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Exploitation of Emerging Technologies and Advanced Networks for a Smart Healthcare System

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Abstract: Current medical methods still confront numerous limitations and barriers to detect and fight against illnesses and disorders. The introduction of emerging technologies in the healthcare industry is anticipated to enable novel medical techniques for an efficient and effective smart healthcare system. Internet of Things (IoT), Wireless Sensor Networks (WSN), Big Data Analytics (BDA), and Cloud Computing (CC) can play a vital role in the instant detection of illnesses, diseases, viruses, or disorders. Complicated techniques such as Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) could provide acceleration in drug and antibiotics discovery. Moreover, the integration of visualization techniques such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) with Tactile Internet (TI), can be applied from the medical staff to provide the most accurate diagnosis and treatment for the patients. A novel system architecture, which combines several future technologies, is proposed in this paper. The objective is to describe the integration of a mixture of emerging technologies in assistance with advanced networks to provide a smart healthcare system that may be established in hospitals or medical centers. Such a system will be able to deliver immediate and accurate data to the medical stuff in order to aim them in order to provide precise patient diagnosis and treatment.

Keywords: advanced networks; emerging technologies; medical sector; smart healthcare

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1. Introduction

Although nowadays the science of medicine has achieved many and great achievements, the population worldwide still suffers from unidentified illnesses, infectious diseases caused by new viruses, and physical or mental disorders, which affect the human respiratory system [1]. Obviously, it is remarkable that there are several barriers and limitations of the traditional medical techniques in the identification, diagnosis, and treatment of these issues. Evidently, there is an urgent need for the integration of new technologies in medicine for optimized solutions to such medical problems. The exploitation of emerging technologies [2] such as Internet of Things (IoT), Wireless Sensor Networks (WSN), Big Data Analytics (BDA), Cloud Computing (CC), Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Tactile Internet (TI)/Haptics, Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) can contribute to the detection, diagnosis, and treatment of the most significant medical aspects leading to a smart healthcare system [3]. Although there is a need for the adaptation of these technologies in everyday life, there are still countries that are not ready to apply them in their population. Nowadays, there are many related studies for the health sector which make use of such technologies as the aforementioned, but still a smart system is a need which has not yet been met.

Today, the proliferation of IoT sensors, faster computing power, and capturing data locally has grown exponentially and is enabling the further development of integrated system models. This segment is based on application, manufacturing process planning, product design, and both software and hardware implementation. Such systems shall be implemented in the developed countries where rapid adaptation of IoT enabled technology by medium and large-scale enterprises is already in place. IoT in combination with WSN, BDA, and CC, which aspire to contribute to medicine, especially in microbiology, can be used together so as to fight against viruses and threats of infectious diseases.

In recent years, the global population came across many mortal pandemic viruses. To prevent and treat these widely spread diseases, there is a need of using ML and DL. It has been widely discussed in the scientific community, the fact that these two emerging technologies will be effective for testing vaccines that will eliminate the mortal viruses. The aforementioned technologies have been used in many cases in the healthcare sector [4–8]. The effectiveness of these technologies was tested by many researchers in the pharmaceutical sector with the use of predictive analytics [9,10]. Some examples are the prediction of drug interactions, drug combinations, and drug toxicity [11,12]. The efforts of drug discovery and development are based on several factors, and they are time-consuming and complex. ML approaches are able to deliver abundant ways that can enhance decision making and discovery for well-specified questions with plentiful and high-quality data. Occasions to utilize Deep Neural Networks (DNN) in addition to ML and DL algorithms arise in all phases of drug discovery. Applications are related to context and methodology, while particular schemes provide accurate forecasts and meaningful information.

Medical imaging data can also be improved by the deployment of novel solutions. The equipment used for the medical imaging can produce 2D images (e.g., radiographs) and 3D volumetric image datasets [13] (e.g., magnetic resonance imaging, computed tomography, and positron emission tomography). New trends of medical data visualization include the traditional representation of the volumetric data which is a close representation method for axial, sagittal, and coronal imaging levels or lateral reshapes. MR, a combination of VR and AR, can provide 3D depth imaging which can be used to reduce the limitations. The technologies already mentioned seem to provide many advances to the medical staff by eliminating the range of their imagination in order to make medical images more meaningful.

Another emerging technology, namely Haptics, aims in providing touch effects to medical professionals in order to access, control, and represent in a more efficient way the patients' 3D imaging data. Due to that fact, the doctors can have a better clinical picture of data and detect disorders or complications that could be potential [14]. So, the health sector can be transformed through these technologies and through the well-trained medical staff that is prepared and capable of using all these advances. Additionally, the haptic technology provides social distancing between medical staff and patients in cases of infectious diseases.

Operations is another area that can be improved and expanded with the help of emerging technologies. As we already know and are widely accepted, detailed preoperative planning leads to more accurate results, increased surgical severity, and reduced morbidity, while reducing operative time. However, the problem remains that the surgical planning systems used today are primitive and rely heavily on the user's ability to design complex tasks using a 2D graphical interface. Since the data is not raw, this approach definitely contrasts with superficial visualizations. Therefore, traditional surgical methods include training residents to use cadavers, animals, and artificial dummies. However, these traditional methods have some drawbacks, such as not using animals for surgical training, which has been heavily criticized by animal rights activists. Traditional use of cadavers may also pose a risk of infection. Comprehensive training models are expensive and not patient specific. Other methods include having the resident undergo surgery by a specialist surgeon and then move slowly to assist with the procedure. This can eliminate outdated methods and technologies and encourage their development by introducing emerging technologies in healthcare.

Therefore, there is a need for a robust system that will integrate these cutting-edge technologies and innovative methods to offer accuracy and optimized speed in the identification, diagnosis, and cure of illnesses, infectious diseases, or dangerous viruses [15]. Such an integrated system could eliminate the potential threats, improving the Quality of Life (QoL) of the human population, and minimizing their fear of infection. This paper mentions that conventional medical methods lack efficient and effective disease confrontation, while medical equipment is usually outdated or malfunctioned. Although future technologies should be launched at the healthcare industry [16], the challenges that may arise through this revolution should not be neglected. A novel system architecture is proposed which incorporates emerging technologies and advanced wireless networks in order to provide a smart health care system.

To sum up, the presentation of the basic theoretical information of the research field of this work provides the main contributions of our work:

- Provide a holistic approach of the exploitation of future technologies in the healthcare industry
- Propose a sophisticated smart healthcare system which combines emerging technologies
- Comparative review of the existing healthcare and medical system

The rest of the paper is organized as follows: Section 2 cites the latest related work; Section 3 mentions the technological challenges for accurate medical detection, diagnosis, and treatment; the involved emerging technologies is presented in Section 4; Section 5 describes the proposed system architecture and analyzes the application fields; Section 6 discusses the potential application of our proposed system, as well as the benefits and limitations of this; and finally, Section 7 concludes the paper and gives some potential future directions.

