MACHINE INTELLIGENCE FOR INTERNET OF MEDICAL THINGS: APPLICATIONS AND FUTURE TRENDS

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Machine Intelligence for Internet of Medical Things: Applications and Future Trends

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CONTENTS

FOREWORD

The COVID-19 pandemic has shed light on the importance of having a more efficient healthcare system. In the era of Industry 4.0, Artificial Intelligence and the Internet of Things have introduced themselves today as must-have technologies in almost every sector, including healthcare.

This book introduces an emerging yet interesting concept, the Internet of Medical Things (IoMT). It refers to an infrastructure of highly connected healthcare devices that can communicate and share data to optimize different medical actions and interventions. The book goes further into suggesting solutions that can provide better performance and security for the Internet of Medical Things.

Moreover, this book presents different successful case studies of combinations of IoMT with Artificial Intelligence and their application in different medical use cases, such as preventing future pandemics, optimizing brain tumor detection, obstacle detection for visually impaired patients, *etc.*

In its last chapter, this book offers an opening to further development in the IoMT area by exploring the possibilities offered by Blockchain technology in securing medical data.

This book aspires to provide a relevant reference for students, researchers, engineers, and professionals working in the IoMT area, particularly those interested in grasping its diverse facets and exploring the latest advances in IoMT.

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PREFACE

The growing development in the field of computing has encouraged the integration of a variety of sophisticated devices inside houses and facilities. These devices communicate with each other to help users in particular situations and according to their needs, such as safety, comfort, and even health. The devices form an object connection environment known as the Internet of Things (IoT). Healthcare professionals are now embracing the Internet of Medical Things (IoMT), which refers to a connected infrastructure of devices and software applications that can communicate with various healthcare IT systems. One of these technologies — Remote Patient Monitoring — is commonly used for the treatment and care of patients.

Often associated with the IoT, Artificial Intelligence (AI) opens the field of possibilities in the medical area, in particular, by allowing the development of new diagnostic and interpretation tools of exceptional reliability and by assessing the large volumes of data that can be generated through the networks by sensors and users.

OBJECTIVE OF THE BOOK

The objective of this book is to focus on how to use IoT, AI and Machine Learning (ML), to keep patients safe and healthy and, at the same time, to empower physicians to deliver superlative care.

This book discusses the applications, opportunities, and future trends of machine intelligence in the medical domain, including both basic and advanced topics.

This book provides core principles, algorithms, protocols, emerging trends, security problems, and the latest e-healthcare services findings. It also includes deep feedforward networks, regularization, optimization algorithms, convolutional networks, sequence modeling, practical methodology, and how they can be used to provide better solutions to healthcare-related issues.

ORGANIZATION OF THE BOOK

Chapters 1-3: The authors introduce the concept of the Internet of Medical Things (IoMT), its roles, challenges, and the opportunities it may present to the healthcare system.

Chapter 4: The authors present a cloud-edge-based IoMT architecture and discuss the performance optimization it may provide in the context of Medical Big Data.

Chapter 5: The authors provide a comprehensive survey on different IoMT interference mitigation techniques for Wireless Body Area Networks (WBANs).

Chapters 6 and 7: The authors explore the possibilities that Artificial Intelligence and the Internet of Things can provide to prevent future pandemics.

Chapters 8-10: The authors provide a comprehensive review of the newest Machine Learning based solutions in different medical areas.

Chapter 11: The authors go through the latest discoveries in curing cardiovascular diseases by implementing Artificial Intelligence in healthcare settings.

Chapter 12: The authors propose a Deep Learning based solution to optimize obstacle recognition for visually impaired patients.

Chapter 13: The authors provide a survey on the latest breakthroughs in Brain-Computer Interfaces and their applications.

Chapter 14: The authors propose a solution to optimize the performance of Deep Learning for brain tumor detection.

Chapter 15: The authors explore the possibilities that Blockchain may offer inpatient data management.

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CHAPTER 1

Internet of Medical Things & Machine Intelligence

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Abstract: Recently, the internet of medical things has been the widely utilized approach to interconnect various machines. While, IoT in combination with machine intelligence, has given new directions to the healthcare industry. Machine intelligence techniques can be used to promote healthcare solutions. The merger of IoT in medical things is a completely advanced approach. The intelligent behavior of machines provides accurate decisions, which greatly helps medical practitioners. For real-time analysis, artificial intelligence improves accuracy in different medicinal techniques. The use of telemedicine has increased so much due to COVID-19. Gathering unstructured data where the concept of electronic databases should be used in the health care industry for advancement. Big data and cyber security play an important role in IoMT. An intrusion detection system is used to identify cyber-attacks which helps to safeguard the entire network. This article provides a detailed overview of the internet of medical things using machine intelligence applications, future opportunities, and challenges. Also, some of the open research problems are highlighted, which gives insight into information about the internet of medical things. Different applications are discussed related to IoMT to improve communication standards. Apart from that, the use of unmanned aerial vehicles is increased, which are mostly utilized in rescuing and sending medical equipment from one place to another.

Keywords: Big Data, IoMT, IoT, Machine Intelligence, UAVs.

INTRODUCTION

With the development of IoT, the healthcare industry is revolutionized, where a massive amount of data can be transferred from one place to another. Therefore, IoMT is introduced to connect medical devices, which can improve decision-making process. Data resource management is the central point of discussion in IoMT. However, machine learning techniques enhance the accuracy level, which has shifted researcher's attention to secure communication between node.

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COVID-19 is considered the most dangerous virus which affects the respiratory system. Machine intelligence-based techniques can be used for the effective treatment of viruses. AI and machine learning refers to solving big problems related to healthcare [1, 2].

An advance in the healthcare industry has enhanced standards for different stakeholders like patients, doctors and researchers. Therefore, AI, machine learning, cyber security, big data and 5G can be integrated with IoMT to give optimal solutions [3]. Sensors and a high level of hardware equipment are needed to modify healthcare industry processes. Due to that, IoT with medical is quite helpful [4]. Integrated applications are designed using AI models for disease treatments [5, 6].

This research work provides novel ideas related to the internet of medical things using artificial intelligence, machine learning, and meta-heuristic search optimization to give directions to researchers. However, the major contribution of this article is as below:

- Big data and AI-designed techniques for the health care industry.
- Machine learning concepts for IoMT.
- Applications for IoMT.
- Safeguarding IoMT from cyber-security attacks.
- Future advances and challenges.

The contribution points are fully incorporated in the rest of the paper, which gives a detailed overview of IoMT applications, challenges, AI, big data and machine learning techniques. Fig. (**1**) illustrates the concept of tele-medicine, which was mostly used during COVID-19 for online consultation with medical doctors. Also, the whole architectural view of tele-medicine is presented.

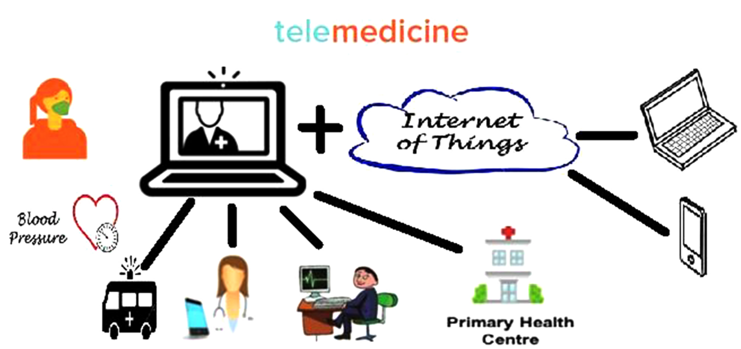

Fig. (1). Internet of medical things (tele-medicine).

LITERATURE STUDY

IoT has interconnected patients, doctors and related equipment's in the healthcare industry. However, different sensors are used to collect, send and manage the data. Various applications of IoT are utilized which use to tackle COVID-19. Therefore, IoT connects each and everything while machine learning techniques diagnose diseases [7]. The Internet of health things has changed the dynamics in health management. Federated learning is a new concept that is sub part of machine learning. This novel technique takes data in central servers and local devices, which makes the data safer in contrast with other traditional methods [8]. However, local models must be properly updated using 5G communication networks [9]. Protocols are designed while integrating 5G networks with federated learning [10]. Lightweight protocols are proposed to bring trust between two nodes in IoMT [11, 12].

COVID-19 has disturbed our daily life routine, where we have to maintain social distancing and make people aware of vaccination [13, 14]. While, the health status of patients and much more information can be easily made available due to various advancements in IoT, cyber security, big data, AI and machine learning [15 - 19].

In addition, UAVs are widely used during COVID-19 to send medical equipment and rescue operations. Also, tele-medicine is nowadays commonly utilized by doctors to properly advise patients. Therefore, secure routing is needed between nodes.

BIG DATA & AI FOR HEALTHCARE

Artificial intelligence is making life easier for humans. Due to advanced communication technologies, life has become more comfortable. AI merger with big data has solved major problems related to healthcare. Electronic healthcare records are quite helpful in improving tumors to optimize treatment methods [20].

The healthcare industry is based on data that should be authentic. Due to this, decision-making process will be quite efficient. The data usually flow from patients to doctors where to share possible information to give possible treatment.

However, in traditional methods, the data or record cannot be preserved for a long period of time. While, digitalization utilizing big data analytics and artificial intelligence has improved the standards of technological equipment's [21].

CHAPTER 2

Health Services and Applications Powered by the Internet of Medical Things

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Abstract: The traditional healthcare system model is now out of date. As the digital era progresses, new advanced technologies and service platforms are highly demanded. The Internet of Medical Things (IoMT), a subset of the Internet of Things, is one such technology. The Internet of Things (IoT) is a network of wireless, interconnected, and linked digital devices that can collect, send and store data without requiring human-to-human or human-to-computer interaction. Understanding how established and emerging IoT technologies help health systems provide safe and effective care is more important than ever. For example, the rapid spread of Coronavirus disease (COVID-19) has alerted the entire healthcare system. The Internet of Medical Things (IoMT) has dramatically improved the situation, and COVID-19 has inspired scientists to create a new 'Smart' healthcare system focused on early diagnosis, prevention of spread, education, and treatment to facilitate living in the new normal. This paper provides an overview of the IoMT design and how cloud storage technology can help healthcare applications. This chapter should assist researchers in considering previous applications, benefits, problems, challenges, and threats of IoMT in the healthcare field and the role of IoMT in the COVID-19 pandemic. This review will be helpful to researchers and professionals in the field, allowing them to recognize the enormous potential of IoT in the medical world.

Keywords: Applications, Benefits, Challenges, COVID-19, Healthcare, IoMT, IoT, Medical, Threats.

INTRODUCTION

Significant changes have taken place in the healthcare industry over the last few years. One crucial factor in this change is the use of new information technology across the business right now. Hospitals and nursing homes need help from many different IT service platforms and cutting-edge technology to meet the growing healthcare demand. The Internet of Medical Things, or IoMT, is one of the most

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commonly used technologies in the healthcare field today. A subset of the Internet of Things is the Internet of Medical Things [1].

The term "Internet of Things" refers to a network of physical things, or "Things," meant to communicate with each other through the Internet. Ashton first talked about the Internet of Things in 1999. Since then, it has overgrown, with about 10 billion connected devices today and an estimated 25 billion by 2025 [2].

Taking care of a person's physical, mental, or emotional well-being is called "health care," usually done by trained and licensed professionals like doctors and other healthcare workers. There are not enough doctors, nurses, or hospital beds because there has been much growth in the population, and a lot more people are getting sick. Scientists who use the latest techniques and methodologies develop new medicine and healthcare trends every day. Researchers have recently focused their attention on the Internet of Things (IoT) because of its popularity as a perfect solution for healthcare systems that do not put much pressure on them [3].

Today, healthcare and modern technology businesses, especially healthcare systems, play a big part in our lives. The main goal of integrating technology into healthcare systems is to make it easier for patients and caregivers to communicate with each other. This will make medical devices and services more efficient and easier to get. The Internet of Medical Things (IoMT) has been essential in monitoring healthcare from afar (RHM). Wearable sensors and devices are often used to get data on patients remotely and store it in cloud databases. The Internet of Things (IoT) is used primarily for this. These data can be used by caregivers right away for analysis and planning [4].

