oct-20	116,615	94	12,811	200	11,507	202,308	120,680	35,608	102,486
Nov-20	109,820	102	13,538	200	11,507	149,081	99,845	75,183	94,594
Dec-20	68,579	102	13,588	200	11,507	158,498	57,759	58,452	61,469
Jan-21	17,935	69	8727	200	11,507	175,902	19,476	29,568	31,794
Feb-21	5120	60	6736	200	11,507	759,893	8224	10,250	21,812
Mar-21	11,797	46	5604	200	11,507	421,168	6459	7885	21,467
Apr-21	241,451	140	13,227	200	11,507	29,479	32,044	23,580	60,138
May-21	548,011	234	24,695	200	11,507	72,421	76,532	34,764	166,125
Jun-21	123,406	203	23,947	200	11,507	NA	67,604	25,555	134,308

Source: Ref. [55]

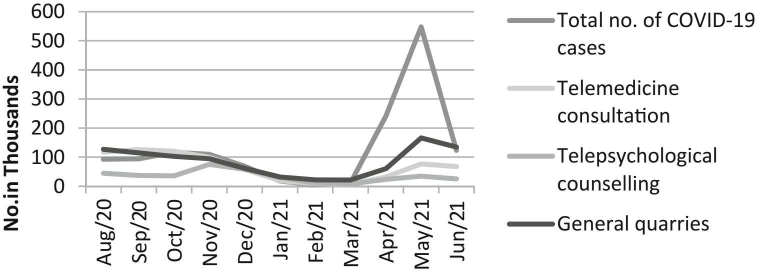


Fig. 20.4 Trend of telemedicine usage in the management of COVID-19 pandemic

functioning [63]. The model was successful for recording old cases and reporting new cases and thus became a repository of information. Data collected through smart health management system can be analyzed through AI to compile the report which will be helpful for real time information analysis. This technique can help to record, & report for monitoring or surveillance and expand resurge capacity to replace the existing inefficiencies of healthcare. This article critically analyzes the COVID-19 pandemic management with the help of smart healthcare interventions as evidenced from secondary data of West Bengal, India. It has been observed that smart healthcare has potentiality to add value in healthcare service expansion in rural areas to manage health crisis provided adequate Tele-density and associated factors doesn't hinder the smooth functioning.

20.7 Conclusion

Smart health initiatives such as telemedicine is a praiseworthy step introduced by the health administration of West Bengal, India as an option to extend the reach of consultative healthcare facilities at remote location to treat critical clinical cases. But, densely populated remote rural territories of West Bengal were not ready with poor literacy and traditional mindset of offline doctor's consultation. Behavioral aspects, such as habitual mismatch also interfered in accepting remote Tele-consultation for health treatment. Residents of the state have partially accepted this as an alternative option to escape COVID-19 as other options were unreachable although they were not accustomed with the complex handling of this option. Inadequate Tele-density was a value addition in partial success of this reactive initiative. Reach of this centralized approach among the target population was inadequate. Even it has been accepted as a uniformed choice. Digital divide is blocking the uniform reach of this smart health at remote location. This replacement has proved as a limited substitution for COVID-19 treatment of the distant victims. A discernable benefit has been designed without thoughtful implementation strategies. Hence, it was a people centric approach but not a demand driven approach. We are on the verge of expected next waves of COVID-19 and other unknown pandemic. Neither people, nor infrastructure can be added overnight and therefore, it will take reasonable time to adapt with the clinical expectation of prospective patients of every nook and corner of the discussed geography. Community based approach such as public-private online consultation centers may help to arrest or attack of future pandemics. Such low cost and time saving health treatment facilities will be better accepted by the rural West Bengal in future if awareness and usefulness is effectively presented before them. Association between perceived health risk related to COVID-19 and choice of option of treatment has to be revealed from the opinion of residents of India. Hence, constructive implementation plan specially with due consideration of these barriers will prepare the health administration for offering quality health services to the common people. Future scope of research lies in identifying the variables impact in the choice of a smart healthcare option with respect to opinion of customer.

Conflict of Interest
There is no conflict of interests.

Funding
This study is a self-funded study done by the authors. There is no funding support.

Data Availability
Not applicable.

References

1. Chaolin, H., Yeming, W., Xingwang, L., Lili, R., Jianping, Z., Yi, H., Li, Z., Guohui, F., Jiuyang, X., Xiaoying, G., Zhenshun, C., Ting, Y., Jiaan, X., Yuan, W., Wenjuan, W., Xuelei, X., Wen, Y., Hui, L., Min, L., . . . Bin, C. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet, 395*(10223), 2020. https://doi.org/10.1016/S0140-6736(20)30183-5
2. Manli, W., Ruiyuan, C., Leike, Z., Xinglou, Y., Jia, L., Mingyue, X., Zhengli, S., Zhihong, H., Wu, Z., & Gengfu, X. (2020). Remdesivir and chloroquine effectively inhibit the recently emerged novel coronavirus (2019-nCoV) in vitro. *Cell Research, 30*(3), 269e271. https://doi.org/10.1038/s41422-020-0282-0
3. Ilan, A., & Shaomin, L. (2020). *COVID-19 response: democracies v authoritarians*. The American Spectator. https://spectator.org/covid-19-response-democracies-v-authoritarians/
4. Manish, K. S., & Yadawananda, N. (2020). Contagion effect of COVID-19 outbreak: Another recipe for disaster on Indian economy. *Journal of Public Affairs, 20*, e2171. https://doi.org/10.1002/pa.2171
5. Abdulmajeed, A. A., & Moath, S. A. (2021). The Psychological Impact of COVID-19 Pandemic on the Students of Saudi Arabia. *The Open Public Health Journal, 14*, 12–23. https://doi.org/10.2174/1874944502114010012
6. Ying, H. J., Lin, C., Zhen, S. C., et al. (2019). A rapid advice guideline for the diagnosis and treatment of 2019 novel corona virus (2019-nCoV) infected pneumonia (standard version). *Military Medical Research, 7*(1), 4. https://doi.org/10.1186/s40779-020-0233-6
7. Sutapa, B. N., & Preetha, G. S. (2020). Assessing health systems' responsiveness in tackling COVID-19 pandemic. *Indian Journal of Public Health, 64*(6), 211–216. https://doi.org/10.4103/ijph.IJPH_471_20

8. Tom, S., & Jessyka, G. L. (2020). Telemedicine in the era of the COVID-19 Pandemic: Implications in facial plastic surgery. *Facial Plastic Surgery & Aesthetic Medicine, 22*(3), 155–156. https://doi.org/10.1089/fpsam.2020.0163
9. Molly, J. C., Ateret, H., & Steven, D. (2009). Remote patient management: Technology-enabled innovation and evolving business models for chronic disease care. *Health Affairs, 28*(1), 126–135. https://doi.org/10.1377/hlthaff.28.1.126
10. Mikael, R., & Ana, C. B. (2007). Patients retrieving additional information via the Internet: a trend analysis in a Swedish population, 2000–2005. *Scandinavian Journal of Public Health, 35*, 533–539. https://doi.org/10.1080/14034940701280750
11. Stephen, R., Paul, K., & Nigel, S. (1993). Methods of helping patients with behavior change. *BMJ, 30*(7), 188–190. https://doi.org/10.1136/bmj.307.6897.188
12. Mikael, R., & Ana, C. B. (2010). Patient characteristics and quality dimensions related to patient satisfaction. *International Journal for Quality in Health Care, 22*(2), 86–92. https://doi.org/10.1093/intqhc/mzq009
13. Sujata, D., Chinmay, C., Sourav, K. G., Subhendu, K. P., & Jaroslav, F. (2021). *BIFM: Big-data driven intelligent forecasting model for COVID-19* (pp. 1–13). IEEE Access. https://doi.org/10.1109/ACCESS.2021.3094658
14. Priyanka, D., & Chinmay, C. (2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence, 2021*, 1–24. https://doi.org/10.1080/0952813X.2021.1958063
15. Ennafiri, M., & Mazri, T. (2020). Internet of Things for smart healthcare: A review on a potential IOT based system and technologies to control Covid-19 pandemic. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIV-4/W3-2020*. Springer. https://doi.org/10.5194/isprs-archives-XLIV-4-W3-2020-219-2020
16. Prithvijit, M. (2020). *Private Hospitals switch to online consultation, telemedicine to minimize virus threat*. Times of India. Retrieved July 16, 2021 from https://timesofindia.indiatimes.com/city/kolkata/pvt-hosps-switch-to-online-consultation-telemedicine-to-minimize-virus-threat/articleshow/74837382.cms
17. Olutosin, T., & Absalom, E. E. (2020). Smart healthcare support for remote patient monitoring during covid-19 quarantine. *Informatics in Medicine Unlocked, 20*, 100428. https://doi.org/10.1016/j.imu.2020.100428
18. (2020). *Government of India, Telemedicine Practice Guidelines*. https://www.mohfw.gov.in/pdf/Telemedicine.pdf
19. Liezl, V. D. (2014). A review of telehealth service implementation frameworks. *International Journal of Environmental Research and Public Health, 11*(2), 1279–1298. https://doi.org/10.3390/ijerph110201279
20. Ankita, S. (2020). *Importance of a National e-Health Authority (NeHA) during COVID-19*. Invest India. www.investindia.gov.in/team-india-blogs/importance-national-e-health-authority-neha-during-covid-19
21. *IBEF, Healthcare Industry in India*. (2021). https://www.ibef.org/industry/healthcare-india.aspx
22. www.oifc.in/Investing-in-India/Investment-Info/In-Focus/Booming-Indian-healthcare-industry
23. Shuo, T., Wenbo, Y., Jehane, M. L. G., Peng, W., Wei, H., & Zhewei, Y. (2019). Smart healthcare: making medical care more intelligent. *Global Health Journal, 3*(3), 62–65. https://doi.org/10.1016/j.glohj.2019.07.001
24. Eric, M. (2003). Integrating health information systems: A critical appraisal. *Methods of Information in Medicine, 42*(3), 428–432. https://doi.org/10.1267/METH03040428
25. Siddique, L., Rajib, R., Junaid, Q., Anwaar, A., Muhammad, A. I., & Muhammad, S. Y. (2017). Mobile health in the developing world: Review of literature and lessons from a case study. *IEEE Access, 5*, 11540–11556. https://doi.org/10.1109/ACCESS.2017.2710800