2. Related Work

Various studies, which make use of several technologies, have been proposed in the medical sector. Many of them focus on the efficient detection of dangerous viruses and infectious diseases, along with optimized methods for finding and accelerating the procedure of drugs and antibiotics discovery. Due to the COVID-19 pandemic, in the last years, a remarkable effort on studying diseases behavior and ways to confine and eliminate them has been noticed. The following works represent studies related to healthcare innovation by implementing emerging technologies. They present frameworks and systems which are able to provide effective and efficient patient treatment. Four criteria were considered for selecting these works to be included in a comparative analysis: the works should be recently published; they propose systems or applications that contribute to the diagnosis, detection, or prevention of viruses or diseases and the treatment of patients or therapy discovery; they implement one or more of evolving technologies; and the results of these studies should be tested and validated. To the best of the authors' knowledge, the selected works provide an indicative sample that proves the benefits of inserting technology within the healthcare industry. Table 1 presents a concise comparative review of the related work.

Table 1. Related work comparative analysis.

Paper	Proposal	Proposal's Scope	Diagnose/Treat/Detect/Prevent	Integrated Technologies	Data Analysis System	Energy Efficient Scenario
L. Bai et al. [17]	COVID-19 Intelligent Diagnosis and Treatment Assistant Program called "nCapp"	• Diagnose COVID-19 earlier • Enable different levels of COVID-19 diagnosis and treatment among different doctors from different hospitals to upgrade to the national and international through the intelligent assistance of the nCapp system	• Detect • Diagnose • Treat	✔ Internet of Things ✔ Cloud Computing ✔ 5G Network ✔ Mobile Computing ✔ Big Data	Yes	No

Table 1. *Cont.*

Paper	Proposal	Proposal's Scope	Diagnose/Treat/Detect/Prevent	Integrated Technologies	Data Analysis System	Energy Efficient Scenario
H. S. Maghdid et al. [18]	Framework to detect COVID-19 using built-in smartphone sensors	• A low-cost solution, since most of the radiologists have already held smartphones for different daily purposes	• Detect	✔ Smartphones ✔ Artificial Intelligence ✔ Machine Learning ✔ Wireless Sensor Network ✔ Convolution Neural Network ✔ Recurrent Neural Network	Yes	No
S. Muthukumar et al. [19]	Sensor based IoT module which monitors the relative humidity of a room and updates the status to the occupants of the room in order to control outbreak of infectious diseases	• Very useful at hospitals where the probability of an infectious outbreak is huge. • Very cost effective and can also be employed in schools, workplaces, and homes.	• Detect • Prevent	✔ Internet of Things ✔ Wireless Sensors ✔ Mobile Application ✔ Smartphone ✔ Wi-Fi	Yes	No
J. M. Stokes et al. [20]	Trained a deep neural network capable of predicting molecules with antibacterial activity	• Utility of deep learning approaches to expand our antibiotic arsenal through the discovery of structurally distinct antibacterial molecules	• Detect • Prevent	✔ Deep Neural Network ✔ Virtual Screening ✔ Machine Learning ✔ Neural Network	Yes	No
K. A. Carpenter & X. Huang [21]	Using a multi-task, deep CNN for a VS of potential MTDLs that inhibit a combination of AD-related targets	• Review ML-based methods used for VS and applications to Alzheimer's disease (AD) drug discovery. • Expect the use of ML in VS for drug discovery to only grow as the scientific world realizes the power that it brings to the field	• Prevent	✔ Virtual Screening ✔ Machine Learning ✔ Artificial Intelligence ✔ Artificial Neural Networks ✔ Convolution Neural Network ✔ Support Vector Machines	No	No
H. F. Rickerby et al. [22]	Platform that combines high-throughput display and selection data generation with ML	• Provide accuracy and reinforcement in research and development productivity of drug discovery	• Detect	✔ Machine Learning ✔ Deep Learning ✔ Big Data	Yes	No
S.Momtahen et al. [23]	New design which combines digital microfluidics with machine learning algorithms for drug discovery applications	• Reviews current and future applications of microfluidic in drug discovery using machine learning	• Detect • Prevent	✔ Machine Learning ✔ Digital MicroFluidic (DMF) ✔ Lab-on-a-Chip (LoC) ✔ Deep Learning ✔ Artificial Neural Networks ✔ Virtual Screening	Yes	No

Table 1. *Cont.*

Paper	Proposal	Proposal's Scope	Diagnose/Treat/Detect/Prevent	Integrated Technologies	Data Analysis System	Energy Efficient Scenario
M. Bahi & M. Batouche [24]	Fast compound classification method based on a deep neural network for Virtual Screening called DNN-VS, using the Spark-H2O platform in order to label small molecules from huge databases	• Outperforms state-of-the-art machine learning techniques with an overall accuracy more than 99%. • Develop improved machine learning algorithms to substantially increase the odds of Virtual Screening success.	• Detect • Prevent	✔ Deep Learning ✔ Machine Learning ✔ Virtual Screening ✔ Deep Neural Network	No	No
J. Cecil et al. [25]	Virtual Surgical Environment (VSE) for training residents in an orthopedic surgical process called Less Invasive Stabilization System (LISS) surgery which is used to address fractures of the femur	• Facilitate and supplement the training opportunities • Provided to orthopedic residents • Ensure the correctness and the usefulness of the VSE	• Prevent • Diagnose • Treat	✔ Virtual Reality (VR) ✔ Virtual Surgical Environment (VSE) ✔ Less Invasive Stabilization System (LISS) ✔ Haptics	Yes	No

The goal in [17] is the timely diagnosis and through the use of medical technology, called the "COVID-19 Intelligent Diagnosis and Treatment Assistant Program (nCapp)", to achieve the optimal treatment. Cloud Computing (CC) technology, which is part of nCapp's functionality, contributes to real-time communication. According to this research, the diagnosis is automated when a suspicious sample is detected and then nCapp classifies the suspects into categories depending on the criticality of the situation. nCapp updates the system in real-time and makes the system a reputable tool for future illnesses as well.

A detection framework for the COVID-19 virus which uses data gathered from the sensors that are integrated in smartphones such as cameras, microphones, and temperature and inactive sensors is proposed in [18]. Machine Learning (ML) practices are devoted for learning and obtaining knowledge about the disease symptoms based on the collected data. A quick and low-cost approach to virus detection is offered by this method. This is debatably conceivable because data acquired from the sensors of the smartphones have been exploited meritoriously in several discrete applications and the proposed method incorporates these applications together in a distinctive framework.