IoMT consists of three main parts: the device layer [Body Sensor Network (BSN)], the fog layer, and the cloud service. The main goal of the device layer (sensing layer) is to build an effective and accurate sensing technology that can collect different types of health-based data. Communication technologies like Bluetooth, RFID (NFC), Wi-Fi, IrDA, UWB, and ZIGBEE help the IoMT system build network solutions and infrastructures. In the cloud layer (data layer), the data is processed and kept safe and sound. Furthermore, the cloud gets the patient's data to analyze, process, and store it. Healthcare workers can then use such data [5 - 12].

The IoMT is a group of medical strategies connected to networks. People can connect their smart glasses, head-mounted devices, belt-worn clothes, smartwatches, woven clothes, and smart wristbands to Wi-Fi, Bluetooth, or the Internet to get information about their health. Diagnostic machines such as ultrasonography, MRI machines, infusion pumps, ventilators, and X-ray machines in healthcare facilities use IOMT technologies. These IOMT wearable devices can be used to keep track of people's health of all ages. They are usually easy to wear and use. IOMT devices are used in applications and software, such as remote data analytics, medical assistance, operations augmentation, medicine monitoring, and accounting systems [13].

Remote Health Monitoring (RHM) is a way to track a person's health data regularly. People's heart rate, temperature, blood pressure, physical activities, and dietary habits are all monitored. The cloud sends health data wirelessly to both patients and caregivers. So, IoMT can make real-time, quick, remote, and trustworthy decisions for various disorders. This process generates many data, which is then analyzed and monitored. Due to the hectic pace of today's lives, most people do not go to the doctor regularly. In addition, healthcare costs are rising, and governments spend a lot of money on healthcare each year. People in Europe and the United States also prefer to get their health care at home rather than in a hospital. These problems can be solved if real-time healthcare monitoring can be done from afar and in real-time. The use of wearable gadgets and sensors to provide continuous monitoring for patients and the elderly has received a lot of interest [14 - 25].

Imagine a world where billions of things are connected through IP (Internet Protocol) networks and have built-in intelligence, communication, sensing, and actuation abilities. This is called the Internet of Things (IoT). Our current Internet has moved a lot away from hardware-based options (computers, fibers, and Ethernet connections) and toward market-based ones (such as apps) (Facebook, Amazon) [26].

This chapter will look at the technologies that make up IoMT and the benefits, problems, security concerns, and ways that IoMT can be used in healthcare. IoMT's role in COVID-19 is also addressed briefly.

CONCEPT FOR INTERNET-OF-THINGS-BASED HEALTHCARE

It is meant to allow for a wide range of types and services, each of which has a different set of Medicare solutions. There is not yet a complete list of IoT services in healthcare. Health care services can be hard to tell apart from other solutions or applications in some cases. It also looks at how potentially building blocks can be used in general service. In Medicare settings, IoT frameworks and protocols have been updated a little to make them work better. Simple, safe, low-power and quick discovery of new devices and services can be made and done quickly. There are many subtopics under the term “health service” that deal with future and emerging health services [3]. Fig. (**1**) illustrates the concept of IoMT in health care.

CHAPTER 3

An Approach to the Internet of Medical Things (IoMT): IoMT-Enabled Devices, Issues, and Challenges in Cybersecurity

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Abstract: As the number of devices connected to the Internet (Internet of Things: IoT) grows, ensuring reliable security and privacy becomes more difficult. With the widespread usage of online medical facilities, security and privacy in the medical arena have become a severe problem that is only becoming worse. The criticality and sensitivity of data in the healthcare industry make guaranteeing the security and privacy of the Internet of medical things (IoMT) even more difficult. The privacy of the patients will be threatened, and their lives may be threatened if effective measures are not implemented in IoMT. Also, it provides novel services, such as remote sensing, elder care assistance, and e-visit, improving people's health and convenience while lowering medical institution costs per-patient. However, with the rise of mobile, wearable, and telemedicine options, security can no longer be assessed just inside the confines of clean physical walls. Nonetheless, by implementing recognized and applicable safeguards, the risk of exploiting vulnerabilities can be greatly decreased. This article provides an outline of the key security and privacy measures that must be implemented in current IoMT environments to protect the users and stakeholders involved. The overall approach can be seen as a best-practice guide for safely implementing IoMT systems.

Keywords: Cybersecurity, Internet of Medical Things (IoMT), Online Medical Facilities, Patient Monitoring, Privacy, Protection.

INTRODUCTION

The Internet of Medical Effects (IoMT) is a network of Internet-connected medical outfits, tackle structure and software operations that connect healthcare IT. IoMT, as mentioned in Fig. (**1**), shows the Internet of Effects in healthcare, allows wireless and remote bias to securely connect *via* the Internet to allow for rapid-fire and flexible medical data processing. The impact of the Internet of Effects on the healthcare business is apparent and unrecoverable [1]. Likewise,

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IoMT operations are explosively associated with sensitive healthcare services, particularly because they manage sensitive patient information similar as names, addresses, and health conditions. The crucial problem in the IoMT sector is maintaining patient sequestration while maintaining a high position of security. Likewise, applicable security and sequestration results should only take minimum calculations and coffers [2].

Fig. (1). Internet of medical things.

IoMT refers to internet-connected bias and operations used by healthcare providers to cut costs and ameliorate patient care. The bias can be employed in hospitals or at the homes of cases. These bias prisoners, store, transmit, and process sensitive data similar to names, addresses, and the state of your health. The following are some instances of it:

- Smart fitness devices and smart blood pressure devices are examples of personal wearable devices.
- Infusion pumps and dialysis machines are examples of medical devices that can be used at home.
- Defibrillators, anaesthetic machines, patient monitoring, and Personal Emergency Response Systems (PERS) are examples of in-hospital and clinical gadgets.
- Cameras that can be consumed.

This application allows patients to provide medical data in real-time *via* their mobile phone and internet connection. Patients with diabetes, heart disease, and high blood pressure, in particular, have found it handy to communicate medical records to doctors using remote health-monitoring apps on their smartphones.

These gadgets are commonly used in hospitals and nursing homes to comfort patients and assist doctors in reducing the number of journeys they make to see patients. The IoMT market is massive, and it's only going to get bigger shortly.

Doctors were unable to continuously monitor a patient's health before the Internet of Medical Things, making even disease identification difficult. The influence of linked gadgets on patients' life is becoming more apparent as their use grows. IoMT lowers healthcare expenditures and delivers more precise data, as well as reduces frequent hospital visits, while enhancing treatment quality.

PATIENT-MONITORING SYSTEM IN IOMT

Patient monitoring in real-time (RTPM), such as glucose and heart rate monitoring, IoMT is primarily concerned with healthcare and medical applications. IoMT requires a more robust security structure than other IoT systems due to the perceptivity and rigorous laws around healthcare data. Fig. (**2**) represents the Case-Monitoring functions of the system, which explains that patient health issues are observed through a medical device and, in turn, shared with the physicians through an assistant using the internet of effects. The Internet of Effects has a variety of goods on healthcare assiduity. These changes are particularly conspicuous when it's used in the home, on the body, in the community, and in the hospital.

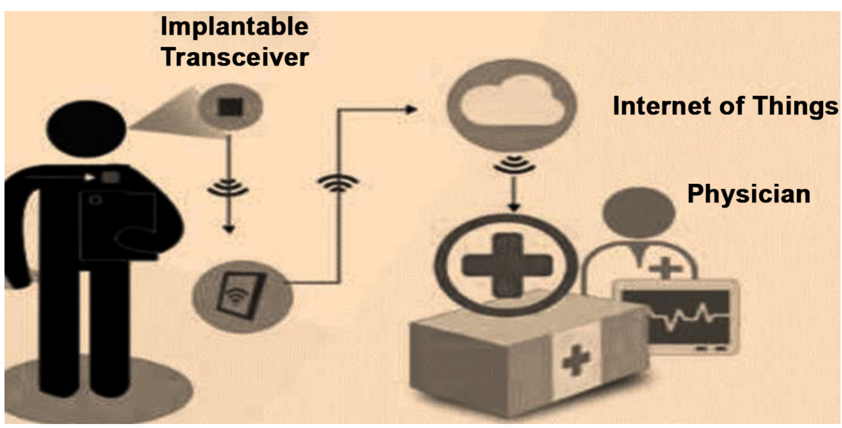

Fig. (2). Patient-monitoring system in IoMT.

At Home

People can transfer medical data from their homes to other locales, similar to their primary care provider or a hospital, using in-home IoMT. Remote case monitoring (RPM), for illustration, is the use of a medical outfit to shoot criteria like blood pressure and oxygen saturation from lately discharged cases to their hospital for

CHAPTER 4

Internet of Medical Things in Cloud Edge Computing

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Abstract: Booming growth of ubiquitous connections and clinical computerization in the 5th generation mobile communication era, the explosive increase and heterogeneity of clinical information have delivered enormous demanding situations to information processing, privacy and security, as well as data access in (IoMT) Internet of Medical Things. Our paper gives a complete evaluation of the way to understand the analysis and timely processing of big data in medical applications and the dropping of healthcare resources in high quality under the limitations of previous medical equipment and the medical environment. We mostly concentrate on the benefits carried *via* the artificial intelligence, edge computing and cloud computing concepts to IoMT. We also explain how to use clinical resources while keeping the privacy and security of clinical information, so that extremely good clinical services can be given to patients.

Keywords: Cloud Computing, Edge Computing, Fog Computing, Healthcare, Internet of Medical Things.

INTRODUCTION

With the speedy growth of technology, economy and science, clinical treatment has emerged as one of the motivations of social, personal or even national interest, as described by Sun *et al.* [1]. The conventional medical design has troubles which include trouble with expensive treatment, occlusion of clinical facts and seeing a physician. But, with the proper establishment of knowledge of the Internet of Things (IoT), as suggested by Al-Fuqaha *et al.* [2], the application subject of IoT has been concerned in every aspect during today's generation of Internet-of-Everything (IoE), as mentioned by W. Wang *et al.*, X. Wang *et al.*, as well as Ning *et al.* [3 - 5]. Regarding the clinical area involved, Internet-of-Medical-Things (IoMT) can be a focused incarnation of the IoT discipline, as well

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as a medium of clinical electronic renovation. IoMT, as described by Shit *et al.* [6], can be difficult IoT skills inclusive of positioning, sensor and radio frequency identity technology, in addition, carried out to clinical subjects in collaboration with network communication, cell terminals and extra gadgets to understand communication medical gadgets and medical institutions, patients, medical staff among patients, to attain the automation, digitalization as well as the intelligence of clinic.

The IoMT helps every phase of clinical areas, such as medical drugs, waste and equipment management, remote monitoring, identification recognition and essential signs monitoring. The medical wireless sensor, as described by Liu *et al.* [7], can be the base as well as a core of every connection; also, wi-fi sensor communication integration of most forms of wi-fi clinical sensors, inclusive of implantable sensor, biosensor, pressure sensor, performs a vital function in gaining essential symptoms information of patients. Now, sensors have been broadly applied inside the (ICU) Intensive Care Unit, emergency room and operation room to screen and show the important disorders of patients. Moreover, Yang *et al.* [8] suggest that wearable medical device, including sensor as core, allows patients to acquire modified clinical services everywhere and anytime, importantly decreasing treatment price for both patients and doctors, giving real-time fitness management for patients and interruptions over restriction of space and time. How to rapidly analyze, process, and choose gathered clinical facts in real-time may be essential to immediately connect patients' lifestyles and fitness. Furthermore, as clinical information includes patient's personal privacy, this can be essential to support the safety of the privacy data of patients and sensitive facts.