26. Xiang, Z., & Badee, U. Z. (2020). Adoption mechanism of telemedicine in underdeveloped country. *Health Informatics Journal, 26*(2), 1088–1103. https://doi.org/10.1177/1460458219868353
27. Thomas, B. (2008). Coordinating care—A perilous journey through the health care system. *New England Journal of Medicine, 358*(10), 1064–1071. https://doi.org/10.1056/NEJMhpr0706165
28. Gunjan, S., & Jagannath, P. S. (2003). *E-medicine in India: Hurdles and future prospects*. International seminar at The International Institute of Professional Studies, Devi Ahilya University. https://themanager.org/Resources/Telemed.pdf
29. Brand Essence. (2021). Telemedicine Market Size By Product Type (Tele-Hospital, Tele-Home), By Component (Products, Services), By Application (Teleradiology, Telepathology, Telecardiology, Telepsychiatry, Teledermatology, Others), By Technology (Store & Forward, Real Time, Other), By Delivery Model (Web/Mobile, Call Centers), By End-Use (Providers, Payers, Patients, Others) Analysis Report, Regional Outlook, Growth Potential, Competitive Market Share & Forecast, 2021–2027., https://brandessenceresearch.com/healthcare/telemedicine-market-global-industry.
30. Medgadget. (2021). *Telemedicine market size 2021: Growing demand for telemedicine statistics outlook trends, growth, latest technology with top company profiles, CAGR values*. Medgadget Newsletter. https://www.medgadget.com/2021/02/telemedicine-market-size-2021-growing-demand-for-telemedicine-statistics-outlook-trends-growth-latest-technology-with-top-company-profiles-cagr-values
31. Anthony, J. B. (2021). Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic. *Health and Technology, 11*, 359–366. https://doi.org/10.1007/s12553-020-00516-4
32. Rajendra, S. S. (2006). *Telemedicine projects in West Bengal, A presentation by Special Secretary, H & FW Dep't, Government of West Bengal & Dr. J. N. Maity, Director*. WEBEL ECS Ltd.. https://webcache.googleusercontent.com/search?q=cache:YnTpGNT7DwYJ:https://darpg.gov.in/sites/default/files/telemedicine.ppt+&cd=2&hl=en&ct=clnk&gl=in
33. Aparajita, D., & Soumya, D. (2008). Telemedicine: A new horizon in India. *CME, 33*(1), 3–8. https://doi.org/10.4103/0970-0218.39234
34. Janmejaya, S. (2020). Let's fight against the ailment not the ailing. *Archives of Mental Health, 21*, 112–115. https://doi.org/10.4103/AMH.AMH_23_20
35. Vinoth, G. C., Nirupama, A. Y., & Neha, T. (2019). Telemedicine in India: Where do we stand? *Journal of family medicine and primary care, 8*(6), 1872–1876. https://doi.org/10.4103/jfmpc.jfmpc_264_19
36. Andrei, Z. (2020). *Four new statistics that prove that telemedicine isn't just a pandemic fad*. Medical Economics. https://www.medicaleconomics.com/view/four-new-statistics-that-prove-that-telemedicine-isn-t-just-a-pandemic-fad
37. Paul, W. (2020). Virtual Healthcare in era of Covid19. *Lancet, 395*(10231), 1180–1181. https://doi.org/10.1016/S0140-6736(20)30818-7
38. (2018). *Government of India, Maternal & Adolescent Healthcare*. https://main.mohfw.gov.in/sites/default/files/03Chapter.pdf
39. Christopher, J. L. M., Theo, V., Rafael, L., Mohsen, N., Abraham, D. F., et al. (2012). Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet, 380*(9859), 2197–2223. https://doi.org/10.1016/S0140-6736(12)61689-4
40. Swadhin, M., Henry, L., David, P., & Barun, K. (2014). Catastrophic out-of-pocket payment for health care and its impact on households: Experience from West Bengal, India. *Economics Bulletin, AccessEcon, 34*(2), 1303–1316. Retrieved July 24, 2021, from https://www.semanticscholar.org/paper/Catastrophic-out-of-pocket-payment-for-health-care-MondalKanjilal/8662b5f4e463f3c8428bb05f80535feea1cbca72
41. Michael, M. E., Anup, K., & Ajay, M. (2012). The Economic impact of Non-communicable Diseases on households in India. *Globalization and Health, 8*(1), 9–18. https://doi.org/10.1186/1744-8603-8-9