A smart humidity monitoring system is proposed in [19], which makes provision for the neighboring correlation between contagious disease and humidity and proposes a solution which can preserve the relative humidity of a room, in this manner restraining an outbreak of infectious diseases. This system has utilized a sensor-based IoT unit, which takes into account the positive effects of humidity retention and observes the relative humidity of a room and gives specific information to the occupants of it. Specifically, the relative humidity of the air is monitored by the sensor-based hardware module, which transmits the data to the user in a separate room or even at a remote location through the internet. This module can easily be programmed to sustain relative humidity levels in a room determined by the user's needs. The system also controls the air conditioning and humidifying devices of the room to maintain optimal humidity levels. The developed system is a cost-effective application that can be incredibly valuable in hospitals because the risk and danger of infectious disease outbreak is high in such buildings. Due to its low cost, it could also be utilized in schools, workplaces, and homes.

A well-promising Deep Learning (DL) approach for antibiotic discovery which can be proved very helpful for the branch of medicine is proposed in [20], where a Deep Neural Network (DNN) has been trained to be able to forecast molecules with antibacterial action. Virtual Screening (VS) is regarded to be an important tool for drug development, while

ML techniques are considered to be an effective and efficient method of performing VS for lead drugs.

ML-based techniques are used for VS and applications in the discovery of drugs for Alzheimer's disease in [21]. Generally, ML for VS includes assembling a filtered training group of compounds, consisting of well-known active and inert compounds. After model training, it is confirmed and, if it is precise enough, used in formerly invisible databases to test unique compounds with favored drug target binding activity.

In [22], a platform that merges high-throughput display and selection data generation with ML is proposed in order to provide accuracy and reinforcement in research and development productivity of drug discovery, while in [23], a combination of ML and digital microfluidics is used to discover and develop drugs, improving the throughput and reliability, thanks to computer-aided design algorithms.

Furthermore, time and economic costs in conventional drug discovery can be eliminated by using a proper DL algorithm which is proposed in [24]. Experimental results demonstrate that this method overcomes other state-of-the-art ML methods, producing an overall accuracy of 99% and more.

In [25], the launch of a Virtual Surgical Environment (VSE) for the education of medical staff in an orthopedic surgical procedure is proposed. The proposed method, called Less Invasive Stabilization System (LISS) surgery, is applied to treat femoral fractures. The general concept includes comprehending the LISS plating process via interactions with specialist orthopedic surgeons and developing information-driven models. The central information models offered a structured basis for the design and construction of the simulator. A tactile interface is integrated to support educational activities to allow users to touch, understand, and interact with diverse surgical tools during these educational activities.

3. Technological Challenges

The challenge with health-related systems is that they must have increased accuracy and sensitivity so that a patient is not misdiagnosed. Therefore, it is necessary to provide a sufficient knowledge to the medical staff in order to give them the ability to validate the correctness of this decision. Three phases constitute the superior aim of the medical sector: immediate detection, accurate diagnosis, and effective treatment of a patient. Although the healthcare industry has done some important steps to improve itself, still conventional medical methods show limited potentials in these phases. Many challenges need to be addressed for humanity in order to have a completed healthcare system.

Nowadays, it is fact that the integration of cutting-edge technologies can successfully support the conventional detection, diagnosis, and treatment methods in order to deal with different microbiological diseases, infectious viruses, common illnesses, and general disorders. A smart healthcare system can provide accuracy and speed in detection, diagnosis, and treatment of several issues from which the human population suffers and deregulate their daily life.

Several recent studies have shown that the speedy development of both mobile and wired networks has generated rapid growth of data. The management, analysis, and transfer of such Big Data (BD) generate new challenges which are related to their life cycle, representation, quality, storage, confidentiality, total effectiveness, etc. [26]. BD is transferred through several of these levels in a way that leaves gaps relevant to its utilization. For this reason, optimized algorithms and methods are necessary to solve such problems [27]. However, many countries do not have the proper infrastructure to host and apply such emerging technologies.

In addition, the challenges posed by the traditional methods of volumetric data display incorporate the information overburden, resulting from the generated volume of data sets. Another challenge is the detection of small faults, where a deep analysis with slice analysis will entail a long time. There is also the task of mentally creating a 3D image by looking at the slices. Therefore, volume visualization is often used in medical applications such as computed tomography and magnetic resonance imaging. Subsequent images of volume visualization are translucent and blurred, making intensity difficult to perceive [28].

Additionally, while surgeons rely heavily on the sense of touch in the operating room, surgical design systems in general do not exploit the sense of touch to supplement the visual interface. Thus, scheduling surgery is not flexible and takes a long time. This may cause a not so optimal reconstruction with complications being.

It is important to mention that there are many challenges from applying Artificial Intelligence (AI) techniques to medicine. These challenges are mainly due to the lack of interpretation and repeatability of the results generated by Machine Learning (ML), which may constraint their application. In all areas, systematic and comprehensive high-level data must be created. With ongoing endeavors to address these concerns, as well as raising consciousness of the aspects required to validate ML practices, the implementation of ML can encourage data-driven decision-making and have the prospective to speed up the process and decrease failure rates in drug discovery and development [29]. Thus, an effective scheme that involves cutting edge technologies is imperative to achieve this goal.

4. Emerging Technologies

The exploitation of emerging technologies can contribute to immediate illness detection, accurate medical diagnosis, and effective treatment. Such technologies that enable healthcare efficiency are Internet of Things (IoT), Wireless Sensor Networks (WSN), Big Data Analytics (BDA), Cloud Computing (CC), Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Tactile Internet (TI)/Haptics, Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies can be used alongside the corresponding network specifications described above, in order to offer multiple benefits and compose an integrated healthcare system. Figure 1 presents these emerging technologies that can be used properly to maximize the healthcare effectiveness.