However, the utility of IoT generation within the healthcare field may assist clinics to understand the intelligence clinical treatment of human beings as well as smart control of things; various healthcare institutions are exceptionally autonomous, therefore it's problematic to obtain useful resource sharing. The IoMT-related cloud computing (CC) presents influential basic resources of IT as well as substantially decreases medicinal costs. It can't fulfill mass storing of clinical information, however additionally recognize the distribution of medical data *via* cloud environment, to enhance the effectiveness and excellence of clinical services. But, totally trusting CC will devour enormous network broadcast resources with a big delay, which will probably create a danger to a patient's life.

The capacity of CC to practice information sinks, creating information processing towards the source, as opposed to cloud or external fact that may reduce time delay, as well as accomplish real-time with quicker processing than evaluation of medical statistics. Edge Computing (EC) decreases dependent on centralized remote/local servers, then answers issues present in CC *via* sensible software of sources over edge gadgets; this means clinics and hospitals acquire an extra responsive and agile IT community, therefore patients may experience higher medical services. Then EC doesn't occur in separation. Cloud and Edge Computing accompany each other and perform exceptionally vital roles.CC focuses on the general understanding, while EC concentrates on the local. The normal usage of cloud edge integration will higher support the improvement of medical application cases. Based on the present situation in the healthcare field, our manuscript integrates 3 favorable skills for 1st time to systematically overview the existing work, as well as examine the experiments that IoMT can face in the future.

The fundamental offerings of our paper are as follows: 1st, we present traditional IoMT architecture, examine IoT key technologies carried out in the clinical area, then present the directions of research to increase its efficiency in the healthcare area. With the fast boom of healthcare statistics and complication of data structure, we observe 3-tier cloud computing architecture for IoMT, then announce tools inclusion of IOMT cloud computing application. By evaluating conventional IoMT as well as medical IOT cloud, we recall the benefits of EC and present its IoMT architecture.

MEDICAL INTERNET OF THINGS

Ning *et al.* [9] explained that the utility of IoT knowledge in the healthcare area subject understands the digital administration of healthcare data, so medical workers are now not busy recording as well as arranging huge quantities of bulky healthcare data, however greater targeted on patients to give higher healthcare services. In this phase, we are able to present the architecture of conventional IoMT, after which we define the key technology applied.

IOMT ARCHITECTURE

IOMT architecture envelops a few associated contents of Wireless Sensor Network (WSN) and EPCglobal, as described by Liu *et al.* [10], as well as is the maximum broadly applied architecture in IoT field. The IoMT can be the focused incarnation of IoT technology within the healthcare sector. Here common 3-tier IOT architecture will be followed. It has 3 layers, namely, transmission, network and perception layer. The architecture of IoMT is shown in Fig. (**1**).

CHAPTER 5

Survey of IoMT Interference Mitigation Techniques for Wireless Body Area Networks (WBANs)

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Abstract: Medical data can be stored and analyzed using the Internet of Medical Things (IoMT), which is a collection of smart devices that link to a wireless body area network (WBAN) using mobile edge computing (MEC). The Wireless Body Area Network (WBAN) is the most practical, cost-effective, easily adaptable, and non-invasive electronic health monitoring technology. WBAN consists of a coordinator and several sensors for monitoring the biological indications and jobs of the human body. The exciting field has led to a new research and standardization process, especially in WBAN performance and consistency. In duplicated mobility or WBASN scenarios, signal integrity is unstable, and system performance is greatly reduced. Therefore, the reduction of disturbances in the project must be considered. WBAN performance may compromise if co-existing other wireless networks are available. A complete detailed analysis of coexistence and mitigation solutions in WBAN technology is discussed in this paper. In particular, the low power consumption of IEEE 802.15.6 and IEEE 802.15.4, 3 of one of WBAN's leading Wi-Fi wireless technologies, have been investigated. It will elaborate on a comparison of WBAN interference mitigation schemes.

Keywords: IEEE 802.11, IEEE 802.15.4, IEEE 802.15.6, Interference Avoidance Schemes, IoMT, WBAN, Wi-Fi.

INTRODUCTION

The Internet of Things (IoT) has transformed modern healthcare, gradually displacing traditional therapies in favor of ubiquitous healthcare technologies. As a result, medical practices must design strategies for providing the best possible

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patient care while yet being profitable. WBAN has evolved into a critical tool for obtaining healthcare services at any time and from any location. In real time, these networks can gather physiological, behavioral, and other health-related data. As a result, the WBAN may give those in need of emergency medical treatment with cost-effective and dependable real-time e-healthcare services. The World Wide Web of Things (WBAN) is also known as the Internet of Medical Things (IoMT) because it affects people by monitoring their health using wearable or implantable medical sensors.

Wireless Body Networks (WBAN) have many small and inactive devices (sensors) with a wireless connection. Sensors can be placed inside or on the body for the purpose of monitoring health. WBAN is made up of many sensors and coordinators. The sensor is sent to the coordinator of the health control center, the environmental and human functions perceive and transmitted to the coordinators. WBAN applications, as described by Tobon *et al*. [1], can be used in two areas: (i) medical applications for patient monitoring, (ii) non-medical applications such as biometrics, which is used for training. Communication uses two standards: IEEE 802.15.4 and IEEE 802.15.6. IEEE 802.15.4 identifies the levels of MAC control for short-term communications. Although IEEE 802.15.6 was proposed for localization in the body. WBAN is widely regarded as technical support for many applications, including health and safety monitoring and emergency situations. The most modern invention, the electronics, the sensor, as described by González-Valenzuela *et al*. [2], is a wireless transceiver, which eliminates the need for the receiving node and the communication infrastructure to transmit the observed data with one or more sensors; the Microcontroller Unit (MCU) allows devices and low-power concepts that can be linked together to create. The human body is mobile, and mobility is supported by this. Suppose the other WBAN service area penetrates the arm or leg transmission. Also, the devices that are in diameter enter the mobility. Interference between WBAN interference sensors (WBAN) of WBAN interference, (ii) interference between the same network using the same frequency band, WBAN, noise, and (iii) interference classification. Interference between domains created by different network interferences with coexistence can be seen in Fig. (**1**).

Multiple techniques exist for interference mitigation and to improve the network parameters like data rate, energy, and latency. Existing techniques will be discussed in section II. Section III describes the conclusion from all existing techniques. Section IV presents a discussion, and finally, references are given in section V.

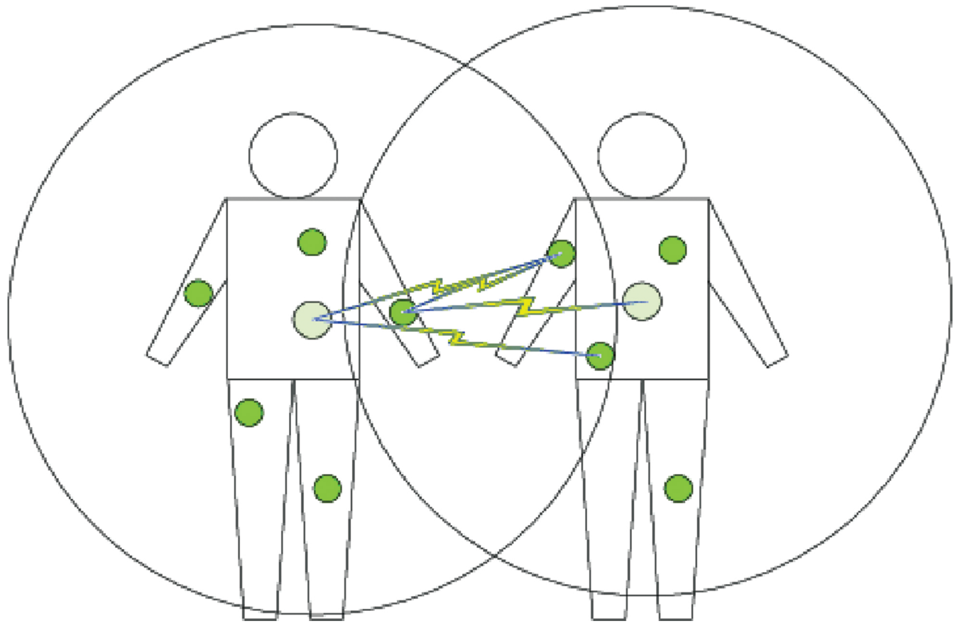

Fig. (1). Coexistence WBANs creating interference.

Difference Between WBAN *vs.* WSN Concerning IoMT

WBAN, as described by Le *et al*. [3], Yang *et al*. [4], and Sana Ullah *et al*. [5], is an effective standard for eHealth applications and telemedicine applications in the introduction starts with IEEE standards 802.15.4 and 802.15.6. It observes and records the main signs and significant changes in the patient's condition. There is a consensus among scientists that WSN and WBAN are not exactly the same. As mentioned by Kailas *et al*. [6], Chen *et al*. [7], and Khan *et al*. [8], there are some differences between WSN and WBAN. Protocols developed for WSN and AD-Hoc networks may not match WBAN properties. WBAN size and energy fields are stricter than WSN. In addition, the WBAN information includes medical data that causes reliability, security, and time problems for WSN applications. Due to health risk concerns, transmission control is extremely limited in WBAN. Therefore, the range and transmission range of WBAN is considerably smaller than WSN. Finally, WBAN sensor nodes change the requirements and characteristics because the WSN's sensors are uniform and play a role in comparison. As mentioned by Lai *et al*. [9], the IEEE 802.15.6 WBAN standard was proposed as a talented wireless invention for very fewer power devices, for example, IEEE 802.15.4 or IEEE 802.15.6 utilized as a part of a human body. This innovation is particularly proposed for WBANs process and arrangement condition, creating it a reasonable choice for various applications in medical and different fields. The different frequency bands used for the transmission contained

CHAPTER 6

Artificial Intelligence-Based IoT Applications in Future Pandemics

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Abstract: One of the greatest issues confronting the globe now is the pandemic disease calamity. Since December 2019, the world has been battling with COVID-19 pandemic. The COVID-19 crisis has made human life more difficult. Decision-making systems are urgently needed by healthcare institutions to deal with such pandemics and assist them with appropriate suggestions in real-time and prevent their spreading. To avoid and monitor a pandemic outbreak, healthcare delivery involves the use of new technologies, such as artificial intelligence (AI), the internet of things (IoT) and machine learning (ML). AI is reshaping the healthcare system to tackle the pandemic situation. AI is the science and engineering of creating intelligent machines to give them the ability to think, attain and exceed human intelligence. The advancement in the use of AI and IoT-based surveillance systems aids in detecting infected individuals and isolating them from non-infected individuals utilizing previous data. By assessing and interpreting data using AI technology, the IoT-based system employs parallel computing to minimize and prevent pandemic disease. In a pandemic crisis, the ability of ML or AI-based IoT systems in healthcare has provided its capacity to monitor and reduce the growth of the spread of pandemic disease. It has even been shown to reduce medical expenditures and enhance better therapy for infected individuals. This chapter majorly focuses on the applications of AI-based IoT systems in tracking pandemics. The ML-based IoT could be a game-changer in epidemic surveillance. With the proper implementation of proposed inventions, academicians, government officials and experts can create a better atmosphere to tackle the pandemic disease.

Keywords: Artificial Intelligence, COVID-19, Healthcare, Internet of things, Machine learning, Pandemic.