42. Thakur, J. S., Shankar, P., Charu, C. G., Shanthi, M., & Nata, M. (2011). Social and Economic Implications of Noncommunicable diseases in India. *Indian Journal of Community Medicine, 36*(Suppl), 13–22. https://doi.org/10.4103/0970-0218.94704
43. (2017). *Government of India, The India State Level Disease Burden Initiative*. https://phfi.org/the-work/research/the-india-state-level-disease-burden-initiative/
44. Soumik, G. (2010). Changing dimension – A journey of Indian hospitals from public to private dominance. *Gyanpratha, 2*(2), 13–18.
45. Soumik, G. (2015). *Noncommunicable Disease, A Potential Danger of Indian Health Disparity: Wait Until Dark*, The Indian Economic Journal special issue on Inequality and Human Development in proceedings of the 98th Annual Conference of Indian Economic Association on Growth, in association with Centre for Economic & Social Studies. Hyderabad and IPE, 212–221.
46. Somnath, C., & Arindam, L. (2016). Association between public health care access and financing of health infrastructure in India: An interstate analysis. *Journal of Health Management, 18*(2), 258–273. https://doi.org/10.1177/0972063416637718
47. Rana, K. P., & Mishra, P. B. (2012). Ailing health status in West Bengal critical analysis. *Journal of Law, Policy and Globalization, 2*, 1–6. https://www.iiste.org/Journals/index.php/JLPG/article/download/1212/1133
48. Syed, M. A., Alayne, M. A., Mushtaque, C., & Abbas, B. (2000). Gender, socio-economic development and health-seeking behaviour in Bangladesh. *SocSci Med, 51*, 361–371. https://doi.org/10.1016/S0277-9536(99)00461-X
49. Mojumdar, K. S. (2015). Access to medical facilities among the slum dwellers: A case study of select towns/cities in West Bengal, India. *Indian Journal of Regional Science, 47*(2), 77–94.
50. Somnath, C., & Arindam, L. (2019). Decision on institutional choice in the healthcare sector: Micro-empirical evidences from West Bengal (India). *Journal of Health Management, 21*(1), 177–191. https://doi.org/10.1177/0972063418822214
51. Runi, D. (2013). The world of quacks: A parallel health care system in rural west Bengal. *IOSR Journal of Humanities And Social Science, 14*(2), 44–53. https://www.iosrjournals.org/iosr-jhss/papers/Vol14-issue2/H01424453.pdf
52. Nilanjana, G., Indranil, C., Manasi, C., & Romy, B. (2013). Factors affecting the healthcare-seeking behavior of mothers regarding their children in a rural community of Darjeeling district, West Bengal. *International Journal of Medicine and Public Health, 3*(1), 12–16. https://doi.org/10.4103/2230-8598.109307
53. Raman, K. (2019). Death of a doctor - Ek Doctor Ki Maut—Time to boost the ailing and failing public health system in India. *Journal of family medicine and Primary Care, 8*(12), 3771–3772. https://doi.org/10.4103/jfmpc.jfmpc_897_19
54. Soumik, G., & Bidyut, K. G. (2011). Factors effecting patient satisfaction in private sector hospitals: A case study of West Bengal. *Indian Journal of Commerce and Management Studies, 2*(6), 102–106. http://scholarshub.net/index.php/ijcms/article/view/487/476
55. *Government of West Bengal, Covid Telemedicine*. https://www.wbhealth.gov.in/contents/covid_telemedicine
56. Satya, P. D. (2020). The impact of IoT in healthcare: Global technological change & the roadmap to a networked architecture in India. *Journal of the Indian Institute of Science, 100*, 773–785. https://doi.org/10.1007/s41745-020-00208-y
57. *Government of India, National Health Profile 2019 report*, (2019). http://www.cbhidghs.nic.in/showfile.php?lid=1147.
58. Annette, M. T., Dana, M. W., Karen, B. E., Marian, S. M., Jessica, C. G., Sara, G., & William, R. H. (2016). *Mapping the Evidence for Patient Outcomes From Systematic Reviews* (p. 27536752). Agency for Healthcare Research and Quality (US). https://pubmed.ncbi.nlm.nih.gov/27536752/
59. Prithvijit, M. (2020). *Private hospitals in Kolkata offer mild patients home –monitoring packages*. Times of India. Retrieved July 16, 2021, from https://timesofindia.indiatimes.com/

city/kolkata/pvt-hosps-offer-mild-patients-home-monitoring-packages/articleshow/76395594.cms
60. Sumati, Y. (2021). *Kolkata: Govt launches portal for real-time info on Covid beds*. Economic Times. Retrieved July 10, 2021, from https://health.economictimes.indiatimes.com/news/health-it/kolkata-govt-launches-portal-for-real-time-info-on-covid-beds/82320756
61. Hemanta, K. B., Chinmay, C., Yogesh, S., & Suvendu, K. P. COVID-19 diagnosis system by deep learning approaches. *Expert Systems, 1*(18), e12776. https://doi.org/10.1111/exsy.12776
62. Vinayakumar, R., Harini, N., Chinmay, C., & Tuan, D. P. (2021). Deep learning based meta-classifier approach for COVID-19 classification using CT scan and chest X-ray images. In *Multimedia Systems* (pp. 1–15). https://doi.org/10.1007/s00530-021-00826-1
63. Josep, V. A., Ruthy, A. R., Nuria, P. H., Unai, S. L., Danielle, M., Silvia, N. P., Jesús, P. L., Angels, S. V., & Francesc, L. S. (2020). *Telemedicine in the face of the COVID-19 pandemic*. Atención Primaria. https://doi.org/10.1016/j.aprim.2020.04.003

Chapter 21
E-Health System for Automatic Control of Travel Certificates and Monitoring of the Spread of COVID-19 in Tunisia

Chokri Baccouch, Chayma Bahhar, Chinmay Chakrabarty, Hedi Sakli, and Taoufik Aguili

Abstract The automatic control system for travel certificates is a platform developed for citizens during the Covid-19 health emergency in Tunisia. It will provide efficiency during the checks carried out at the checkpoints, by making it possible to minimize any contact between the agents and the citizens. It will also allow the spread of the infection to be monitored via a dashboard, indicating the infected cases and a traceability of their movements at the national level to take all the necessary precautions to limit as much as possible a large contamination of the population. The platform, which is still under development, consists first of a desktop application, dedicated to citizens to submit their certificate requests, and to authority officers in the local authority annex to process the requests. Then a mobile application for authority officers at checkpoints to verify citizens' travel authorizations.

Keywords Telemedicine · COVID monitoring system · M-health · IoT and health · Medical IT

C. Baccouch (✉) · T. Aguili
SYS'COM Laboratory LR99ES21, National Engineering School of Tunis, Tunis El Manar University, Tunis, Tunisia

C. Bahhar
MACS Research Laboratory RL16ES22, National Engineering School of Gabes, Gabes University, Gabes, Tunisia

C. Chakrabarty
Department of Electronics & Communication Engineering, Birla Institute of Technology, Mesra, India
e-mail: cchakrabarty@bitmesra.ac.in

H. Sakli
MACS Research Laboratory RL16ES22, National Engineering School of Gabes, Gabes University, Gabes, Tunisia

EITA Consulting, Montesson, France

C. Chakraborty, M. R. Khosravi (eds.), *Intelligent Healthcare*,
https://doi.org/10.1007/978-981-16-8150-9_21

21.1 Introduction

As part of the implementation of new protocols to fight the Covid-19 pandemic in Tunisia, this project will be used to automate the process of requesting a derogatory travel authorization during confinement. This will allow Tunisian citizens to first avoid long queues to make a simple request at the level of the local administrative annex, simply by going through an online application form. Once validated by the authorities concerned, the authorization is generated in digital form and then transferred to the citizen via email or SMS.

Each authorization is identified by a QR code, which will subsequently allow remote reading of the data for each authorization at the level of authority checkpoints. This data reading is possible via the Android mobile application which can be installed on smartphones operating with the Android system. This procedure will not only minimize the risk of contamination of citizens by minimizing their use in administrative annexes, but also by eliminating any exchange of paper between the supervisory authority and the citizen, by moving from a document verification in paper form to digital verification by simply using remote smartphones.

In addition to these features, the platform offers a dashboard allowing traceability of infected cases and monitoring of the spread of the pandemic nationwide. In this article we present all the stages of development of said system from the phase of design and description of functional needs described in Sect. 21.3, as well as the implementation phase detailed in Sect. 21.4, to finally conclude with the perspectives.

21.2 Motivation of Telehealth Against COVID-19

21.2.1 Tele-Health on the Move

Mobile tele-health, or M-health (from English M-health), is the constant monitoring of health information from a mobile patient. M-health opens up new perspectives: monitoring patients with high-risk pathologies (diabetes, heart risks for example), monitoring the activity of the elderly, for example. It is also possible to consider monitoring the monitoring of medical treatment while on the move. More broadly, this type of application can also be used for monitoring physical activity, either for sports training means, or even to improve knowledge of biology, physiology and health. In the field of M-health, the traditional view consists of relying on mobile equipment worn by patients (typically smartphones or touchscreen tablets), this equipment possibly being accompanied by sensors intended to record certain parameters relating to the patient patient's state of health (heart rate monitor or electronic scale, for example). Communication takes place via telecommunications networks (UMTS / 3G), or even Bluetooth or Wi-Fi if the patient is at home or near such networks.

This type of configuration can then be used to carry out health monitoring scenarios of a wide variety of types.

In medical remote monitoring (health monitoring) for example, objects worn by patients are often in direct connection with the remote monitoring center. Among the scenarios applicable to this variation, we can cite the detection of falls of elderly people, or the detection of work accidents. This detection is generally followed by a lifting of the alert to remote emergency centers, by sending an SMS for example. More recently, WBANs offer the possibility of integrating different sensors to achieve the same types of medical scenarios.

Some versions of M-health offer patients full mobility without a direct link to the monitoring center. Among the scenarios applicable to these variations, we can cite the muscular rehabilitation of mobile individuals. These applications often use the accelerometers of smartphones, or even wearable sensor platforms (Wearable Sensors).