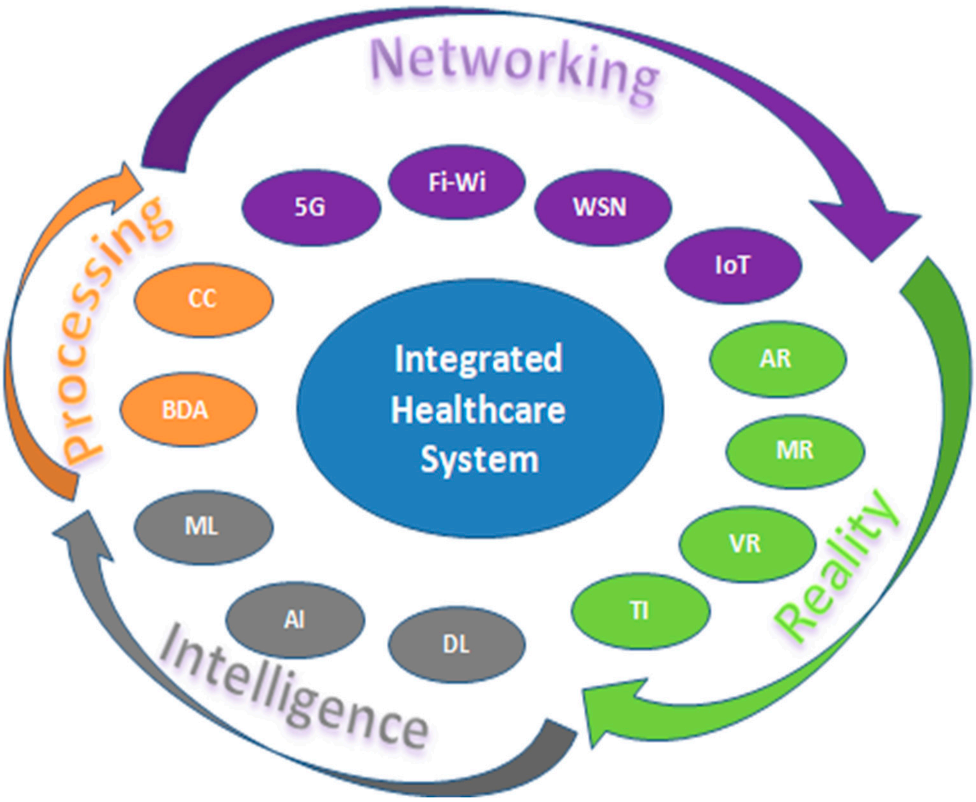

Figure 1. Combination of various emerging technologies into an integrated healthcare system.

4.1. Networking

4.1.1. Internet of Things (IoT)

Internet of Things (IoT) is a new revolutionary technology that enables the connection of all the everyday physical objects to the internet. Thus, IoT can constitute a huge global network with a lot of uniquely connected things, as depicted in Figure 2, which communicate with each other for a specific operation (e.g., in a medical application), providing a high impact on a society, since it improves the humans' Quality of Life (QoL) and Quality of Experience (QoE). Generally, IoT has three components: smart devices, communication networks to provide connectivity to the devices, and computer systems.

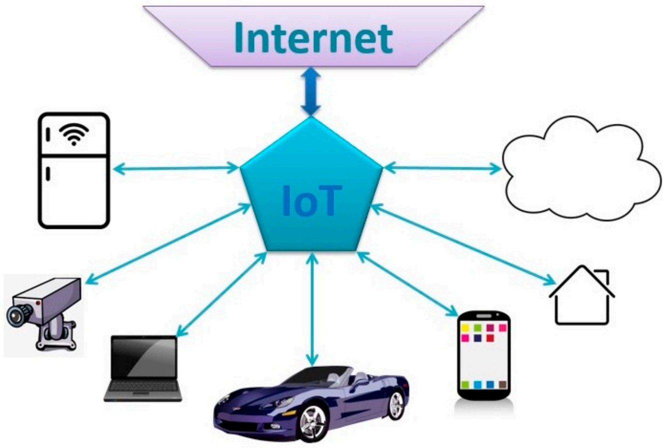

Figure 2. Internet of Things.

Remarkably, the IoT-based devices can be wearables and have application in healthcare, providing a full range of new capabilities thanks to pervasive connectivity. Such medical wearables include medical devices, sensors, smartphones, imaging devices, personal digital assistants (PDAs), and electronic health records (EHRs) that are able to have a great impact on medicine as providing significant potential to improve patients' lives and doctors' work globally. IoT-based wearables can be used to monitor patients remotely, and hence, enable early diagnosis of an epidemic disease or pandemic, such as the recent COVID-19 [30].

Today, the industry is moving towards replacing human resources for measurements and research using electronic Patients Reported Outcomes (ePRO) and electronic Clinical Outcome Assessment (eCOA) [31]. In medicine and specifically in medical research labs, an IoT-based platform can provide higher quality but more affordable healthcare solution globally, reducing the workflow of medical staff [32].

4.1.2. Wireless Sensor Networks (WSN)

A Wireless Sensor Network (WSN), as illustrated in Figure 3, is a wireless network of multiple sensor nodes which have limited resources and are densely deployed in an environment or a restricted area. These nodes can sense data from the surroundings and deliver them, thanks to the wireless networking, to people who need this information. The main objective of WSN is to interconnect the IoT-based devices (e.g., of a patient) in order to deliver useful information wherever and whenever it is needed, such as in a medical center [33]. In addition, medical areas can be surveilled by measuring and evaluating the air pressure, sound, light, and vibration, if they belong to a healthy environment [30].

A WSN consists of sensors that operate in close proximity to a person's body and transfer measurement values wirelessly via communication protocols. Sensor nodes have a processing unit with limited computational power and capacity. WSN are developed in specific environments, such as forests, mountains, and glaciers, in order to collect environmental quantitative metrics during long periods. These networks may interface and operate any kind of biomedical sensors such as electrocardiogram, blood oxygen level, blood pressure, blood glucose, bodyweight, heart rate, oxygen saturation, and many other quantities so as to give minimal feedback for the maintenance of optimal health level.

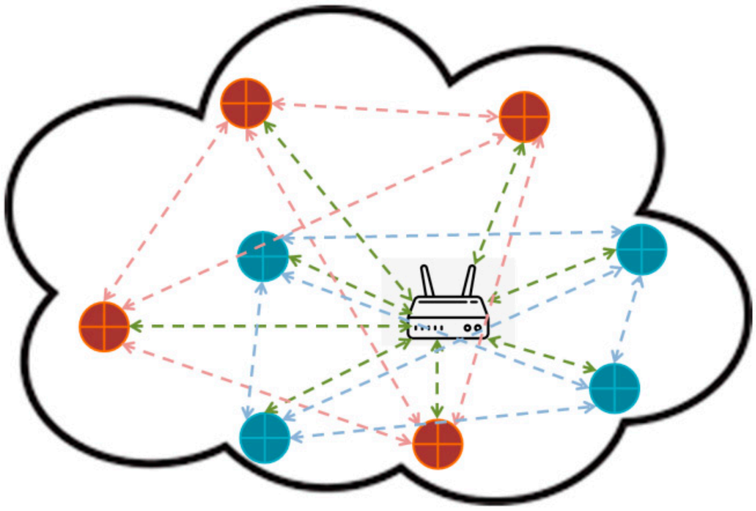

Figure 3. Wireless Sensor Networks.

It is of great importance that WSN can offer ubiquitous real-time or close to real-time information about vital patient's state. Therefore, it may send alerts and notifications to the patient's IoT device, based on the sensor measurement values using specific thresholds or limits. This will lead to the production of large amounts of data. The benefits of a WSN are that it consists of autonomous devices with no need for wires, and it is energy efficient since the right algorithms and mechanisms are used. Transferring, managing, analyzing, and securing a large amount of data are the main challenges of WSN [34].