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INTRODUCTION

The viruses that originate from wild birds or animals are the main cause of pandemic diseases. The virus enters the human body through mutation. India has endured a wide range of epidemics and pandemics over the years. An epidemic is an uncommon occurrence of specific health-related problems, events, and diseases in a region or community. It involves a sudden, severe outbreak of a disease that pre-existed in the community. The term pandemic is used to describe the rapid spread of diseases throughout the world. Thus, there is a need to confront and eradicate the problems of global health along with adequate measures to prevent further transmission. The history has been replete with reports about cholera, smallpox, dengue, influenza, polio, plague, and several other diseases. Throughout history, many pandemics have occurred. Their control has been difficult in many instances because a functioning global surveillance system has not been in place. In India, Cholera had been a major issue throughout the 19th century, increasing death tolls each year. However, the influenza pandemic came later in the early 20th century [1, 2]. It has been reported that the primary cause of the sudden and rapid outbreaks of the disease is a lack of sanitation, proper public health, and malnutrition [3 - 5]. To manage the pandemic in India, the government and health organizations had been taken effective measures which are critical in controlling the pandemic [6, 7]. COVID-19, a recent outbreak that began in Wuhan City in December 2019, is one example of a pandemic. Humanity is now living in a limited area due to the pandemic situation. Pandemics have disrupted the normal life of humans. This situation has also influenced social, business, and regional activities and thus forced them to live within certain limits. COVID-19 was declared a worldwide pandemic based on its severity on January 30, 2020 [8, 9]. Recent updates on COVID-19 cases were approximately 452 million confirmed cases, with 6.02 million deaths reported [10]. The COVID-19 virus can be transmitted to others from infected individuals in numerous ways and is considered hazardous [11]. Therefore, a complete lockdown has been imposed throughout the country to prevent the virus from spreading further. Several countries have curbed their outbreaks by enforcing a strict lockdown. Still, despite a complete lockdown, the disease is not completely eradicated. Numerous nations have worked jointly on developing medicine to treat COVID-19 [12, 13]. However, as of now, there has been no known treatment to completely eradicate this disease. Nevertheless, few medicines are being investigated as prospective therapies. Moreover, the WHO has recommended clinical trials for the proposed medicine [14, 15]. A timely and accurate diagnosis of COVID-19 patients is essential to their medical treatment and thus helps in preventing the spread of outbreaks.

During the worldwide crisis, the medical industry is seeking new technologies that can monitor and control this pandemic of the COVID-19 virus. One such technology is artificial intelligence (AI), which identifies patients at risk, offers them medical help, and controls the spread of infection in real-time. Moreover, helps in easily tracking the transmission of the virus. To track cases, locate disease clusters, diagnose COVID-19, keep records, and predict future outbreaks, an AI system has been effectively used [16]. Machine learning (ML) and deep learning (DL) are the two types of AI subfields. Both ML and DL are part of AI. ML is a branch of computer vision that uses algorithms to assess, make decisions, and learn from raw data. ML is also applicable to support medical discovery and clinical decisions [17]. They have limited capabilities when it comes to processing raw data. DL, a recent and fastest-growing subfield of machine learning, has inspired great global interest in the previous few years. Unlike machine learning, DL does not necessitate the creation of handmade features or the manual extraction of data. It's a more advanced form of machine learning that allows computers to extract, understand, and analyze meaningful facts or information from raw data, then process it and make decisions based on it. Different representations of learning mechanisms are attempted by DL. DL assists in the abstraction of process input data from large-scale data by applying a multi-layered deep neural network (DNN) [18, 19]. Radio imaging technology, such as X-ray, clinical blood test data, and computed tomography (CT), are utilized to screen patients utilizing ML and AI. Radiological images such as CT filters and X-rays can be used by doctors to supplement traditional diagnosis and screening methods [20]. Internet of things (IoT) is the most up-to-date, popular, and advanced technology that can automate remote control, intelligent management, data monitoring, and management *via* a real-time network. As a result, using AI-supported IoT technology is of great importance to clinical medicine and particularly in the context to prevent and control the spread of future pandemics. Fig. (**1**) represents the benefits of AI and IoT in the field of the healthcare field.

The IoT powered by AI allows the emulation of intelligent behavior that aids in decision-making with a minimum amount of human interventions. IoT systems are used to collect data remotely from COVID-19 patients. Healthcare workers are given this information to diagnose COVID-19. In addition, using the previous patient's data, the software can forecast the mortality risk. AI is about devices learning from their experience and stored data, whereas IoT involves devices communicating using the internet [21 - 23]. Any device that is capable of connecting to the internet for transferring and monitoring data is an IoT device. IoT has gained traction in industry and academic disciplines, particularly in healthcare, in recent years. Modern healthcare systems are being transformed by the IoT revolution, including economic, societal, and technological implications. It is transforming the healthcare system from traditional to become more

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CHAPTER 7

Cyber Secure AIoT Applications in Future Pandemics

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Abstract: In the era of digitalization, artificial intelligence and IoT play an important role in COVID-19. Collecting real-time data using the internet of things has removed barriers and improved end-to-end delays between patients & doctors. During COVID-19, IoT connected people through wireless communication technology. However, by utilizing AI, different diseases can be identified easily. This research article has merged IoT with AI, which is called the Artificial Internet of Things (AIoT). Monitoring of patient health can be made possible due to the sub-class of AI known as machine learning. Industry 5.0 has combined big data, IoT, AI, 5G and cognitive ICT technologies to exchange information. Due to the widespread of dangerous diseases, people face several challenges, including inadequate preparation, shortage of medicines and poor resources, and increasing death rates. Data collection is the initial step toward research and innovation. Therefore, many applications are discussed properly, which include tele-medicine, early warning systems, wearable devices, and UAVs that help to support the healthcare industry.

Keywords: AI, COVID-19, IoT, UAVs.

INTRODUCTION

Integration of AI & IoT has gained a lot of attention, improving standards, especially in the healthcare industry. Internet of things uses sensors to collect information. Zigbee is a contemporary protocol that is considered the backbone of IoT [1]. Every country tried a lot to reduce COVID-19 by giving awareness using social and mainstream media. However, there exist many applications related to healthcare which include remote patient monitoring, fighting against COVID-19, heart disease detection, electronic medical report cards and tracking the infectious disease. Utilizing machine learning, doctors predict different diseases easily [2]. IoT enhances machine-to-machine and human-to-machine cognition to learn from

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the environment [3]. Smart IoT-based machine learning concepts train algorithms to provide efficient results in the healthcare industry [4].

Industry 5.0 will provide combined knowledge of IoT, big data, AI and 5G to give possible solutions regarding healthcare. While multi-kernel is used in IoT applications for processing better-quality images [5]. Also, smart mobile applications are developed to monitor the health status of every patient [6]. Moreover, telehealth web and mobile applications are used all over the world to give optimal consultation to patients [7]. Traditional server-client environments can be utilized using wireless body area sensor networks to provide high accuracy levels in healthcare applications [8, 9]. The major contribution points of this research paper are as under:

- Artificial Internet of things applications for healthcare
- Machine learning techniques for COVID-19
- Industry 5.0 for smart healthcare systems
- Using flying vehicles in the health industry
- People's facing challenges because of future pandemics

This research article has diverse studies about AIoT, machine learning techniques, industry 5.0, UAVs and future challenges because of pandemics. Fig. (**1**) shows wireless body area IoT sensor nodes connectivity with mobile devices using the internet for tele-medicines.

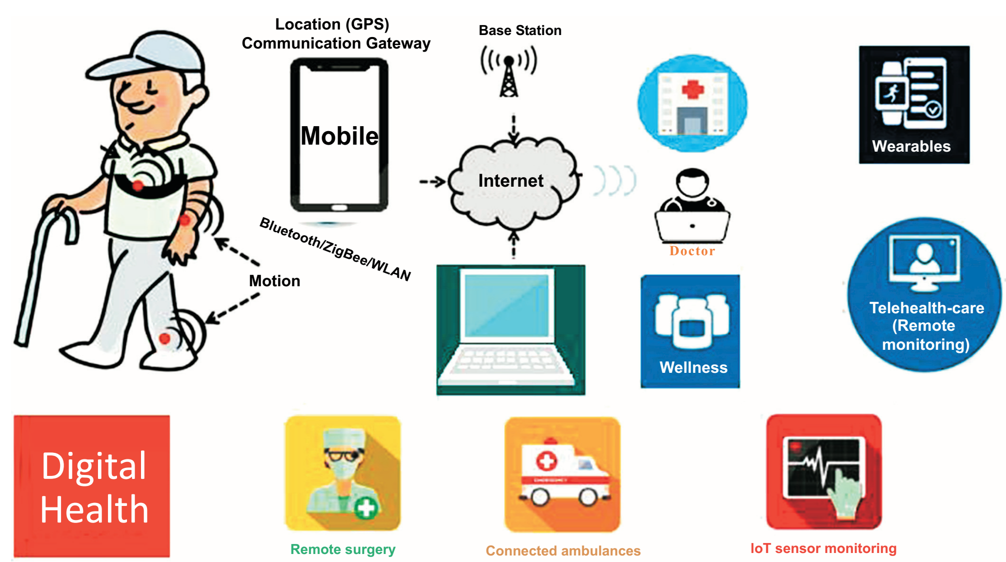

Fig. (1). Wireless body area IoT sensor networks for tele-medicine.

LITERATURE STUDY

AI-based models are designed to mimic the threat and unstable behavior of patients. Various types of AI technologies are initialized due to that COVID-19 can be tackled easily [10]. However, IoT can be used to secure communication mediums between patients & doctors [11]. Wearable systems need to be utilized, which give signals to satellites and base stations for further action [12]. Investigation of IoT-based applications is designed to improve the healthcare industry [13]. Industry 5.0 has revolutionized healthcare by utilizing IoT, AI, big data and communication networks. Tele-medicines applications are used a lot during COVID-19 to remotely discuss health-related issues with doctors [14]. Online smart clinics and IoT sensors or wearables are introduced to help people during COVID-19 [15].

The whole world has suffered COVID-19, which has exhausted my entire life. AI & and IoT have made a huge impact to facilitate humans [16]. A novel algorithm is formulated to optimize UAV energy levels using E-AntHocNet, which has many healthcare applications. UAV's can be used for monitoring rescue operations and sending medical equipment's from one place to another. Flying ad hoc networks is the combination of UAVs. Due to the high level of mobility, aerial vehicles use routing techniques to send information using the shortest routes [17].

Table 1. Various applications for patients monitoring.

Author/Reference	Applications	Description
Timmers T. *et al.* [18]	Education based application	Providing information about patients
Bourdon H. *et al.* [19]	Hospital information system application	Pandemic COVID-19
Medina M. *et al.* [20]	Monitoring-based application designed for home	Collecting information on the telephone
Drew D & Nguyen L. *et al.* [21]	IoT-based monitoring app	Data collection from the internet of medical things
Ben Hassen H. *et al.* [22]	Students Mental Health Monitoring	Checking & evaluating behavior of students during COVID-19
Yamamoto K. *et al*. [23]	Data sharing using a simple mail transfer protocol	Email-based observation and generating a receipt
Huckins J.F. & daSilva A.W. *et al.* [24]	Tele-net communication using a phone	Specifically designed for eyes

CHAPTER 8

Machine Learning Solution for Orthopedics: A Comprehensive Review

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Abstract: Bone provides support to the skeletal system, associated with joints, cartilage, and muscles attached to bones to help move the body and protect the human internal organs. Bone fracture is a common ailment in the human body due to external force on the bone. The structure of the bone is disturbed, which causes pain, frailness, and bone not functioning properly. Avulsion fracture, Greenstick fracture, Comminuted fracture, Compression fracture, Simple fracture, and Open fracture are different types of fractures. The literature presents a significant number of research papers covering the detection of different kinds of fractures (wrist, hand, leg, skull, spine, chest, *etc.*). There are different medical imaging tools available such as X-ray, Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and ultrasound, which detect different types of fractures. This paper represents a review study to discuss various bone fracture detection and classification techniques between fracture and non-fracture bone.

Keywords: Bone Fracture, Classification, CT, Detection, Machine Learning, MRI, Orthopedics, X-ray.

INTRODUCTION

Medical image processing is an evolving field of science growing immensely in the healthcare industry because of its advancements in technology and software breakthroughs. It plays an essential role in disease diagnosis, improves patient care, and helps medical practitioners with the treatment type. Detection, assessment and adequate fracture care are considered important as a misdiagnosis frequently contributes to inadequate medical intervention, heightened frustration and expensive lawsuits, as described by Umadevi *et al.* [1]. In medical image processing, bone is the structural framework of the body called a skeleton, which protects the internal organs such as the ribs, making a shield around the heart, liver, and lungs, as shown in Fig. (**1**). The skull protects the human brain, and the

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spine protects the nerves in the human body's spinal column. Bone, as mentioned by Abubacker *et al.* [2], provides the environment for bone marrow for blood cell creation and acts as a storage area for minerals and calcium.