21.2.2 The Essential Limits: Continuous Monitoring

Continuous monitoring of the health status of mobile patients is still a serious challenge. As soon as a patient leaves home, the only possible mode of communication is to rely on cellular networks (UMTS / 3G). However, these offer only imperfect coverage of the territory.

In addition, they are designed to favor downlink traffic (from the network to the subscriber), while the monitoring of the state of health of mobile patients implies that data flows rather pass from each patient to the network in order to be treated remotely. Finally, since cellular networks are not specifically dedicated to monitoring the state of health of individuals, their availability to transport data relating to this state of health cannot be guaranteed.

A complementary solution is to rely on other radio technologies (Wi-Fi, Bluetooth, etc.). The latter offer higher transfer rates than cellular infrastructures. However, the major constraint of these technologies in a context of mobility lies in their low radio range, of the order of a hundred meters. By relying on mobile communicating equipment during the continuous monitoring of patients, other constraints in material resources are added to the previous constraints. Indeed, the sensor platforms generally have only low material resources in computation and transmission. This is also the case for mobile terminals (PDAs, smartphones, touch tablets) with regard to energy.

When patients are highly mobile, environmental constraints can hamper radio communication. These include obstacles, such as noise, which prevent synchronized collection of vital signs to distant medical centers. These constraints therefore raise a major risk of loss of medical data during collection. Because of the various constraints in material resources, transmission, and energy, the medical scenarios mentioned in mobile tele-health must implement secondary emergency mobile medical applications. By way of example, we can cite scenarios such as prevention against pathologies and epidemics, muscle rehabilitation, permanent storage of vital signs for mobile patients, etc. In other words, it becomes very difficult, if not impossible, to deal with very critical scenarios such as the continuous monitoring of highly mobile individuals by relying on these kinds of technologies. This difficulty is a direct consequence of the disruption of connectivity when collecting data to remote medical centers.

21.3 One Possible Solution: Opportunistic Communications

The issues of managing disruption of connectivity and loss of data are rarely raised in practice in existing modes of communication, even less when it comes to transmitting vital data from mobile patients in the field of tele-health (tele-health in mobility, telemedicine).

However, there is a mode of communication called DTN (Disruption-Tolerant Networking) which can help to cope with the constraints mentioned above, in particular by tolerating the frequent breaks in connectivity that may be observed at the level of a device worn by a patient. The DTN communication mode allows communicating devices to withstand the connectivity breaks observed on the radio links. The concept is based on the principle of intermediate storage when it is not possible to get the data to its destination. When connectivity is again available, this mode of communication carries the stored data to its destination, hence the qualifier of opportunistic communication given to this type of communication. It is therefore interesting to introduce this mode of communication in the continuous monitoring of mobile patients. Indeed, in a context of data collection, the DTN approach eliminates the need for permanent connectivity. Its intermediate backup and transport scheme (called Store, Carry and Forward) helps ensure data integrity when connectivity is absent. Note that the invention of opportunistic communication dates back only 10 years and remains untapped in the medical field to date.

21.4 Medical IT: Overview and Variations

In this chapter we provide an overview of the field of medical informatics. As this field has evolved considerably over the past decade, it is not easy to distinguish its multiple variations. Standardization efforts here are relatively recent, and not all have been successful.

We are particularly interested in the problem of collecting biometric data on mobile subjects, and show that this problem relates to the so-called mobile tele-health (M-health) applications, which themselves constitute a subset of the applications of tele-health (Ehealth).

21.4.1 Medical IT

Health informatics [1, 2] is a field that involves putting information technology and electronics at the service of medicine. This field is also referred to as healthcare computer systems, clinical informatics, or biomedical informatics. It includes activities common to information science and health care. It involves the digital resources, devices and methods required to automate the process of acquiring, storing, collecting and interpreting health information.

The field of medical informatics involves several computer disciplines, one can cite information systems, knowledge engineering, artificial intelligence, model engineering etc. In our study, we are interested in the medical discipline which is based on communication infrastructures (E-health).

21.4.2 Tele-Health (E-Health)

Tele-health [3] (E-health) is a medical discipline that consists of putting information technology and communication infrastructures at the service of medicine. As defined, telehealth appears to be very broad and very diverse. Being a discipline in the field of medical informatics, the main feature of telehealth is the exploitation of the Internet and telecommunications networks. The use of these technologies makes it possible to ensure a distant and permanent link between different medical actors and their patients. We can distinguish seven disciplines in tele-health. These disciplines are sometimes differentiated according to the information exchanged, the fields concerned, and depending on whether the application concerned mainly aims to:

- Remotely assist, mainly through diagnostic advice, a locally deprived patient (tele-assistance);
- Monitor at home, on an outpatient basis, a faulty vital function: remote monitoring, ...;
- Completely and exclusively perform a remote medical procedure: telediagnosis, ...;
- Organize the circulation of data in a health network: health cyber-networks;
- Providing information or even teaching: e-learning;
- Participate in the management of health systems: cybermanagement;
- Offer patients direct access to their health record or to medical teleservices (e-health).

21.4.3 Telemedicine

Among the disciplines of tele-health, we can cite telemedicine:

“Telemedicine is a form of remote medical practice using information and communication technologies. It connects, with a patient, one or more health professionals, who necessarily include a medical professional and, where applicable, other professionals providing care to the patient “.

As the aforementioned article of the Health Code specifies, telemedicine is a discipline of tele-health. It brings together medical practices facilitated by the use of telecommunications infrastructures and technologies that allow the delivery of health care at a distance. Through the use of these infrastructures, the main objective of telemedicine is the exchange of medical information. Telemedicine is divided into several activities, namely:

- Tele-expertise: its purpose is to allow a medical professional to seek and share the opinion of other medical experts;
- Medical tele-assistance: its purpose is to allow a medical professional to assist another health professional remotely during the performance of an act;
- Medical remote monitoring (monitoring): it allows a medical professional to remotely interpret the data necessary for the medical follow-up of a patient and, if necessary, to make decisions relating to the care of this patient. Data recording and collection can be automated;
- The medical response: it defines the diagnosis made by health specialists.

21.4.4 Tele-Health in Mobility (M-Health)

M-health [4–6] (or Mobile Health) is also a discipline of tele-health. It designates the practice of medicine and public health on ambulatory patients. To ensure the acquisition and processing of mobile patient data, several mobile devices are common in the daily life of individuals. We can cite cell phones, PDAs (Personal Digital Assistant), smartphones, touch pads, netbooks, etc. M-health defines several activities which consist of running mobile medical applications on the mobile devices mentioned above. M-health applications generally aim to automate certain medical treatments for patients. In some cases, the results of processing these data are delivered to practitioners and remote laboratories. Delivery of medical data, such as patient vital signs, is sometimes performed in real time.

Several initiatives to integrate M-health into the daily life of ambulatory individuals have been proposed. These initiatives encompass various activities, namely:

- Awareness against serious diseases;
- The collection and storage of physiological data (vital signs);
- Remote medical supervision (monitoring);
- Precaution and specialized training (against work accidents, etc.);
- Screening and the fight against communicable diseases and epidemics;
- Support for the diagnosis and treatment of diseases.

21.5 COVID-19

It was in China, on December 31, 2019, that the infection with a new Coronarovirus appeared, now well identified: COVID 19. The epidemic is in full swing in China and the number of cases continues to expand across the world causing concern among health specialists and of course, all populations. The exact origin of this virus has not yet been confirmed. In order not to let panic set in, all health authorities communicate regularly about this infection. Like all other countries, Tunisia has set up a crisis unit which ensures information on the current state of the infection and to educate and reassure citizens. A toll-free number and an interactive application for making a diagnosis have been set up.

21.5.1 Epidemiological Data

Confirmed cases are only “the tip of the iceberg”, and according to expert opinion, the virus is circulating at a minimum in populations, which represents a source of diffusion that is difficult to control. Hence the drastic containment measures imposed in China, especially in the Hubei region, the first focus of the infection. Studies conducted by WHO should provide answers on viral penetration in the population.

Current data is based on the numbers of confirmed cases reported by authorities in each country. According to current data, the most serious cases with death mainly concern elderly people suffering from other pathologies.

Only the studies in progress to date will make it possible to establish the profile of the disease: proportion of asymptomatic or pauci-symptomatic subjects, of symptomatic but mild subjects, of subjects requiring hospitalization for medical reasons, of subjects justifying hospitalization in resuscitation, death.