4.1.3. Fiber and Wireless Technologies (Fi-Wi)

A wired infrastructure of optical fibers can be used alongside the use of wireless infrastructure in a medical center or a hospital. Optical fibers are very thick, flexible, and transparent fibers from drawing glass or plastic in such a way to support light transmission between their two ends. Hence, optical fibers allow transmission over longer distances at very high bandwidths, supporting higher data transmission than conventional electrical cables. Optical fibers can be used instead of traditional metal wires if reliability and high data rate are necessary. In optical fiber networks, the signals travel with less loss and without electromagnetic interference, which is a common problem in wired networks.

There are two types of fiber optic cables: multimode and single-mode. Multimode fiber is capable of carrying multiple light rays (modes) at the same time as it has varying optical properties at the core. Single-mode fiber has a much smaller core size, and it has a single light path and can travel much longer distances of up to 100 km. Multimode optical fiber can readily transmit high bandwidth data over long distances. A typical bandwidth-distance product for multimode fiber is 500 MHz/km, thus a 500 m tether can transmit 1 GHz. Signal losses over 500 m are negligible as the bandwidth is limited by dispersion of signals. On the other hand, lightweight copper cable has very high losses at high frequencies. Twisted pair optimized for high data rates can transmit 500 MHz over only 100 m [35].

Potentially, as the design of advanced communication systems focuses on ultra-responsive connectivity, the convergence of both optical fiber and wireless technologies (Fi-Wi) could, possibly, play an important role to unveil a completely new world in the healthcare industry, as well. A well-promising converged Fi-Wi scheme is the analog Radio-over-Fiber (RoF) fronthaul that enables an analog radio frequency or intermediate frequency signal to be propagated over fiber and wireless fronthaul communication links [36].

Fi-Wi is a useful and powerful technology that can help doctors and medical staff to examine and diagnose patients' diseases in a better way, as they provide clearer endoscopic imaging. It is worth noting that many patients owe their lives today thanks to fiber-optic endoscopes. Of course, optical fibers are not only vital in endoscopes, but can also be used to transmit light to tissue regions of interest in such a way as to either illuminate the tissue so that it can be inspected or to cut it directly or to remove it. Therefore, fiber optics can be widely used both as laser delivery detectors and as imaging conductors in optical coherence tomography [37].

Furthermore, Wireless Local Area Networks (WLAN) have application on the branch of medicine, and more specifically, in a hospital or a medical center. WLAN is a physical network which provides communication without the use of cables (no wired). WLAN services include Wi-Fi 802.11, Bluetooth, LoRa, ZigBee, or other futuristic technologies and protocols. An 802.11/Wi-Fi network supports medical services, such as data, voice, and video transmission across clinical and patients' applications and devices. Moreover, a layered Wi-Fi architecture provides dedicated channel use for specific Wi-Fi enabled services, and thus, it is vital for healthcare wireless environments, especially when it is needed for transmission of wireless signals from medical devices.

Wi-Fi 6, also known as 802.11ax, builds and improves on the 802.11ac standard. Its nominal data rates are increased up to 9.6 Gbps which means 1.25 times faster than the previous standard. Moreover, it offers more efficient data management for faster speeds and supports both the 2.4 GHz and 5 GHz frequencies for faster Internet across both frequency channels. 802.11ax has the power to serve a higher number of connected devices and deliver more data to those devices due to 8×8 uplink/downlink, MU-MIMO, and OFDMA, as a result to provide up to 4 times larger capacity than 802.11ac. A new feature called Targeted Wake Time (TWT) allows the router to put the Wi-Fi connection to stand-by when not in use, saving the battery life of the connected devices until they are needed [38].

4.1.4. 5G Networks

5G networks are the fifth generation of mobile networks that can support a maximum speed up to 10 Gbps theoretically, which are translated to about a hundred times faster than 4G networks that their corresponding speed are up to 100 Mbps only. Therefore, 5G networks can demonstrate a great low latency of 1 ms, promising faster loading times and enhanced efficiency. Eight criteria have been outlined by ITU IMT-2020 standard for mobile networks, which should be fulfilled in order to be considered as 5G [39]: 10 Gbps maximum achievable data rate, 10 (Mbit/s)/m^2 traffic capacity across coverage area, 1 ms latency, 106/km^2 total number of connected devices, 3 times higher spectrum efficiency compared to 4G, 100% network coverage, Mobility up to 500 km/h with acceptable Quality of Services (QoS), and 100 times lower network energy usage compared to 4G.

The technology of 5G is anticipated to become a strategic priority for telecommunication operators and this is the reason why there is a persistent cooperation between operators and governing bodies to uncover their intentions to develop technologies such as smart cities or smart hospitals, including smart healthcare. 5G can be divided in three network services: enhanced mobile broadband (eMBB) focuses on data rates of 10 Gbps, massive machine type communications (mMTC) for a plethora of interconnected devices, and ultra-reliable low latency communication (URLLC) for solving both latency and reliability issues. Thus, it is obvious that 5G networks can play a vital role in many scientific areas, such as in the medical industry.

4.2. Processing

4.2.1. Big Data Analytics (BDA)

A large amount of data that usually is transmitted through advanced wireless technologies consists of Big Data (BD). Big Data is a term used to describe data gathering that is huge in volume and yet grows exponentially over time. For simplicity, BD is also data but with a huge size. Such data are so huge and complex which none of the conventional data management tools can store or process it effectively. In terms of medicine, models from BD can support the prediction of a pandemic or help for the production of the cure. As shown in Figure 4, Big Data Analytics (BDA) is the use of advanced analytic methods for inquiry of large and diverse data sets, such as structured, semi-structured, and unstructured data, from different sources, and in different sizes, in order to reveal worthy information, which can assist businesses to make informed decisions [40].

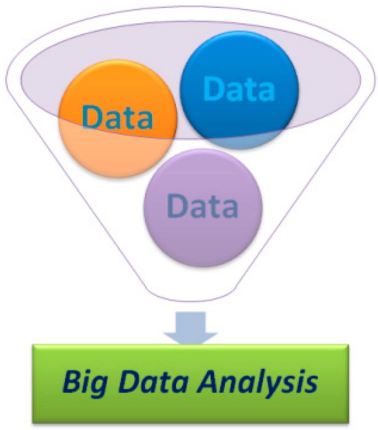

Figure 4. Big Data Analytics.

BDA could be a good method that can be applied in medicine for analyzing the gathered data from the patients' sensors. BDA can lead to a more accurate clinical image and thus, to improved medical diagnosis and treatment. This can be achieved by utilizing advanced BDA tools to a series of medical issues and infectious diseases. It is fact that BDA plays a vital role in controlling and facing the current COVID-19 pandemic [41].