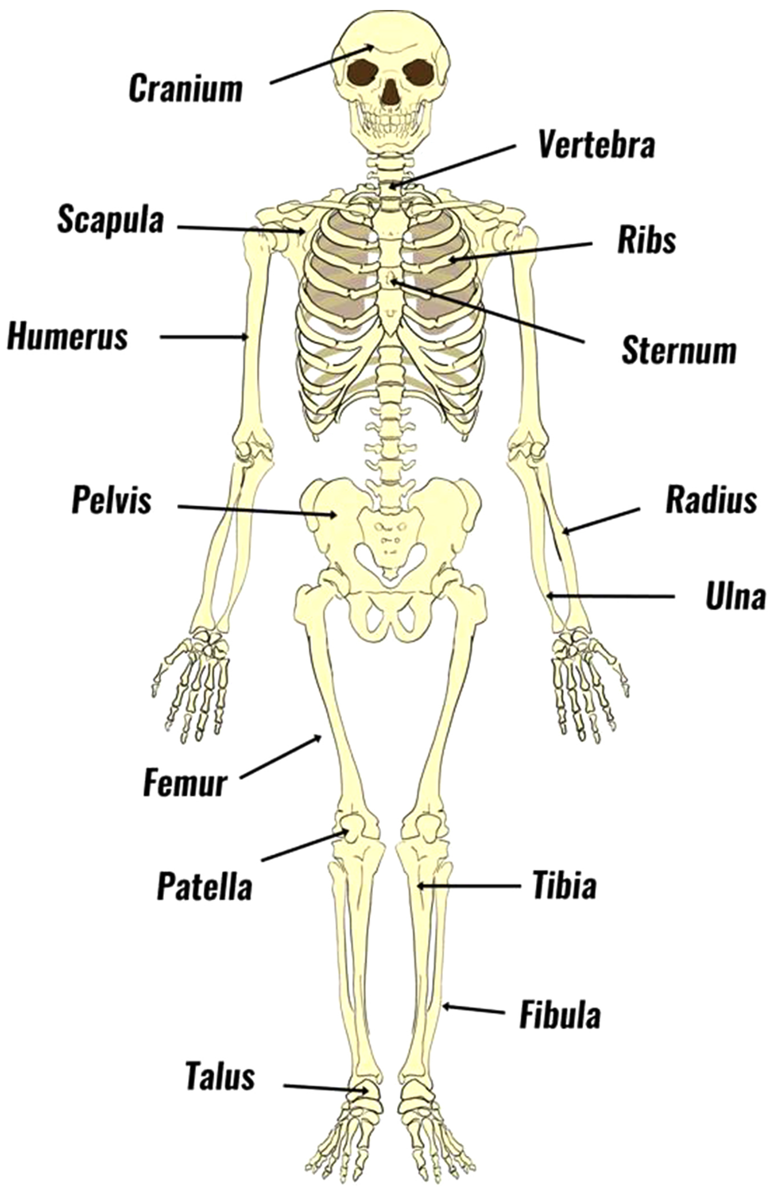

Fig. (1). Bones in human body.

At birth, there are around 270 soft bones which are reduced to 206 in adulthood.

The largest bone in the human body is the thighbone or femur bone, and the smallest is the stapes in the middle ear, which is 3mm long. As shown in Fig. (**2**), the internal structure of bone provides strength to the body, as described by Vijayakumar *et al.* [3].

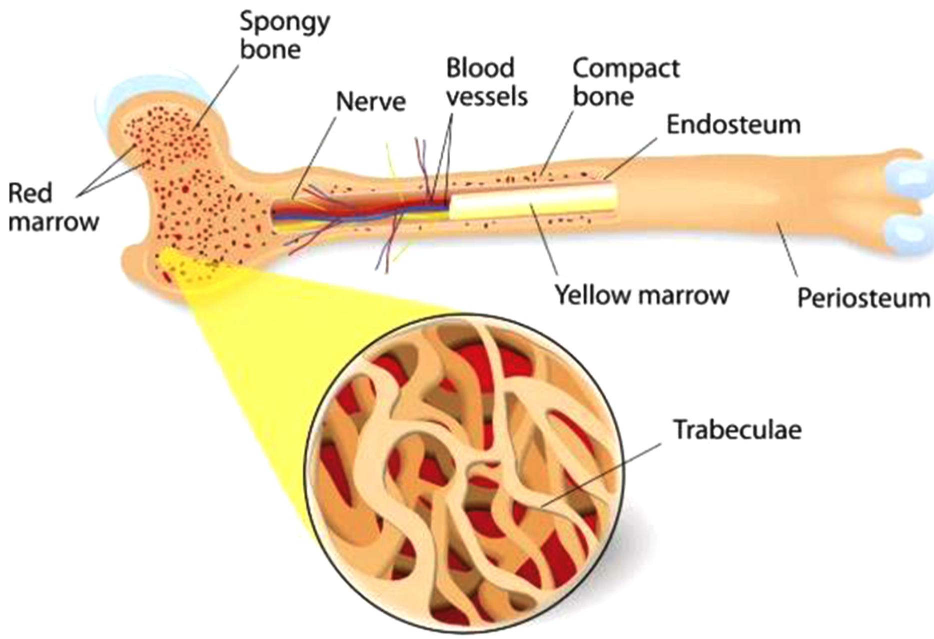

Fig. (2). Internal structure of bone.

In the human body, a fracture is the main ailment of human bone due to external force and crack. The images are further analyzed using medical image processing to identify the bone fracture. According to Al-Ayyoub *et al.* [4], medical imaging can automatically diagnose the image using an advanced computer.

Human organs in digital form, as described by Imad *et al.* [5], are created by using different equipment, such as X-ray, Mammography, MRI, Ultrasound, Endoscopy, Positron Emission, Tomography, Fluoroscopy, Clinical Imaging, and bone scanning. According to Irfan Ullah *et al.* [6], X-ray is the latest non-invasive, painless, and economical solution. An X-ray can make the bone image in the body, such as the wrist, knee, ankle, and leg.

A crack, also known as a fracture, can be any bone in the body. The fracture may include the hip, wrist, ankle, spine, Jaw, and ribs. Fractures are classified as open (if the skin is damaged) or closed (if the skin is intact). A break to the bone that does not harm the surrounding tissue or rip through the skin is a closed fracture.

CHAPTER 9

A Review of Machine Learning Approaches for Identification of Health-Related Diseases

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Abstract: The field of medicine is one of the most respected and oldest professions in human history. It has a direct impact on human life. The main purpose of this chapter is to present a brief introduction to the use of advanced computer science technologies like machine learning in the process of disease detection. The chapter also discusses different machine learning algorithms which are used in the process of disease detection. It also points out which algorithms give better accuracy. This chapter lists all major and most commonly used machine learning libraries to detect various life-threatening diseases. Lastly, a discussion on the future trends of technology which can be used in disease detection, and viral disease control is presented.

Keywords: Disease Detection, IoMT, Machine Learning, Machine Learning in IoMT.

INTRODUCTION

Currently, computational technologies are applied almost in every field of life. The medical field is considered to be one of them. During the past few years, a lot of research has been conducted in this domain to identify and treat diseases early on using machine learning approaches. Since machine learning can perform human cognitive functions effectively, thus it becomes a more suitable approach in the detection and treatment of disease. Recently, there has been lots of research done for the development of specialized methods in machine learning which can be highly accurate in the detection of a variety of diseases. However, we still struggle to detect and diagnose several life-threatening diseases because of the highly heterogeneous environment [1]. Several life-threatening diseases can be

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treated if they are detected at early stages, as shown in Fig. (**1**). Thus early detection of disease is essential.

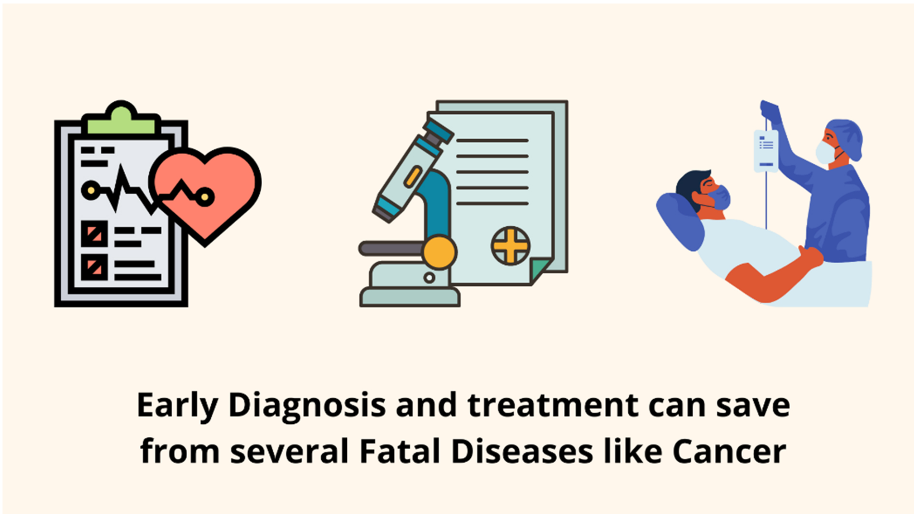

Fig. (1). Early detection can save lives from fatal diseases.

In the past few decades, a lot of research has been conducted in the development of Machine learning algorithms that can perform human cognitive tasks. The medical field has greatly benefited from it; researchers developed machine learning models which can accurately detect or predict diseases like tumors, cysts, pneumonia, *etc.* They use MRI and CT Scan X-ray images coupled with computer vision technologies to detect or predict high-risk diseases at a very early stage. Machine learning algorithms also work on numeric and Boolean values obtained through different types of sensors [2]. Through the use of machine learning, computers can mimic human cognitive behavior and recognize different patterns. Computers can then effectively detect any abnormalities in those patterns and classify whether the patient has a specific disease. Machine learning has two major approaches: Supervised Learning and Unsupervised Learning (there also exists a hybrid of these two, semi-supervised learning). Fig. (**2**) shows a pictorial representation of different types of Machine learning techniques.

Supervised Learning

Supervised machine learning provides a labeled dataset during the training phase. The model learns to map an input to an output based on the examples provided during the training period. Examples of supervised learning are classification and logistic regression. Classification algorithms are used to assign a distinct label based on learning performed on test data. For example, a classification algorithm can differently classify a dog and a cat. There are various classification algorithms like *Naïve Bayes, KNN, Decision Tree, Support Vector Machines, etc.* [3].

Regression algorithms are used to estimate the relationship between the dependent and independent variables. They are used to predict numeric values. For example, many companies use linear regression models to predict costs, profit, loss, *etc*. There are several types of regression models: Linear Regression, Logistic Regression, Ridge Regression, Polynomial Regression, *etc*. [4].

Unsupervised Learning

Unsupervised learning is a type of learning labeled dataset that is not provided to the computer. Instead, the computer finds different patterns on its own. It is based on pattern recognition without being provided with any target attribute, like in supervised learning. It finds hidden patterns and insights in data. It can be used when we do not have any labeled data for training and want to get useful insights and patterns in that data. Unsupervised learning's example is clustering, where the model group data based on similarities. There are different types of clustering algorithms like *Partition based clustering, Fuzzy clustering algorithms, Model-based clustering algorithms, Density-based Clustering Algorithms, K-Means Clustering, etc.* [5].