21.5.2 Symptoms

The incubation time is in the range of 5–6 days, which can last up to 14 days.

Most often, the symptoms present are fever, fatigue and a dry cough; and sometimes pain, stuffy and runny nose, sore throat or diarrhea. These symptoms are usually mild and appear gradually. Most often, even infected people have few or no symptoms.

Evolution: According to current data, most people recover without needing any special treatment (nearly 80%), and about one in six people have more serious symptoms, including breathing difficulties.

People at risk of developing a severe form are the elderly and those who are carriers of other pathologies such as high blood pressure, heart problems or diabetes. About 2% of sick people died.

Anyone with a fever, cough, and difficulty breathing should be advised to see a doctor.

21.6 Similar and Related Work

A study was carried out with the aim of identifying all the platforms (nationally and internationally) whose functionalities are particularly similar to those of our project, or in relation to the management of the movements of individuals during the Covid19 pandemic. Nationally, “wiqaytna” [7] is the only application for detecting Covid-19 contacts which has been developed by multidisciplinary teams from the Ministry of Health and the Ministry of the Interior in collaboration with the National Telecommunications Regulatory Agency (ANRT) and the Digital Development Agency (ADD) and the gracious and voluntary contribution of Moroccan companies and startups who are experts in their fields. It aims to allow the Ministry of Health to inform citizens that they were at a very short distance from a patient infected with Covid-19. It is a mobile application that, when activated, uses Bluetooth technology to detect other smartphones using the application in the vicinity. Thus, once the person infected with Covid-19 is hospitalized, the department concerned at the hospital recovers all the contacts of people who have been in contact with the patient, to ask them to take all the necessary precautions and to report to the services. Health emergencies once the first signs of contamination are detected. The app worked well, but such an approach requires absolute commitment from all citizens, something that is still hard to achieve. Internationally, several applications have been developed, either to detect people who were in contact with someone with Covid-19, or to supervise people who were in quarantine for a certain period of time. Table 21.1 summarizes some of these applications by country as well as their different functionalities. To detect Covid-19 contacts, the applications offered are based on Bluetooth technology, or on location information obtained from activating the position of the citizen via his smartphone. Being prohibited in Morocco, this last approach is not possible since it presents a violation of the law relating to the protection of natural persons with regard to the processing of personal data.

The COVID-19 epidemic and its effects from early 2020 surprised both politicians and scientists. One or more studies aimed at understanding the phenomenon globally and including environmental factors would be welcome. As soon as COVID-19 appeared in Wuhan, a showcase for 5G technology in China, hypotheses and even assertions appeared in the press and on the internet that the new virus was correlated or even resulted directly from the introduction of this virus new generation of telecommunications. Some sources went so far as to claim that the virus did not exist, and that the symptoms that appear in the patients were directly due to the effects of the millimeter-scale non-ionizing radiation (NIR) of 5G at 60 GHz, which would inhibit the absorption of oxygen in the lungs.

For all continents (North America, South America, Europe, Asia, Africa, Oceania), a strong correlation exists between the use of the Internet and the incidence of COVID-19, this for standardized data. Figs. 35.1 to 35.6 show on the abscissa the percentage of internet users and on the ordinate, deaths from COVID-19, normalized per million inhabitants. These graphs clearly show progressions similar to quadratic functions (Asia, Africa, Oceania) or closer to the exponential (North America and

Table 21.1 Summary of applications developed to control the spread of the COVID-19 pandemic

Covid-19 application	Country	Language / Technology	Features
Wiqaytna [7]	Morocco	Kotlin / Bluetooth	Notification of exposure to Covid-19 (deadline 21 days). Statistics of infected cases each day.
TousAntiCovid [8]	France	Kotlin / Bluetooth	Warning of people who have crossed paths with a person tested positive for Covid-19. An anonymous alert will be sent to nearby users. The app considers contacts within 1 m for at least 5 min, as well as contacts within 2 m for at least 15 min.
COVID Watch [9]	USA	Vue.jsNuxt. jsNode.jsKotlin/ Bluetooth	Detect users when they are in close proximity to each other and notify them anonymously if they come into contact with someone who has tested positive.
TraceTogether [10]	Singapour	Kotlin /Bluetooth	Notify user if they have been exposed to COVID-19 through close contact with other users of the application. The app enables the Ministry of Health to provide timely care and advice.
PeduliLindungi [11]	Indonésie	Kotlin /Bluetooth	Notify users if they have come across someone with a positive diagnosis
StayHomeSafe [12]	Hong Kong	Kotlin /Bluetooth Wi-Filocation service	Guarantee that the confined remain at their designated location during the quarantine period, thanks to big data and artificial intelligence technologies, in conjunction with the electronic wrist band. If the mobile application detects a suspicious location of a confined person, it follows it according to government regulations

Europe), with a point of "separation" towards 50% of use of the internet (on the x-axis).

The literature informs us that human immune function is impacted by RF MO to the point that the symptoms of 90% of patients with disorders of this system are markedly or strongly improved if they are protected from microwave frequencies [13], to the point that it is advisable to remove these patients from INR in order for the treatments to be effective. Note that the levels considered are at values several orders of magnitude lower than those encountered in living and working places (a few tens of millivolts per meter (mV / m) only).

Prof. Olle Johansson also concluded that there is very strong evidence that artificial EMFs are able to disrupt the immune system and therefore increase the onset of disease [14], at much lower power density levels at the levels encountered daily in our living environments.

21.7 Radiological Aspects of COVID-19 Lung Disease: From Conventional Imaging to Artificial Intelligence

During the pandemic caused by the emergence of the novel coronavirus (SARS-CoV-2; COVID-19) that causes acute respiratory distress syndrome (ARDS), we must rethink the diagnosis of patients with respiratory symptoms. Indeed, although the use of RT-PCR remains the cornerstone of the diagnosis, the delay in diagnosis and the overload of the microbiological platform have led us to use chest imaging to manage patients almost systematically.. In this case, thoracic imaging shows a great interest in assisted diagnosis in order to better guide the management of admitted patients. The most frequent signs are well described in thoracic computed tomography. Typical imaging associated with bilateral, multilobed, predominantly peripheral and posterior frosted glass lesions. Significant lesions are usually identified in asymptomatic patients, and imaging tests are sometimes done before symptoms appear. In addition to traditional chest imaging, many teams have also developed new artificial intelligence tools to better help clinicians make decisions.

At the CHU de Liège, we use an artificial intelligence model, performing an automated segmentation and analyzing the entire lung parenchyma in order to determine whether the chest scanner is compatible, or not, with an infection by COVID-19 (“COVIA”) (6). The COVIA system, developed on a group of 181 patients compared to 1200 control cases, identifies a COVID-19 infection with a positive predictive value of 53.6% and a negative predictive value of 97.1%. The model can identify COVID-19 infection with an accuracy of 89.7% (95% CI: 84.0–93.9). The particularity of COVIA is to integrate an automated segmentation in a model based on five main characteristics: the average intensity of the image of the lungs, a matrix of co-occurrence of gray levels, modifications of the textures in intensity or localization. One of the strengths of this model is its excellent negative predictive value, useful as a decision-making aid in the management of inpatient flows.