Many BDA platforms and tools are available for use in the healthcare domain for improved analysis of e-health data. These tools include Apache Hadoop Distributed File System (HDFS), MapReduce Yet Another Resource Negotiator (YARN), mapR, IBM Big Structured Query Language (SQL) integration with Apache Spark, Amazon data analysis system, Microsoft Azure, Qubole, High-Performance Computing Cluster (HPCC) system, Konstanz Information Miner (KNIME) Analytics Platform, Datameer Spotlight and Spectrum, etc. [41].

4.2.2. Cloud Computing (CC)

Cloud Computing (CC) is a useful technology, which provides the chance to store, manage, and transmit data through various platforms (desktops, mobile devices, etc.) and applications, as depicted in Figure 5. Depending on their use, the cloud is divided into three main categories: private cloud, public cloud, and hybrid cloud. Private cloud is dedicated for use by a single organization, while the public cloud is open for everyone where the IT services are delivered across the internet. Hybrid cloud merges private and public cloud capabilities. In all cases, a cloud can be used alongside WSN and IoT.

In recent years, the development of CC simultaneously with other emerging technologies, such as mobiles and wearable devices, has been keen to introduce novel technological advances affecting sectors such as society, science, and especially healthcare. Moreover, CC technology, as a recently developed trend, tries to achieve the expectations of users in order to manage, store, access, and analyze BD, and the application using them. CC and BD due to their basic features are closely related.

Some of the main goals of CC, such as the computing power and the storage resource management, could offer advantages in the use of BD applications. Additionally, there are several solutions for the processing and storage of large-scale data provided by the use of CC. With the use of distributed technology, the management of data like this might be processed effectively from the cloud. Additionally, by using the parallel computing capacity of CC, the efficient collection and analysis of BD can be improved. Thus, it could be concluded that through the effective integration of BD and CC, the use of the novel and significant technology of IoT is hidden. As a result, it is a mandatory requirement for any vendor or service provider to provide the need for a robust cloud infrastructure for BD delivery [31].

Figure 5. Cloud Computing.

Specifically, the collected data from wireless sensors, wearables, or other IoT-based devices constitutes a large amount of data that can be considered as BD. Medical wearables on patients or other mobile smart devices such as smartphones generate a huge data set from different types of data which can be stored in remote cloud servers [34]. Thanks to CC, these data can be stored in a remote location, usually, a cloud server, outside of the computer, and can be accessed through an internet service from anywhere [27]. CC regarding the healthcare area could offer the chance of using and accessing healthcare data of the patients to the nursing stuff and the doctors, from everywhere and in any time.

Cloud applications perform BDA and train reasoners to detect clinical conditions and apply intelligent decisions support mechanisms with the use of ML, and AI techniques for premium services, such as coaching. Hence, both the IoT environment and the cloud infrastructure of ePRO/eCOA applications are highly critical, since they include sensitive personal healthcare data, contributing to critical processes, such as the medication monitoring procedure [31].

Additionally, several cloud platforms could be used by the medical stuff and the doctors in order to run complicated applications on them, without the additional need of strong hardware systems [34]. In the healthcare area, cloud platforms are usually used in order to calculate genomic, protein, and molecular medicine. According to many reports, CC is only introduced as a replacement technology for the today's computer networks. However, other areas such as health information systems, health information exchange, or image processing and management still appear to be underrepresented. The concept of smart healthcare is regarded to include all those related to the diagnosis activities, treatment, and prevention of human diseases or injuries, as well as clinical research and healthcare management.

Some examples of cloud platforms that use CC for data storage are Riak, Amazon Web Services, Microsoft Azure as Software as a Service (SaaS), Platform as a Service (PaaS), or Infrastructure as a Services (IaaS), Google Cloud Platform, IBM Watson, ThingSpeak, SAP

Cloud Platform, and many others. Most of them can be used harmoniously for the storage of patients' e-health data, providing also a variety of processing tools and services.

4.3. Intelligence

4.3.1. Artificial Intelligence (AI)

Artificial Intelligence (AI) is the recreation of human brainpower performed by machines, specifically by a computer. Thanks to AI, humans' intelligence can adapt to machines. Machines operate based on standards and prototypes driven by sophisticated algorithms for various procedures. Thus, machines can move and manipulate things, identify different actions, or understand and solve complex problems [42].

As the use of AI in the healthcare industry is growing, it has become a subject of great concern. Research has been conducted on the AI interface and its use by patients or doctors for decision making and its related work in the field of the healthcare sector. Recently, with the use of AI and the Internet of Medical Things (IoMT), consumer health applications have been a boon to mankind. With the advent of a voice-assisted installed base in many smart gadgets, consumers are more dependent on AI for their regular updates which also includes healthcare. Smart devices and gadgets are used to monitor patients' health. AI enables the ability to identify any complications or health deterioration, which can drastically do cost-cutting for both the hospital and the patients [43].

Moreover, extracting, integrating, and analyzing from a huge set of unstructured and inconsistent patient data leads to an effective, accurate, and faster prediction and better clinical decision with the help of special intelligent tools. Although it has some limitations, the learning algorithms significantly improve clinical care. With all this in mind, few would argue that AI causes a paradigm shift in healthcare and that there may be value in applying AI to predicting potential disorders [44]. AI is becoming the crux of healthcare and now it is rapidly evolving to make its presence in the medical field. It is becoming extremely sophisticated at human-level intelligence and performs tasks more quickly and at a lower cost. As we are in an era of integrating physics-based models and data-driven models with AI, and continuously update a real asset in the operation of the existing models, it seems that in the near future robotic systems, through well-established AI techniques, will be capable to substitute surgeons and provide accurate surgical operations without the need of surveillance. Hence, it could be understood that improved and quicker results through AI provides appropriate timely decisions and predictive analysis that can assist in decision making and framing strategies to come out with innovative ideas for the betterment of the healthcare industries [43]. New data mining techniques such as Machine Learning and Deep Learning have been integrated to AI in the last years for improved behavior of the machines.

4.3.2. Machine Learning (ML)

Machine Learning (ML) is an AI application offered on computer systems that can automatically learn and improve from experience without explicitly programming. ML focuses on developing programs that can access data and use it to learn on their own, without human intervention or assistance.

In the medical field, a major problem in hospitals is the monitoring and detection of nosocomial infections. The goal with the help of ML will be to identify patients with infection, based on the clinical data collected by the patient. This will allow a patient to be diagnosed with the disease and their progression will indicate an effective monitoring system. The monitoring will be held by a supervised ML algorithm integrated into a clinical decision support system to diagnose infection during hospital presentation [45]. The parameters to be determined by doctors, who must be in order to know that the patient is sick, will be listed under supervised ML algorithm. This provides an automated evaluation of diagnostic probability of infection. The available data should provide personalized pollution management recommendations to doctors. In this way, we achieve optimal recovery of the patient and prevent the non-proliferation of the virus. A supervised algorithm ML proves that it can be effective and is accepted by most scientists to be incorporated into a tool to support clinical decisions to be able to support the diagnosis of infection in hospital patients [46]. In recent years, the continuous development of ML algorithms in the medical field focuses on exploring the potential impact of systems, such as decision making by clinicians who manage infections with various decision support.