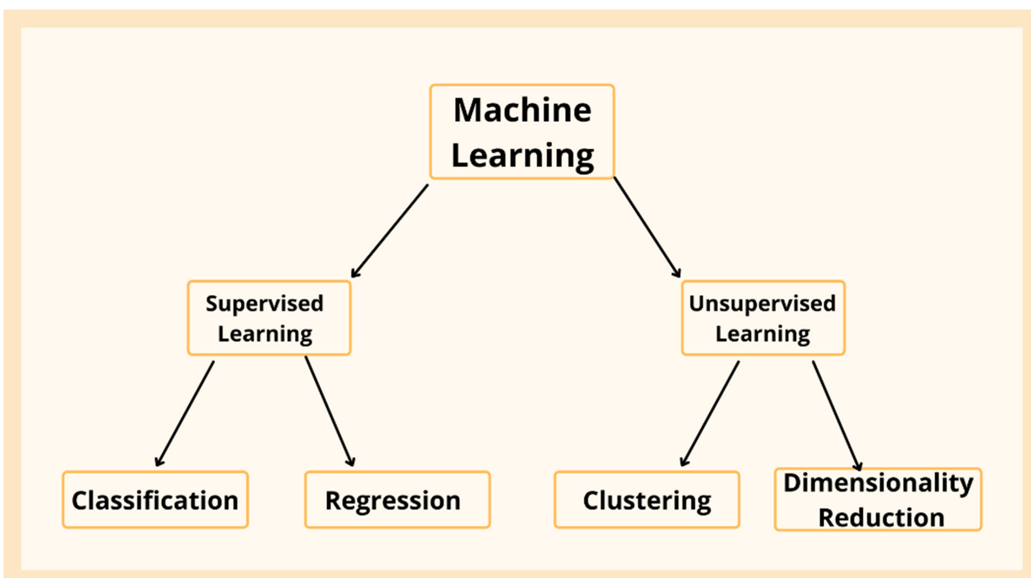

Fig. (2). Different machine learning algorithms and their uses.

CHAPTER 10

Machine Learning in Detection of Disease: Solutions and Open Challenges

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Abstract: Disease diagnosis is the most important concern in the healthcare field. Machine Learning (ML) classification approaches can greatly improve the medical industry by allowing more accurate and timely disease diagnoses. Recognition and machine learning promise to enhance the precision of diseases assessment and treatment in biomedicine. They also help make sure that the decision-making process is impartial. This paper looks at some machine learning classification methods that have remained proposed to improve healthcare professionals in disease diagnosis. It overviews machine learning and briefly defines the most used disease classification techniques. This survey paper evaluates numerous machine learning algorithms used to detect various diseases such as major, seasonal, and chronic diseases. In addition, it studies state-of-the-art on employing machine learning classification techniques. The primary goal is to examine various machine-learning processes implemented around the development of disease diagnosis and predictions.

Keywords: Classifiers, Machine learning Disease classification, Machine Learning Methods.

INTRODUCTION

Everybody remains so concerned with their families and careers that they do not have time to care for themselves in today's era. Due to their hectic lives, most individuals suffer from anxiety, nervousness, sorrow, and various other ailments. Taking this into consideration key, they are acquiring factors, are severely ill, and have acute diseases. Numerous diseases cause individuals to die each year, such as heart disease, cancer, liver cancer, tuberculosis, and so on, but major or chronic diseases cause the biggest number of deaths in the healthcare domain [1]. Modern

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technology contributes to the expansion of advanced healthcare methods, such as smart human health monitoring systems, and individualized treatment to make a diagnosis for everyone with the utmost care. People are affected by many diseases every day, all around the world. Some of these diseases remain undiagnosed and reach the critical phase [2]. COVID-19, malaria, dengue fever, the common cold, and fever are all detected and treated along with basic laboratory examinations and readily obtainable drugs.

However, featuring cancer, chronic, seasonal, psychiatric problems, and several diseases and infections can be controlled at a certain stage with more effort. In rare cases, they can even be treated if caught early enough [3]. Most previous research attempted to predict disease occurrence using patient laboratory testing and drugs [4, 5]. These models remained also widely applied to describe unknown risk factors, typically although simultaneously increasing detection specificity and sensitivity. Multiple approaches, including supporting vectors, machines logistical regression, random forests method, neural networks model and time cycle modeling methods, have been found to be useful in predicting disease in recent research [6, 7]. Before doing a thorough analysis of the problem, it is necessary to have a deeper understanding of basic ML techniques. The main objective of this work is to offer an overview of existing ML approaches [8]. The major contributions of this survey paper are listed below:

1. A novel state-of-the-art literature survey on diseases' detection based on Machine and Deep Learning is presented.

2. Taxonomies based on supervised, unsupervised, reinforcement, and deep learning are proposed.

3. A critical analysis of state-of-the-art is presented in a tabular way.

4. Issues and challenges concerning disease type and ML approach are presented.

The rest of the paper is organized as follows: Section 2 presents a classification and taxonomy of ML approaches used in disease prediction. Section 3 details disease detection mechanisms, and finally, Section 4 provides the conclusion and future directions.

MACHINE LEARNING APPROACHES

This research focuses on categorizing ML approaches into supervised, unsupervised learning, reinforcement learning, and DL, as seen in Fig. (**1**). The categories are mentioned below:

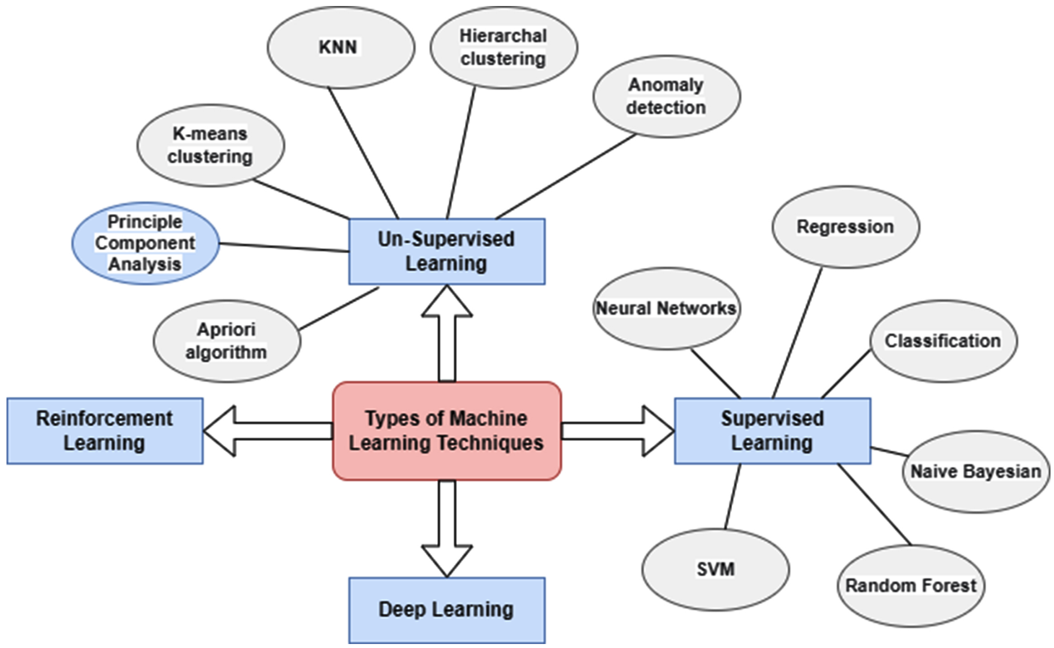

Fig. (1). Diagrammatic representation of machine learning techniques.

Supervised Learning (SL)

Given a training number of instances with appropriate targets, processes respond accordingly to the complete possible inputs created on this training set. The SL method is also known as learning from exemplars. The two-step SL method is as follows and shown in Fig. (**2**).

- A predictive model is a combination of available data and known answers.
- When showing new data, the predictive model offers appropriate responses.

Unsupervised Learning

There are no appropriate responses or targets specified. Unsupervised learning explores commonalities between the stored data and classifies the data based on these commonalities. Data acquisition is yet another name for this. Clustering is a feature of unsupervised learning. When no outputs are provided, un-supervised ML is used to learn patterns in the data from the inputs. Clustering, NNs, and HMM are often used as unsupervised learning techniques. These methods allow the exploration of unlabeled data to find intrinsic or hiding patterns.

CHAPTER 11

Breakthrough in Management of Cardiovascular Diseases by Artificial Intelligence in Healthcare Settings

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Abstract: The cardiovascular system includes the heart and its associated blood vessels. Disorders of this cardiac system are called Cardiovascular disorders (CVD). Management of CVDs is often complex due to challenges like inadequate patient care, readmissions, low cost-effectiveness, and cost reductions in preventions, treatments, and lifestyle modifications. Hence, to overcome these challenges, Artificial Intelligence (AI) is being developed. They addressed emerging problems in clinical and health care settings and had a tremendous impact on the public. Implementation of AI in cardiovascular medicine affects more on new findings. It also provides a high level of supporting evidence that may be useful within the evidence-based research paradigm. A review of available free full-text literature in the PubMed database was carried out to study the influence of AI on health care settings. This work reviews AI-based algorithms used in cardiac practice and the applications of AI in cardiovascular medicine in terms of interpretation of results and medical image analysis.

Keywords: Algorithms, Applications, Artificial Intelligence, Cardiovascular Disorders, Healthcare.

INTRODUCTION

Artificial intelligence is a technology-based approach established in the mid-1950s. It is the trendiest technology in the contemporary world due to the imitating nature of human intelligence. Artificial means discovered by humans and intelligence represents thinking ability. This covers the aspects like machinery/systems/algorithms based on beneficial results in making decisions.

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They work like the biological brains and maximize the success ratio [1]. Artificial intelligence is being used for various purposes in the present world. It can solve complex problems efficiently in multiple industries like Healthcare, finance, education, agriculture, robotics.

AI is useful in the healthcare field and used in various fields like education, Astronomy, Agriculture, business, Surveillance, Social media, apps, Transportation, Gaming, Banking, and Electronic prescriptions.

Cardiovascular diseases (CVDs) raise death concerns globally, which accounts for 17.9 million lives annually. CVDs constitute the pumping organ, heart, circulatory system like arteries, veins, capillaries, *etc*. Their damage may lead to fatal conditions, such as Coronary blockade, inflammatory conditions of heart valves leading to cardiomyopathy. Statistics provide data that most CVD deaths are mainly because of heart attacks, strokes, and nearly one-third of deaths in 70 years aged people (https://www.who.int/health-topics/cardiovascular-diseases). These are caused due to various factors like genetic, environmental, and lifestyle changes leading to the alteration of valuable microorganisms in the intestinal system of humans. The annual report of the American Heart Association (AHA) and the National Institute of Health confirmed possible causes for heart problems among the population are mentioned below:

1. Cigar inhalation,

2. Lack of Physical exercise,

3. Inappropriate food habits,

4. Weight gain,

5. Cholesterol,

6. Rise in systolic blood pressure (BP),

7. Elevated blood sugars [2].

There exists a two-way correlation allying technology as well as health. To explore the challenges among advanced and growing countries, they utilize innovation as a prime focus to cope with the problems. Hence technology-based approaches especially AI in health care, slowly drifted the entire medical system. It also transformed the hospitals, lives of the public. For example, they aid in interpreting results, lessening the test, and allowing the public to take their verdicts.

The use of expert systems within the cardiology department is limited to only some countries for various reasons; however, instead of its limitations, it finds very useful. Using such approaches, we can analyze the disease models efficiently, and also a considerable amount of data can be easily saved in the databases. Advantages with the integration of AI in cardiovascular settings are described in Fig. (**1**).