21.8 Certain Investigations on IoT System for COVID-19

The coronavirus is a group of viruses that cause the common cold, severe acute respiratory syndrome (SARS), and Middle East respiratory syndrome (MERS). Coronavirus was discovered after being identified because it explained one of the diseases that started to spread in China in 2019. This disease is considered one of the most dangerous things in the world, it directly affects many regions and cause heavy economic losses. The danger of this disease is that it spreads widely, so it is difficult to manage and manage it. Therefore, remote technology is the simplest solution to observe the patient’s condition and monitor the progression of symptoms. The Internet of Things can be a modern technology designed to share files, software, programs and other tools, allowing users to use devices with each other to use

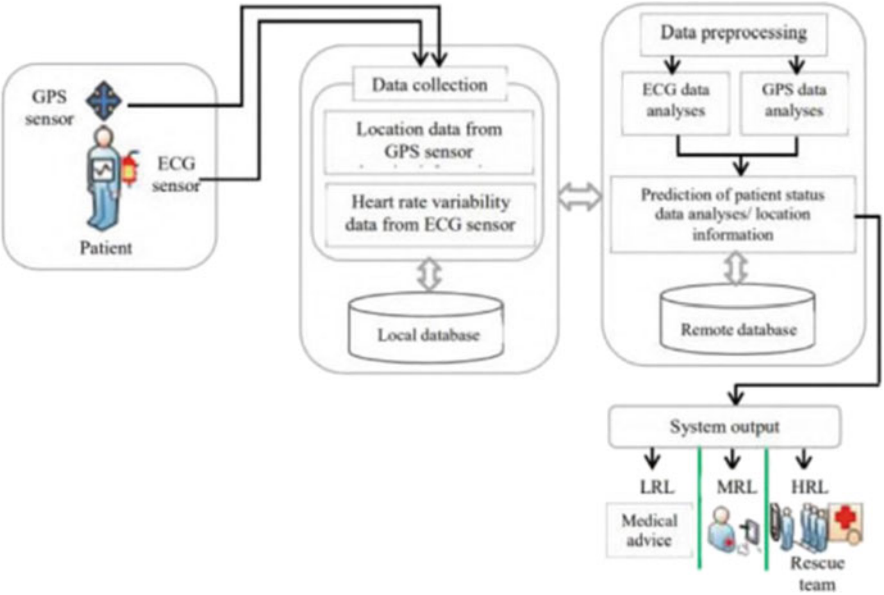


Fig. 21.1 IoT system for COVID-19 monitoring

communication between them. It includes many devices that communicate with each other through intelligent decision making. Building smart devices and sensors that support modern IoT systems is the best solution for real-time detection of COVID-19 patients. Research shows the device's effectiveness in detecting COVID-19 patients in an IoT system.

The proposed research system consists of three main parts: patients, data collection and pretreatment. The following figure shows these parts.

In the first part, GPS sensors and ECG sensors are connected to the patient to read patient information, such as location identification, understanding of fever, pulse, and symptoms indicating coronavirus. In the second part, all the information will be saved in the local database and will be used by the doctors after sending the information to most of the system servers. In the last part, the patient's data will be analyzed; ECG and GPS analysis. From the results of statistical analysis data is employed to work out the patient's condition, which helps identify which patient is affected by COVID-19 (Fig. 21.1).

21.9 New COVID-19 Detection and Diagnosis System Using Smart Headsets Based on the Internet of Things

Coronavirus is that the new virus that has not been identified in humans before which it causes the coronavirus disease called COVID-19. The disease was first discovered in Wuhan, China in December 2019 and has spread round the world thus far. The virus can easily pass from person to person, causing it to spread quickly. One among the common symptoms of COVID-19 which will be easily identified is fever. Since the virus outbreak, thermal screens using infrared thermometers are utilized in public places to test blood heat to spot the indicated infected among the crowd.

This prevention remains lacking because it takes an extended time to test the blood heat of every person and therefore the most vital is that the close contact of the infected person which may cause transmission to the person doing the screening or to the one responsible of screening to persons checked. This study proposes the planning of a system capable of automatically detecting the coronavirus from the thermal image with less human interaction using smart headphones with mounted thermal imaging system. Thermal camera technology is made into the smart headset and combined with IoT technology to watch the screening process to urge the info in real time. Additionally, the proposed system is provided with face recognition technology, it also can display the private information of the pedestrian which may automatically take the temperature of the pedestrians. This proposed design features a high demand on the healthcare system and has the potential to assist prevent the spread of the coronavirus.

Figure 21.2 shows the system configuration. The present innovation relates to the applicable sort of thermal imaging frames for the detection of a rise in blood heat also because the monitoring process, and more particularly to an improved camera system which may be attached to a helmet which may be quickly deployed and wont to visualize a thermal image with high resolution for the infected site is coordinated to either user's eye while maintaining directed and coordinated eye contact of the client with the situation for provide superior perceptibility of surrounding areas. An important indicator of an infection is a rise in blood heat (relative to people within the immediate environment), commonly referred to as a fever. Thermography is that the ideal method for scanning not only individuals, but also large flows of individuals to try to to this, the temperature is measured, and an alarm is triggered if it deviates. This makes it possible to quickly and reliably identify people with an elevated blood heat, and to be isolated for more precise tests. Beyond checking blood heat, AI is employed to diagnose COV19. Infervision, software that automatically detects symptoms through screening images, can speed up diagnoses and reduce the danger of human error. Figure 21.2 illustrates the overall operation of the smart headset.

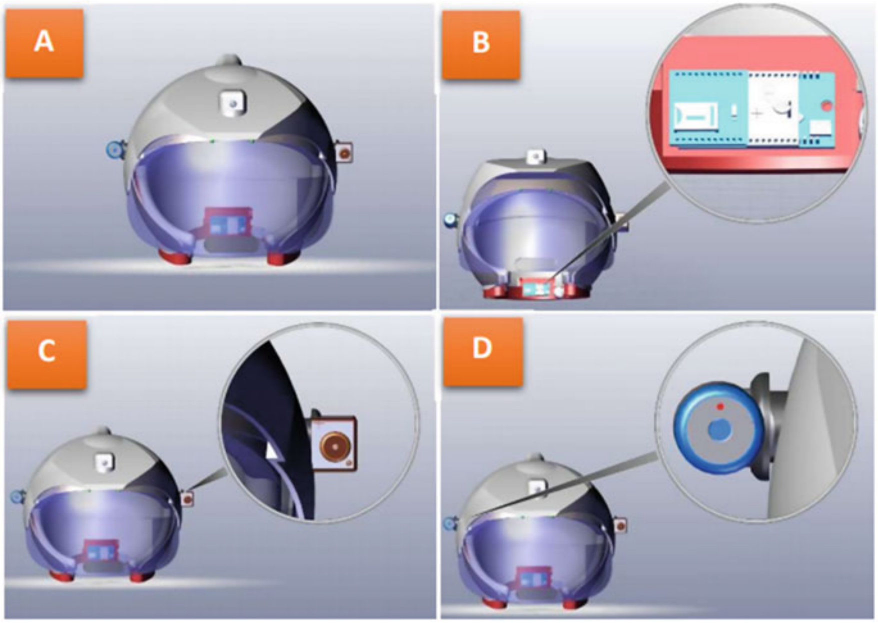


Fig. 21.2 Configuration design of the system (**a**) Over all system, (**b**) System Controller, (**c**) Thermal Camera and (**d**) Optic Camera

Fig. 21.3 Social distance detector usingdeeplearning, computer vision

21.10 Smart Infrastructure

Automatic human body temperature detection machines are installed in many countries where the camera is integrated with the sensor and sends real-time information to the server (Fig. 21.3). The system also uses AI to acknowledge the face and match it to the centralized database [15, 16]. Using these devices helps track the COVID-19 patient. Social distancing is enforced by enabling a sensible infrastructure during which the environment is sensed and reports generated in real time for enforcement agencies [17]. Sensor data is consistently recorded in a web database for constant monitoring [18]. The damaging gas or carbon content is communicated to the environmental protection agency and is updated on the server to be verified online [19]. Researchers are performing on detecting the coronavirus which may even be operated on within the same way. IBM, Microsoft, Huawie and Cisco are among the leading companies providing intelligent infrastructure solutions [20].

21.11 IoT Compatible Ambulances

Medical personnel related to ambulances are generally faced with very high and error-prone situations [21]. During the present COVID-19 pandemic, situations became even more tense and struggling for medical staff treating COVID-19 patients. IoT assisted ambulances offer an efficient solution during which remote doctors suggest the required actions to the medical staff treating the patient within the ambulance. This results in a rapid response and efficient patient management. Figure 21.4 shows the smart ambulance equipped with IoT-based technology. WAS