The use of ML algorithms can improve the identification of different types of viruses in order to cope with it and prevent it as soon as possible. This will also reduce the spread of vulnerable populations [47]. During the period of prevention and control of the epidemic, ML can be useful in the prognosis, diagnosis, and control of patients infected with some type of flu based on the characteristics of the air in the environment. According to the latest clinical research [48], the respiratory pattern is different from any type of infection that a person receives and the common cold. However, the benefits of implementing ML techniques in risk management will be quite effective with the increased performance of these algorithms, as well as the ability to exploit large volumes of data with different characteristics [49]. ML algorithm should provide for deployment of an epidemic, analyzing conditions in areas where people are affected [50]. This technology focuses on statistics about the behavior of the virus and the uncontrolled spread likely caused by exposure to infected individuals [51]. Provision will be made to analyze the spread of the disease on the basis of movement through the population by implementing ML techniques to predict the spread.

4.3.3. Deep Learning (DL)

Deep Learning (DL) is a new advanced application of AI which improves ML algorithms, offering multiple advantages in many fields. DL is an integrated to ML and AI technology, which has application in the last 10 years. DL creates powerful data models and the proven success of these techniques in many public tenders has helped to significantly increase ML applications in pharmaceutical companies over the last 2 years [52]. The DL uses intelligent, multilayer Deep Neural Networks (DNN) to create systems that can perform detection characteristics of massive amounts of training data without label. DL can have a huge number of hidden levels because it uses more powerful CPU and GPU hardware, while conventional neural networks typically use one or two hidden layers because there is hardware constraint.

Neural network technology was developed to solve many difficult tasks, including many medical problems, such as B. formula. DNN models can more accurately diagnose diseases or disorders because they are very effective with severe class imbalances. A typical DNN includes a prediction module for predicting disease likelihood and an interpretation module for identifying risk factors for disease progression to identify whether patients at high risk of developing a disease are exposed Disease in severe disease. In addition, DNNs can be used to predict early recurrence of a patient's condition or disease [53].

In a neural network (NN), the input features are fed to the input layer, and projections are generated from the output layer after a series of nonlinear transformations using hidden layers [54]. This usually happens because back-propagated errors are used to gradually reduce the difference between expected and received output values. Each node to be predicted corresponds to an output with a class. When only one node in the network is at egress level, the network is called NN operating system [29].

In the branch of medicine, DL offers the ability to analyze data at exceptional speeds with efficiency and accuracy. Moreover, DL can solve complex problems. Thus, DL can be used in order to reduce the admin load and increase insights into patient care and requirements, as it provides an improved analysis of medical images and data [55]. Furthermore, DL algorithms are widely utilized in biometrics. Behavioral biometrics such as gait, keystroke, or electrocardiogram have been researched through DL approaches. Biometrics is a field heavily related to patterns, while DL tools have offered remarkable performances in pattern recognition. Therefore, it has been highly affected by these sophisticated algorithms because data classification implemented within a DL network avoids complex and time-consuming signal transformations. Thus, the capability of identifying patterns in time-inconsistent signals, such as biometric ones, via DL algorithms has broadened the potentials of enabling and advancing accurate medical diagnosis and treatment [56]. The evolution of AI, ML, and DL is depicted in Figure 6.

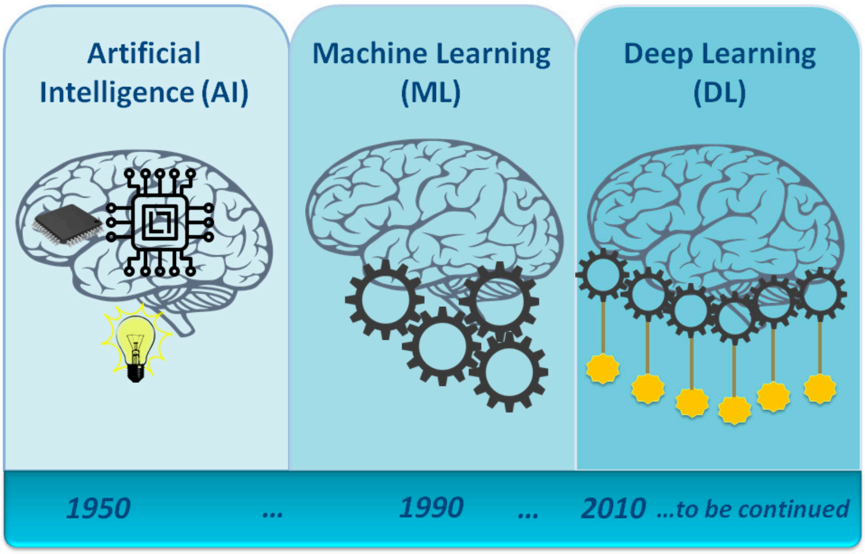

Figure 6. Artificial Intelligence, Machine Learning, and Deep Learning.

4.4. Reality

4.4.1. Tactile Internet (TI)/Haptics

Tactile Internet (TI) can be outlined as an internet network that unites exceedingly high availability, reliability, and security with ultra-low latency, which could be regarded as a revolutionary level of development for the society. TI is expected to become the next advancement of the IoT, integrating Human-to-Machine (H2M) and Machine-to-Machine (M2M) communication. Tactile information refers to touch, pressure, and temperature feelings [57]. Haptic data, also known as haptics, which imitates these tangible sensations of real-life experience, can be utilized to a variety of clinical subjects, from medical interaction and clinical practices to reflect exercise of surgical procedures. This is possible as a robot can be manipulated by observing a surgeon during performing an operational process and then learn from the movement data to replicate the same actions and so to proceed to a successful surgery [58]. Thus, medical robots could be deployed to provide adherence to treatment regimens and continued social interactions and without fear of spreading the disease [59].

Haptic data offer the feeling of touch and has application in several areas such as telerobotics, entertainment, and education. In healthcare, haptics could be used to increase the actuality in simulators for planning and training of specific surgical procedures. Haptic data have the ability to improve surgical procedure by offering to the surgeon familiar virtual tools to the operating room. A haptic interface can give accurate precision and rapid execution of tasks by minimizing the technical errors, while a visual-haptic interface makes available a better system to perform force sensitive tasks. Haptic devices allow end users to feel, touch, and manipulate objects in a remote environment through an appropriate interface [60]. The sensation and interaction capabilities of the haptic device depend mainly on the DOF of the device. Haptic devices have inputs, such as position and orientation components, and outputs such as force and torque components. These devices differ in terms of DOF, mechanical bandwidth, workspace, possible inputs and outputs, interfaces, and maximum range of displayed force [61]. Table 2 introduces a list of common market available haptic devices with the main features of each device [62].