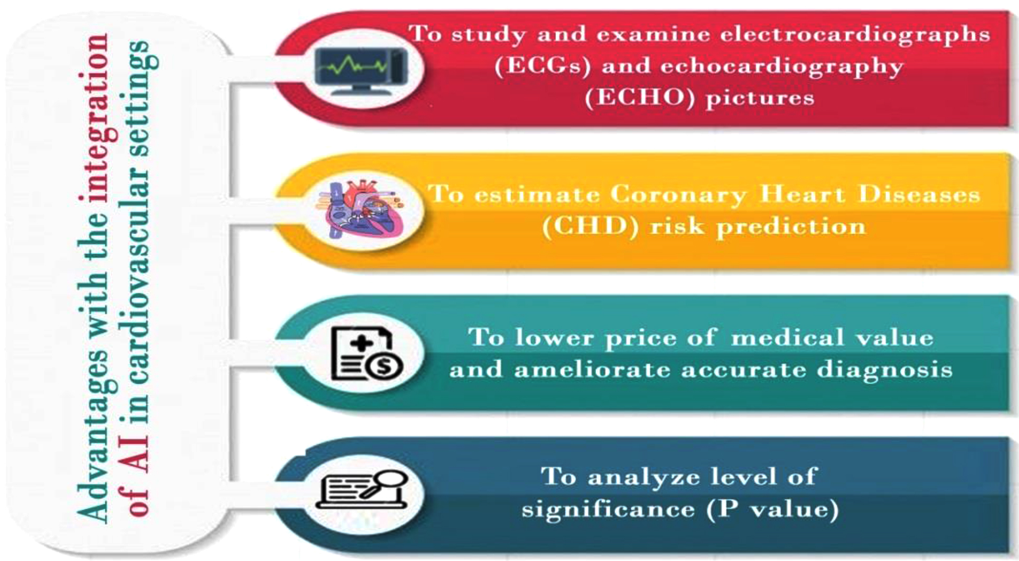

Fig. (1). Advantages with the integration of AI in cardiovascular.

However, this version needs several fixed hypotheses that do not depend on factors like observations and other multicollinearity values. The conventional logistic regression method improves the statistical value, but it is sometimes independent towards the target, therefore, obstructing the model's execution. On the other side, AI algorithms are used in various clinical departments as they provide results exactly by using the information stored in the data sets.

The impact of computational intelligence in cardiology clinics changed cardiac clinic experimentation patterns and, thus valuable for clinical practice and general public health, as shown in Fig. (**2**) [3].

CHAPTER 12

Smart Cane: Obstacle Recognition for Visually Impaired People Based on Convolutional Neural Network

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Abstract: According to the World Health Organization (WHO), there are millions of visually impaired people in the world who face a lot of difficulties in moving independently. 1.3 billion people are living with some visual impairment problem, while 36 million people are completely visually impaired. We proposed a system for visually impaired people to recognize and detect objects based on a convolutional neural network. The proposed method is implemented on Raspberry Pi. The ultrasonic sensors detect obstacles and potholes by using a camera in any direction and generate an audio message for feedback. The experimental results show that the Convolutional Neural Network yielded impressive results of 99.56% accuracy.

Keywords: Convolutional Neural Network, Raspberry Pi, Ultrasonic Sensors, Voice Message.

INTRODUCTION

According to the World Health Organization, at least 2.2 billion people have vision impairment problems, of which 1 billion people have been prevented or yet to be left addressed. The world faces extensive challenges related to eye care, including treatment, shortage of trained eye care service providers, and poor integration of eye care in the health system [1]. The report was released on world sight day to warn the population of aging, an increasing number of vision impairments, and blindness problems from different eye diseases, such as Presbyopia, affecting 1.8 billion individuals, which can occur at an early age. Myopia affects 2.6 billion, with 312 billion under the age of 19. Other diseases are cataract, which affects 65.2 million, glaucoma affects 6.9 million, corneal opacities affect 4.2 million, diabetic retinopathy affects 3 million, trachoma affects 2 million people, which is the cause of vision impairments [2].

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A visually impaired person faces many difficulties that take a sighted person's aid to find their way. In an unfamiliar environment, blind persons can't find their path themselves. Generally, visually impaired persons use a white cane or walking cane. Electronic Aid technology like Ultrasonic sensors can be used to help visually impaired persons. In the ultrasonic system, energy waves are emitted, reflecting from the obstacles on any side (left, right, front) to help the visually impaired person detect the obstacle within the defined range. The distance between visually impaired persons and the objects is calculated according to the starting and ending pulse from the ultrasonic sensor. We have used a buzzer sensor to inform the blind user about the obstacles. Suppose the obstacles are too close to the blind user. In that case, the proposed system will generate a voice message, and also, a buzzer will be active to inform the visually impaired person about the obstacles. The main objectives of the smart cane system are to develop a model of cane for the blind, which is widely used in mobility. The second objective is to design a proposed model that consumes less power, is weightless, and has precise, accurate object/obstacle detection and recognition performance. This proposed design can provide full support against obstacle avoidance with a voice message. The proposed module will be useful for blind people. It is easier for them to find daily activities without using the standard mobility aid and available for individuals with this disability since mobility aids are less costly, light in size, and can be taken easily anywhere.

The Nivedita presented an electronic aid device consisting of a Raspberry pi device, an ultrasonic sensor, a web came microphone, and an LDR sensor. The ultrasonic sensor with a camera has been used to detect obstacles. The LDR sensor has been used to detect the brightness of the environment to check whether there is dark or bright automatically. The proposed system detects the object around the visually impaired person and sends feedback by voice using a microphone [3].

The Mary presents a Raspberry pi-based system for blind people with unique features, such as tracking the object around, sending feedback through voice, and providing information about the environment. The most important feature of the paper is to track the location of the blind person and notify the caretaker to ensure safety [4].

The rest of the paper comprises a literature review in Section 2, details of the proposed methodology (convolutional neural network) are given in Section 3, experimental result analysis, and discussion in Section 4. Finally, the paper is concluded in Section 5.

LITERATURE STUDY

The Tapu has been implemented as a smartphone-based obstacle to detect and classify to aid visually impaired people to walk freely and safely in an indoor and outdoor environments. The Lucas Kanade algorithm has been used to extract the feature from images or frames [5].

The camera and the background motion have been estimated through homographic transforms. The obstacles are detected as critical or normal, based on a specific distance, and then the obstacle has been detected and recognized [6].

The model has been proposed, which they used for obstacle detection techniques. Two methods have been used: adaptive colour segmentation and stereo-based colour homography. The pixels are classified into a frame or image in colour segmentation to find the obstacle or free space. The present system has been built on a training algorithm [7].

The proposed design model consists of a 2D laser scanner, foot-mounted pedometer, and three-axis gyroscopes to aid visually impaired people in an indoor environment. They presented 2-layered estimators. In the first estimated layer, the blind cane location has been tracked in the last layer. The second estimated layer finds the person's location keeping a blind cane is tracked [8].

Rodríguez has been presented as a method for obstacle prevention devices to help visually impaired persons. They have implemented an incremental map of the environment with the help of optical SLAM techniques to provide spatial direction and location of the visually impaired people at the same. The proposed design also provided audio feedback to inform the blind person about obstacles [9].

The electronic aid device consisted of three ultrasonic sensors and a microcontroller to detect the object range. The audio and vibration system also has been used to warn visually impaired people to avoid obstacles [10].

Pradeep proposed a device that involves an RGB-D camera for environment perception. The proposed system imposes three things; self-localization, obstacle detection, and object recognition. In self-localization, depth has been perceived based on the tracking technology of colour information. Obstacle detection and recognition provide meaningful information to visually impaired people and help recognize the obstacles such as stairs, walls, vehicles, and doors [11].

Leung has proposed a head-mounted, stereo-vision-based direction system for visually aiding impaired people. They have used visible odometry and feature-

CHAPTER 13

A Survey on Brain-Computer Interface and Related Applications

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Abstract: Brain Computer Interface (BCI) systems are able to communicate directly between the brain and computer using neural activity measurements without the involvement of muscle movements. For BCI systems to be widely used by people with severe disabilities, long-term studies of their real-world use are needed, along with effective and feasible dissemination models. In addition, the robustness of the BCI systems' performance should be improved, so they reach the same level of robustness as natural muscle-based health monitoring. In this chapter, we review the recent BCI-related studies, followed by the most relevant applications. We also present the key issues and challenges which exist in regard to the BCI systems and also provide future directions.

Keywords: Artificial Intelligence, BCI, EEG, Machine Learning, MEG.

INTRODUCTION

Brain Computer Interface (BCI) uses the brain's power to compute to make use of relatively new technology. According to Berger [1], research has been trying to decode the brain's signals since the first discovery of electroencephalography (EEG) a century ago. Until recently, the development of BCIs was thought of as science fiction. BCI system collaborates the brain with an external device that uses signals from the brain for performing external activities, such as moving a wheelchair, robotic arm, or a computer cursor.

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There are four main components of a BCI model, namely, the sensing device, the amplifier, the filter, and the control system. According to Herwing *et al*. [2] and Jurcak *et al*. [3], the sensing device comprises a cap consisting of the electrodes which are placed according to the international 10–20 standards. Furthermore, according to Zhang *et al*. [4], an amplifier could be one of several biological amplifiers available on the market, and the research on BCI is geared toward developing a filter and control system that can be applied to brain signals.

When a person thinks of performing any task, such as moving a cursor, then in such a case, signals will be generated in the brain, which is transferred from the brain to the finger on the computer's mouse *via* the body's neuromuscular system. As the follow-up step, the finger will move the cursor. In contrast, in BCI, such signals are transferred to an external device where they will be decoded for moving the cursor. As another example, research on BCI also aims to help such people who suffer from issues related to damaged hearing and sight and damaged movement. An estimated 1.5 billion people suffer from neurological and neuroanatomical diseases and injuries worldwide, resulting in movement impairments, which make it difficult to communicate, reach, and grasp independently. A cortical prosthetic system consists of an end effector, which receives a command for a particular action *via* a BCI that records the cortical activity of individuals who have suffered neurological injuries such as spinal cord injuries, amyotrophic lateral sclerosis, and strokes. In addition, a BCI decodes information pertaining to the intended function. There is a wide range of end effectors in use now, ranging from virtual typing communication systems to robotic arms and hands, as well as functional electrical stimulation for the reanimation of limbs.

BCI can be invasive in varying degrees, have varying spatial and temporal resolutions, and record a wide range of signals. In BCI applications, such as the low-throughput communication spelling systems, EEG, MEG, and fMRI can be used as non-invasive brain imaging technologies, according to Speier *et al*. [5]. Daly *et al*. [6] enumerated several problems associated with these noninvasive BCI approaches, such as the fact that they are often slow (*e.g.*, fMRI), have a low spatial resolution and are susceptible to being corrupted by external artefacts. Thus, such options are not suitable for complex real-time applications like high-performance communications, tracking multidimensional robotic limbs, or reanimation of paralyzed limbs with coordinated grasps and reaches. An invasive BCI, on the other hand, is able to command higher dimensional systems naturally and restore more complex functions, as a result of its higher resolution and wider transmission bandwidth.

According to Rosenow *et al*. [7], brain implants are among the most promising and popular technologies for assisting patients with motor paralysis (such as paraplegia or quadriplegia) caused by strokes, spinal cord injuries, cerebral palsy, and amyotrophic lateral sclerosis (ALS). Similarly, eye tracking can be used to control external devices by paralyzed people, but this tech has numerous drawbacks, as it relies on cameras or electrodes on the face to record eye movements or electrical signals, such as electrooculography (EOG). As a result of BCI, neural commands are delivered to external devices by translating human brain activity into external actions, according to McIntyre *et al*. [8], Chen *et al*. [9], and Donoghue [10]. While BCI is most often used to help disabled individuals with motor system disorders, it is also very helpful to those with healthy motor systems as well as the elderly. The development of intelligent, adaptive, and rehabilitative BCI applications for adults and geriatric patients will enhance their relationships with their families, improve their cognitive and motor skills, and help with household tasks. BCIs are generally regarded as mind-reading technologies, but this does not hold true in most cases. As opposed to mind readers, BCIs provide the user with control by using brain signals rather than muscle movements, so they don't extract information from unknowing or unwilling subjects. A BCI and a user are thus working together through training sessions which involve the user generating brain signals that inform the BCI of the intended action, and the BCI converting the signals into instructions that the output device is supposed to carry out.

As per the aforementioned, the research community faces numerous challenges in the implementation of BCI devices. Specifically, it is required that the electrodes and the surgical methods used in the BCI process are minimally invasive, which has resulted in much research focus on the non-invasive methods of brain-computer interfacing.

In this chapter, we survey the recent research on BCI and its related applications. The related works are detailed in Section 2. Section 3 discusses the most relevant applications of BCI. In Section 4, we highlight the main challenges in regard to BCI and propose the relevant directions. Finally, Section 5 concludes the chapter.