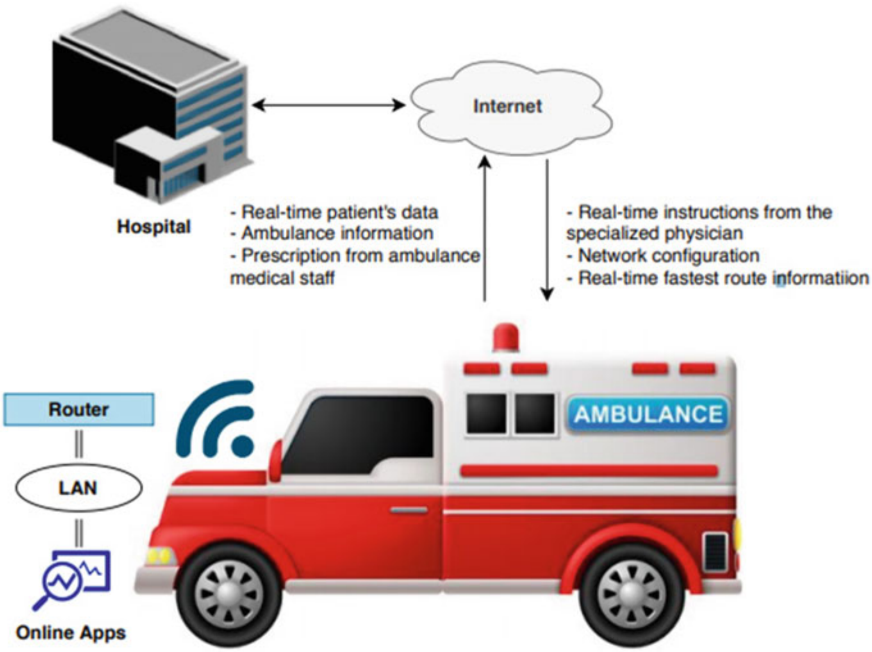


Fig. 21.4 IoTbased smart ambulance system

vehicles [22] provide intelligent solutions supported emergency vehicles frequency identification (RFID) based equipment is connected to a wireless local area network (WLAN). Patient information are often accessed remotely by the medical staff concerned.

21.12 Ai-Based Forecasting and Social Distancing

Artificial intelligence (AI) is one among the foremost promising technologies that's helping to revolutionize many fields. The introduction of AI algorithms in IoT has opened new doors during this field [1–4]. AI provides the power to find out and extract meaningful patterns from data. As data from IoT devices is aggregated into a database, it are often easily wont to predict the outbreak and therefore the effects of the coronavirus and the way to mitigate it [10]. Data from COVID-19 patients helps predict future behavior of the virus and compare its effects at the world level. Besides, it also helps to match symptoms of COVID-19 efficiently and quickly. AI-based treatment also enables rapid recovery and patient follow-up [5]. The patient's medical history and therefore the results generated help predict the simplest treatment choices supported AI and machine learning (ML) algorithms [6–12]. BlueDot [23] was one among the primary utilities to predict the spread of the coronavirus and identify the worldwide threat. They provided information on the virus's mobility pattern also as its epidemic potential. Other AI-powered companies that have joined and worked within the fight against COVID-19 are Deargen [24], InsilicoMedicine [25], SRI Biosciences and Iktos [26], Benevolent AI [27], DeepMind [28], Nanox, Baidu, Alibaba and Endo Angel Medical Technology Company [14].

Computer vision and deep learning provides real-time social distancing measure by detecting people within 2 m or 6 ft. of every other, which works in real time on GPU and includes a pre-model -trained [29]. In Fig. 21.5, the red box indicates that the social distancing protocol is violated while the green marks a secure distance. The knowledge is transmitted continuously on the web where the authorizing body intervenes in real time if a violation of social distancing is detected. This is often helping to attenuate the spread of the coronavirus and is one among the foremost powerful tools to assist fight the present COVID-19 pandemic (Fig. 21.5). AI-based emergency control paves the way for ambulances and other emergency service providers. Red Ninja [30] may be a Liverpool-based company that has developed an algorithm called Life First Emergency control (LiFE) which allows paramedics to use real-time congestion data to control traffic [31].

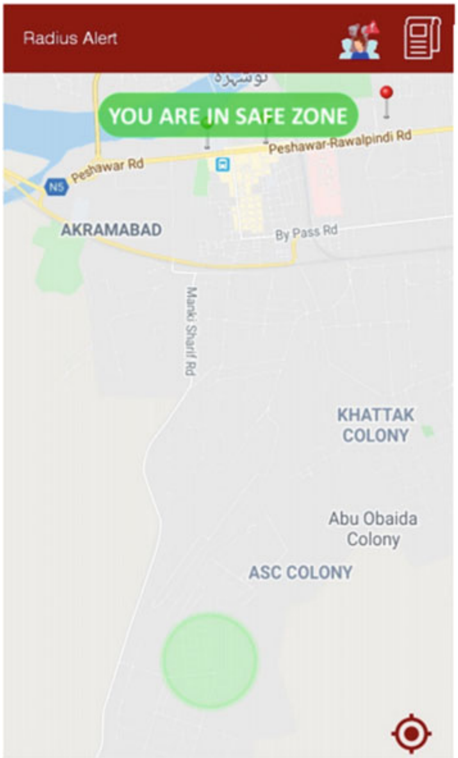


Fig. 21.5 Real-time area monitoring for Covid-19 patients

21.13 Our Agent Tracking Application against Covid-19 in Tunisia

The goal of the project of our proposed application is to enable, on the one hand, the detection of people infected with Covid-19, once scanned in a control point in the Covid-19 emergency room, during their first hospitalization. The roaming of their trips can be easily recovered, thanks to the various checkpoints established at supermarkets, public establishments, access to different towns and rural areas. On the other hand, this platform manages travel authorization requests, made online by citizens, then their validation by the authorities, to subsequently send them in digital form to citizens via email/SMS. At the same time, the platform will have to respond to requests for verification of any movement, issued by the authority checkpoints via a simple reading of the QR code via a smartphone. The platform consists of a web application intended primarily for Tunisian citizens affected by exceptional travel. Citizens will be invited to complete a web form through which they provide their information such as: Name, First name, CIN number, Address and reason (s) for travel. After validation of this form, citizens will receive a derogatory travel certificate via email / SMS containing a QR code which encodes the information relating to the travel certificate. Then, secondly, to the officials of the relevant administrative

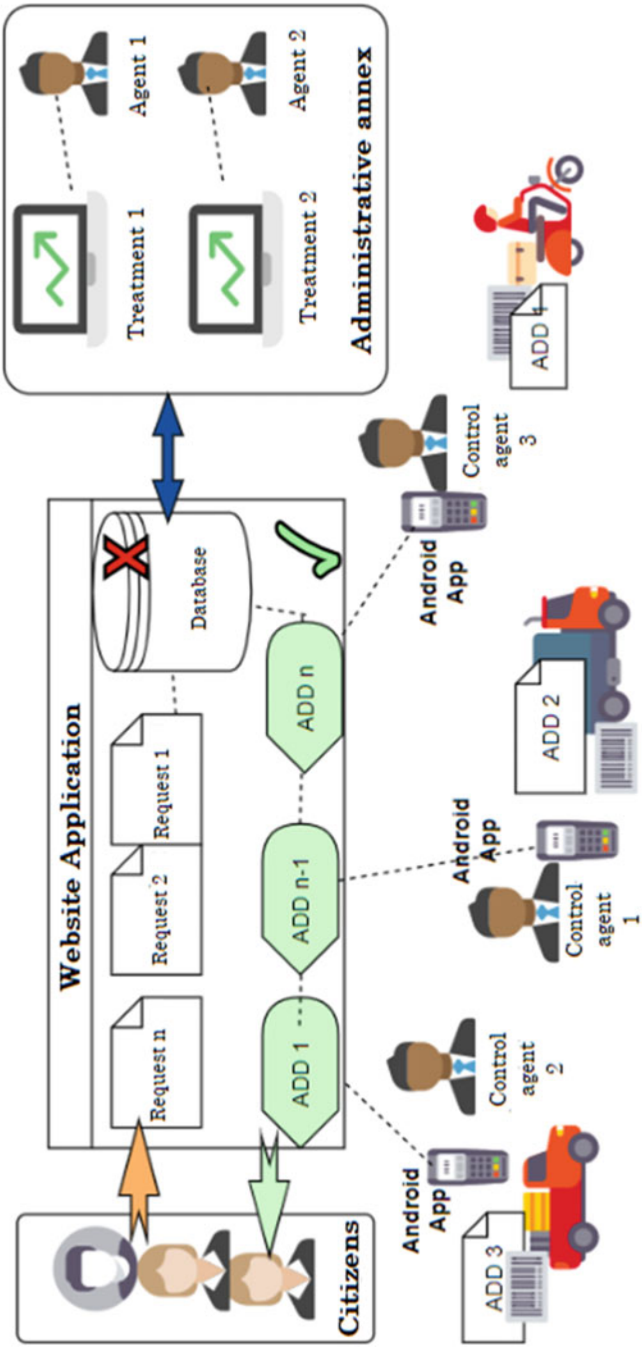


Fig. 21.6 COVID-19 agent tracking application

annex, depending on the citizen's place of residence, for validation of the authorization request sent.

A second mobile application is being developed, intended for authority officials, to check exceptional travel certificates. In fact, at each checkpoint, citizens must present their certificate bearing the QR code (on their smartphone). The screening officer will allow the citizen to pass to the desired area once the status of their authorization is verified. The main objectives of this procedure are to minimize the number of citizens visiting the administrative annexes, and to avoid as much as possible the exchange of documents in paper format between the citizen and the authority, which will minimize the risk of contamination, to then present a monitoring of contaminated cases, their travel history. Thus, determine and visualize areas with a high contamination index in a dynamic dashboard. Figure 21.6 summarizes the three main functionalities provided by the platform, firstly the sending of ADD requests from citizens online, secondly the processing of these requests from the agents of the administrative annex, and lastly the verification phase of these authorizations during the movements of the various citizens.

21.14 Conclusion

The application is a project to develop a control and management system for exceptional travel certificates in the context of the spread of the Covid-19 pandemic. This project is in progress seeking funding from the Tunisian State. The duration of the project is 12 months, scheduled to end in December 2021. Until then, we will try to achieve all the main objectives set out at the launch of the project.

Conflict of Interest
There is no conflict of interests.

Funding
There is no funding support.

Data Availability
Not applicable.

References

1. Akash, G., Chinmay, C., & Bharat, G. (2019., ISBN 978-981-13-7398-5). Medical information processing using smartphone under IoT framework, springer: Energy conservation for IoT devices, studies in systems. *Decision and Control, 206*, 283–308. https://doi.org/10.1007/978-981-13-7399-2_12
2. Chinmay, C., Gupta, B., & Ghosh, S. K. (2016). CH. 11 Mobile telemedicine systems for remote patient's chronic wound monitoring. In *M-Health innovations for patient-centered care* (pp. 217–243., ISBN: 9781466698611). IGI Global.
3. Chinmay, C., & Megha, R. (2021). CH 2 Smart healthcare systems using big data. In *Demystifying big data, machine learning and deep learning for healthcare analytics* (pp. 1–16). Elsevier. https://doi.org/10.1016/B978-0-12-821633-0.00002-7
4. Lalit, G., Emeka, C., Nasser, N., Chinmay, C., & Garg, G. (2020). Anonymity preserving IoT-based COVID-19 and other infectious disease contact tracing model. *IEEE Access, 8*, 159402–159414. https://doi.org/10.1109/ACCESS.2020.3020513. ISSN: 2169-3536.
5. Pham, Q.-V., Nguyen, D. C., Hwang, W.-J., Pathirana, P. N., et al. (2020). *Artificial intelligence (ai) and big data for coronavirus (covid-19) pandemic: A survey on the state-of-the-arts*. IEEE.
6. Vaishya, R., Javaid, M., Khan, I. H., & Haleem, A. (2020). Artificial intelligence (AI) applications for covid-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14*(4), 337–339.
7. Kishor, A., & Chakraborty, C. (2021). Artificial intelligence and internet of things based healthcare 4.0 monitoring system. *Wireless Personal Communications*. https://doi.org/10.1007/s11277-021-08708-5
8. Kishor, A., & Chakraborty, C. (2021). Early and accurate prediction of diabetics based on FCBF feature selection and SMOTE. *International Journal of Systems Assurance Engineering and Management*. https://doi.org/10.1007/s13198-021-01174-z
9. Kishor, A., Chakraborty, C., & Jeberson, W. (2021). Intelligent healthcare data segregation using fog computing with internet of things and machine learning. *International Journal of Engineering Systems Modelling and Simulation (IJESMS), 12*(2), 3.
10. Kishor, A., & Jeberson, W. (2021). In P. K. Singh, S. T. Wierzchoń, S. Tanwar, M. Ganzha, & J. J. P. C. Rodrigues (Eds.), *Diagnosis of heart disease using internet of things and machine learning algorithms* (Proceedings of Second International Conference on Computing, Communications, and Cyber-Security. Lecture Notes in Networks and Systems) (Vol. 203). Springer.
11. Kishor, A., Chakraborty, C., & Jeberson, W. (2021). Reinforcement learning for medical information processing over heterogeneous networks. *Multimedia Tools and Applications, 80*(3), 108400. https://doi.org/10.1007/s11042-021-108400
12. Taulli T. (2020). *Coronavirus: Can ai (artificial intelligence) make a difference?* Retrieved May 26, 2020, from https://www.forbes.com/sites/tomtaulli/2020/02/02/coronavirus-can-ai-artificial-intelligence-make-a-difference/.
13. Iktos, S. R. I. (2020). *Iktos and sri international announce collaboration to combine artificial intelligence and novel automated discovery platform for accelerated development of new antiviraltherapies*. Retrieved February 6, 2020, from https://www.sri.com/.
14. Srivastava, S. (2020). Top 10 AI poweredcompanies standing against coronavirus pandemic. Retrieved February 6, 2020, from https://www.analyticsinsight.net/top-10-ai-powered-companies-standing-coronavirus-pandemic/
15. Konstantakopoulos, I. C., Barkan, A. R., & He, S. (2019). Tanya Veeravalli, Huihan Liu, and Costas Spanos. A deeplearning and gamificationapproach to improvinghuman-building interaction and energyefficiency in smart infrastructure. *Appliedenergy, 237*, 810–821.
16. Priyanka, D., & Chinmay, C. (2021, 2021). Application of AI on post pandemic situation and lesson learn for future prospects. *Journal of Experimental & Theoretical Artificial Intelligence*, 1–24. https://doi.org/10.1080/0952813X.2021.1958063

17. Gupta, M., Abdelsalam, M., & Mittal, S. (2020). Enabling and enforcing social distancingmeasuresusing smart city and its infrastructures: a covid-19 use case. arXivpreprint, *arXiv*, 2004.09246.
18. Mehmood, R., Katib, S. S. I., & Chlamtac, I. (2020). *Smart infrastructure and applications*. Springer.
19. LiberataUllo, S., & Sinha, G. R. (2020). Advances in smart environment monitoring systemsusingiot and sensors. *Sensors, 20*(11), 3113.
20. smartcityhub. (2017). *These are the top tencompaniesthatbuild smart cities*. Retrieved February 6, 2020, from http://smartcityhub.com/technology-innnovation/the-top-ten-companies-that-build-smart-cities/.
21. Park, E., Kim, J. H., Nam, H. S., & Chang, H. J. (2018). Requirementanalysis and implementation of smart emergency medical services. *IEEE Access, 6*, 42022–42029.
22. WAS. *Making vehicles special*. Retrieved February 6, 2020, from https://www.was-vehicles.com/en/home.html/.
23. bluedot. (2020). *Bluedot'soutbreakrisk software safeguardslives by mitigatingexposure to infectiousdiseasesthatthreatenhumanhealth, security, and prosperity*. Retrieved February 6, 2020, from https://bluedot.global/.
24. Deargen. (2020). *Integrate all intelligence, to create radical cure*. Retrieved February 6, 2020, from https://deargen.me/.
25. Insilico Medicine. (2020). *Artificial intelligence for drugdiscovery, biomarker development & aging research*. Retrieved February 6, 2020, from https://insilico.com/.
26. Iktos SRI. (2020). *Iktos and sri international announce collaboration to combine artificial intelligence and novel automated discovery platform for accelerated development of new anti-viral therapies*. Retrieved February 6, 2020, from https://www.sri.com/.
27. Benevolent. (2020). *Weenvision a world where no diseasegoesuntreated*. Retrieved February 6, 2020, from https://www.benevolent.com/.
28. DeepMind. (2020). *What if solving one problemcouldunlock solutions to thousands more?* Retrieved February 6, 2020, from https://deepmind.com/.
29. Adrian Rosebrock. (2020). *Opencv social distancing detector*. Retrieved February 6, 2020, from http://pyimg.co/ahnjg/.
30. RedNinja. (2020). *Life first emergency traffic control*. Retrieved February 6, 2020, from http://www.redninja.co.uk/8mins2savelives/.
31. Katherine Whelan. (2018). *Smart ambulances: The future of emergency healthcare*. Retrieved February 6, 2020, from http://emag.medicalexpo.com/smart-ambulances-the-future-of-emergency-healthcare/