RELATED WORKS

Any human being usually produces a wide range of signals at any point in time, from the eyes, ears, nose, and other sensory organs in the body. These signals travel to the brain *via* the nervous system. The cerebral lobes play an important role for humans or animals when understanding perception, thoughts, language, and memory, and thus EEG sensors, NIRS detectors, *etc*., are used to acquire neural signals. With the help of these signals, the brain activity of a human or an

CHAPTER 14

Data Augmentation with Image Fusion Techniques for Brain Tumor Classification using Deep Learning

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Abstract: Brain tumor (BT) is a serious cancerous disease caused by an uncontrollable and abnormal distribution of cells. Recent advances in deep learning (DL) have helped the healthcare industry in medical imaging for the diagnosis of many diseases. One of the major problems encountered in the automatic classification of BT when using machine learning (ML) techniques is the availability and quality of the learning from data; these are often inaccessible, very confidential, and of poor quality. On the other hand, there are more than 120 types of BT [1] that we must recognize. In this paper, we present an approach for the automatic classification of medical images (MI) of BT using image fusion (IF) with an auto-coding technique for data augmentation (DA) and DL. The objective is to design and develop a diagnostic support system to assist the practitioner in analyzing never-seen BT images. To address this problem, we propose two contributions to perform data augmentation at two different levels: before and during the learning process. Starting from a small dataset, we conduct the first phase of classical DA, followed by the second one based on the image fusion technique. Our approach allowed us to increase the accuracy to a very acceptable level compared to other methods in the literature for ten tumor classes.

Keywords: Artificial Intelligence, Autoencoder, Brain Tumor, CNN, Data Augmentation, Deep Learning, Image Fusion, Machine Learning, Medicine 4.0, Visual Recognition.

INTRODUCTION

The emerging medicine, Medicine 4.0 [2], has dared to take the step of digitization; three-dimensional imaging, the connectionist power of artificial

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intelligence (AI) algorithms, surgical planning with specific software using AI, and the creation of personalized or adaptable implants to face the most complex situations. There are few industries where visual recognition (VR) [3] does not open up huge opportunities. VR technologies are capable of assimilating the textual content of photographed documents, and this ability could have a major impact on employment. The key will probably be to consider these technological solutions not in opposition, but as a complement to human work. This was proven by a Harvard study in the health sector. It found that DL alone effectively analyzes magnetic resonance imaging (MRI) in 92% of cases. For their part, doctors achieve a rate of 96%. But helped by AI, their rate exceeds 99.5% [4].

The Brain can be infected by a lot of tumors, principally if they are malignant or [5] persistent. According to the American association of neurological surgeons, there are 11 BT main classes: gliomas, meningioma, primitive neuroectodermal tumors, pituitary tumors, pineal tumors, choroid plexus tumors, dysembryoplastic neuroepithelial tumor, tumors of nerves sheaths, cysts, skull base, and primary central nervous system lymphoma [5, 6]. Each main class is subdivided into several subclasses to have in total more than 120 types of BT according to the World Health Organization.

DL is an application of ML, a field of AI, which represents a set of algorithms that automatically learn to recognize and classify data such as images. DL is inspired by the structure of the human brain and is heavily used in computer vision problems. The challenge of the use of DL in computer vision is how to find the best model (conventional neural network architecture and parameters). This operation requires a data set of labeled images and a specific learning algorithm to optimize the DL model parameters.

To solve the BT classification problem, we propose in this paper to use a combination of techniques to achieve very high recognition rates. These techniques are based on convolutional neural networks (CNN), data augmentation, image fusion and autoencoders. We have proven that the right combination of these techniques can overcome the problem of lack of data.

The rest of this paper is organized as follows: state of the art to present the different concepts used in this paper, such as DL, CNN, and the different techniques of DA and IF. The section of related works for the presentation of some scientific results concerning the subject of BT classification. The methodology section to the general presentation of our approach is subdivided into three large parts, one for the standard classification, one for the use of the DA techniques, and one for the use of the IF technique based on autoencoders. The results and discussion section for the presentation of the results obtained for each proposed approach and a possible comparison with the state-of-the-art methods, and at the end, a general conclusion is proposed.

BACKGROUND

The history of medicine remains inseparable from innovation, driven by generations of designers, engineers, doctors, clinicians, and then developers, startups, data scientists, and other researchers [7]. AI-based accurate diagnosis (diabetic retinopathy fundus diagnosis, the first direct AI diagnostic algorithm to be recognized by the Food and Drug Administration, in April 2018) [8], automatic and instantaneous skin cancer recognition and classification [9], automatic electrocardiogram reading [10], arrhythmia detection [11] and personalized chemotherapy [12].

Deep Learning

DL is one of the main ML technologies subfields of Artificial Intelligence [13]. The ML concept dates back to the middle of the 20th century. In the 1950s, Alan Turing, the British mathematician, imagined a machine able to learn, a "Learning Machine" [14]. Over the following decades, various ML techniques were generated to create algorithms to learn and improve themselves. Among these techniques are artificial neural networks (ANN) [15]. These algorithms are the basis for Deep Learning, but also for technologies such as image recognition or robotic vision. ANN is inspired by the neurons of the human brain [16]. They are made up of several artificial neurons connected to each other (Fig. **1**).

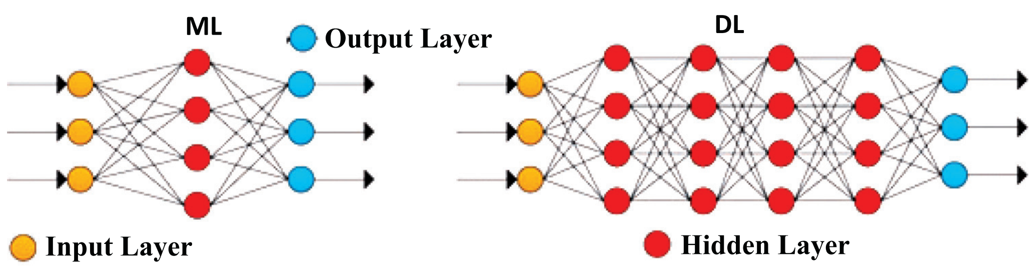

Fig. (1). DL is implemented by a deeper ANN architecture with multiple hidden layers.

Data Augmentation

CV processing models use a DA approach to cope with data sparingly and insufficient multiplicity [17]. DA algorithms can increase the accuracy of DL models and perform better in terms of training loss accuracy than a DL model without DA for image [18]. There are a lot of DA methods for images to create diversity in the learning data set of the model. It is easy to find many examples of

CHAPTER 15

Convergence Towards Blockchain-Based Patient Health Record and Sharing System: Emerging Issues and Challenges

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Abstract: The traditional technologies and digital systems of managing and maintaining data are inherently prone to manipulation at various levels. Ensuring the anonymity of the patient's identity, the safety of the medical records, and preventing the patient data from accidental and intended manipulations have been the industry's biggest challenges for decades. Failing to control the integrity of the Patient Health Records (PHRs) and Medical Health Records (MHRs) in the Healthcare Data Management System (HDMS)/ Healthcare Information System (HIS) may create challenges in identifying, diagnosing, and treating the disease and puts the patient at a greater risk. The frequency of healthcare data breaches, the magnitude of compromised records, and the financial impact rapidly increase with time. This chapter systematically and critically reviews the issues and challenges faced by various healthcare stakeholders in PHRs/MHRs-based HDMS/HIS systems. Blockchain powered patient health record and sharing schemes can be used to ensure the integrity and safety of healthcare data and share data among various healthcare ecosystem stakeholders using smart contracts to promote transparency, tamper-proofing, and consented access to data in distributed multi-stakeholder environment. This chapter highlights the need for post-quantum cryptography and recommendations for future improvements in blockchain-based patient health records and sharing system.

Keywords: Blockchain, Distributed Ledger, Healthcare Data Management System, Healthcare Information System, Medical Health Records, Patient Health Record, Post-Quantum Cryptography, Smart Contract.

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INTRODUCTION

The demand for quality healthcare has grown significantly not only in urban as well as rural areas. Modern healthcare industries are driven by privatization, liberalization, and globalization. Most of the new hospitals in developing economies are driven by public-private partnerships. Today's healthcare industry revolves around data, and the data's integrity, privacy, and truthfulness are at the center of the industry's evolution, operation, and further growth. The adoption of technology in healthcare has been increasing significantly, and the healthcare industry is becoming more paperless to reduce costs and enhance their service quality and efficient management of healthcare-related data. The healthcare data management system started with paperless departmental planning records and medical items inventory, followed by patient billing, laboratory testing, diagnostic report, and pharmacy stock and billing management [1].

The most important task is in HDMS/HIS collection of PHR/MHR data responsible, authentic, reliable, and secure. In Section 1, the authors tried to represent the healthcare ecosystem, followed by the methodology adopted in Section 2. The chapter discusses HDMS/HIS and its evolutions followed by the issues and challenges these systems face in Section 3. Section 4 explains the fundamental concepts of Blockchain, which can be best fit to solve the problems in data collection and sharing of PHR/MHR records to various healthcare stakeholders in a secure, transparent, and real-time manner in a distributed and multi-stakeholder environment without the need for any trusted third party in section 4. Section 5 discusses various Blockchain-based models and highlights the issues and challenges of multiple models. The authors presented the overall points, challenges, and recommendations for future improvements in Blockchain-based patient health record and sharing systems.

METHODOLOGY

In this chapter, the authors adopted a systematic review-based qualitative research methodology. The authors followed phenomenology and explanatory research to study conceptual terms of healthcare, PHR/MHR, Blockchain, and DMS/HIS-related phenomena from the available literature. We used analysis and synthesis techniques to study various healthcare information systems and narrowed our focus area to Patient Health Records (PHRs) and Sharing Systems in HDMS/HIS, then followed successive refinement and implementation methodology to lay down the foundation of future enhancements of the Blockchain-based patient health record and sharing systems by highlighting the issues and challenges in the past and current such systems.

THE HEALTHCARE DATA MANAGEMENT SYSTEM (HDMS) OR HEALTHCARE INFORMATION SYSTEM (HIS)

The Healthcare Data Management System (HDMS) or Healthcare Information System (HIS) is useful in systematically managing records, ease of access and usage. It provides fast and easy information retrieval, fiscal control and financial planning, inventory management, efficient process management, human resource management, and patient clinical and diagnosis history management to enhance the quality of service and achieve healthcare governance excellence [2].

Evolution of the Health Data Management System (HDMS)/ Health Information System (HIS)

The HDMS/HIS has seen a significant transformation over the last few decades from a paper-based record maintenance approach to computerized maintenance of records. The web-based systems have given liberty to access various features of HDMS/HIS using multiple offices over the Internet. While Cloud Computing has offered the Infrastructure as a Service (IaaS) model to reduce the ownership of IT infrastructures, and Software as a Service (SaaS) has given a standard version of HDMS/HIS at a low cost [3, 4]. Using Internet of Things (IoT) devices, real-time health data is collected, and patient health is monitored. In contrast, complex clinical trials, the effectiveness of medicines, diseases spread over a geographical area, mutation patterns, *etc.,* can be analyzed and forecasted using big data analytics. The Blockchain addresses the issues of trust, security, data tempering, secure communication, transparency, privacy issues, well informed and authorized use of medical/health data using consensus. The evolution of the Health Data Management System (HDMS)/ Health Information System (HIS), along with timelines, is given in Table **1** [5]. The vast processing power and resources are needed to perform big data analytics. Supercomputers and highly reliable Cloud Computers, and it is expected that in the future, HDMS/HIS systems, will be using Blockchain on distributed Quantum networks and powerful Quantum Computers as nodes in Blockchain networks.

Table 1. Technical Evolution of the HDMS/HIS.

S. No.	HDMS/HIS Approach	Timelines
1	Paper Based	1793
2	Standalone Computer Based	1960
3	Client-Server Web Based	1990
4	Cloud Computing Based	2012
5	Internet of Things (IoT) Based	2012

SUBJECT INDEX

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