Table 2. Haptic devices with their features.

Device	DoF	Max. Force/Torque	Stiffness
Touch/Geomagic Touch	6	3.3 N	1.26 N/mm 2.13 N/mm 1.02 N/mm
Phantom Premium	6	8.5 N 37.5 N 22 N	3.5 N/mm 3.5 N/mm 1 N/mm
Virtuose 6D	6	35 N	8 N/mm 30 N.m/rad
omega.7	7	12 ± 8 N	14.5 N/mm
sigma.7	7	20 ± 8 N	Unequal closed loop stiffness

Moreover, wearables make it achievable to deliver haptic feedback to the human wearer throughout physical interaction with the environment. For example, tactile feedback can provide elements that improve and simplify the user interface. Vibro-tactile haptic effects may be practical in offering cues to users of devices in order to alert them for particular events or provide realistic feedback to generate better sensory immersion or provide users with real-time feedback regarding its health condition into a virtual or simulated environment. Therefore, the scientific community and industry demonstrate the design and elaboration of Wearable Health-Monitoring Systems (WHMS), which have low cost and constitutes of several tiny physiological sensors, transmission modules, and processors. Hence, they are absolutely suitable for wearable and unpretentious physical and mental health level monitoring solutions and do not enforce constrains in terms of location or time. The situation that doctors can monitor their patients remotely could be proved to be a lifesaver for them as there is no need for contact that may spread the disease.

4.4.2. Virtual Reality (VR)

Virtual Reality (VR) has been implemented to generate an immersive and interactive environment and it can be full-immersive or semi-immersive. Full-immersive VR displays a virtual image while the real environment is omitted from vision, on the other hand semi-immersive VR displays the virtual image while the real world is partly excluded from vision [63]. Recently, the use of VR has been developed in a fast pace benefiting the area of healthcare industry by supporting 3D visualization from many angles, without covering details compared to 2D models. VR allows doctors to virtually interact with patients and intensify the regularity of therapeutic treatment. In such a way, this technology can assist to the rehabilitation of patients with several health problems, and moreover, in the study of viruses that may lead to serious vaccine research. VR can be used in the training of surgeons and doctors mainly in performing virtual surgical procedures.

VR technology exploits the potentiality of user interaction and immersion. In such a way, the manipulation of a system becomes simpler and intuitive. Thus, the implementation of VR technologies can help to achieve superior image quality and smooth interaction with the patient, facilitating a faster and more precise diagnosis, as the doctor can move around the system and visualize patient's body with more details. Evidently, it is meaningful to thoroughly examine areas that are considered of utmost importance for accurate medical diagnosis [64].

4.4.3. Augmented Reality (AR)

The limitation of VR systems in the medical industry comes mostly from the user's concern about the surrounding physical world in reverse of the virtual world. Augmented Reality (AR) overwhelms these matters by delivering an immediate and simple user interface on top of the electronically enhanced physical world.

AR offers a straightforwardly functional space for the medical staff where the consultation and diagnosis of the 3D model produced from the medical results can be achieved effortlessly. With this technology, the virtual elements of the system can be visualized in the real world and accomplish an efficient interaction by utilizing a haptic device. This entails that the surgeon may be controlling the device in the operating room and interact, with smooth actions, with the patient. This interaction is incredibly essential to avoid any danger of contamination, as it is not obligatory to operate any external device [64].

In medical applications, when there is a need of pre-planning, intraoperative procedures, or a physical examination that demands medical imaging, the real-world image can be the actual patient's body. AR is broadly used in both medical imaging systems and surgery procedures. Some of these produced promising results, such as the interaction between physicians and overdue 3D virtual data. The main goal of visualization during surgical procedures is to make the medical staff feel like they are in a real operation room. Reliability, usability, and interoperability are three essential requirements for any system based on the visualization of AR. As the persuasive power of this type of visualization is exceedingly high, the visualization software is imperative to guarantee specific accuracy margins by following it during the operation time.

4.4.4. Mixed Reality (MR)

VR recreates real life in a digital world, while AR enriches the real world with virtual displays. Combining these two distinctive perceptions unveils the idea of Mixed Reality (MR) [65], which is an amalgam of real and virtual worlds. MR is an immersive technology that merges the physical and the real world to provide a new visualized environment where physical and digital items and objects coexist and interact with each other in real-time.

MR not only overlays virtual objects in the real-world environment, but also embraces virtual objects into the real world. There are two kinds of MR technologies: MR that begins with the real world, where virtual objects are overlaid on the virtual world (real to virtual), and MR that begins with the virtual world and the virtual world content is anchored to real world devices (virtual to real) [66].

MR has already been used in various applications across fields, including the medical sector. MR combines smart glasses with surgical processes so as to provide a better level of healthcare. Specifically, headsets based on MR have the ability to share information between doctors. This means that it is not necessary for many doctors to be in close proximity to the patients. In some diseases such as contagious disease, the distance between doctors and patients enhances doctor safety and reduces the use of personal protective equipment [67]. Furthermore, MR gives surgeons the ability to perform an operation on a patient from a distance, while it improves the skills of the nursing staff that are able to perform many nosocomial operations virtually without touching the patients. Figure 7 illustrates the virtualization technologies.

Table 3 presents some popular healthcare applications of each technology separately and the corresponding 5G network services of appliance in order to meet the specifications of efficient operation.

Table 3. Healthcare application domains and network services of emerging technologies.

Technology	Healthcare Applications	Network Services
Big Data Analytics	• Medical diagnosis	eMBB mMTC
Cloud Computing	• Real-time health status monitoring	eMBB mMTC
Artificial Intelligence	• Illness or disorder prediction • Drug discovery	eMBB mMTC URLLC

Table 3. *Cont.*

Technology	Healthcare Applications	Network Services
Machine Learning	• Disease identification • Illness or disorder prediction • Drug discovery	eMBB mMTC URLLC
Deep Learning	• Disease identification • Illness or disorder prediction • Drug discovery	eMBB mMTC URLLC
Tactile Internet	• Remote patient examination • Robotic surgery • Telesurgery	URLLC
Virtual Reality	• 3D medical image visualization • Virtual training surgical procedures	eMBB
Augmented Reality	• 3D medical image visualization • Virtual training surgical procedures	eMBB
Mixed Reality	• Remote patient examination • 3D medical image visualization • Virtual training surgical procedures • Robotic surgery • Telesurgery	eMBB URLLC

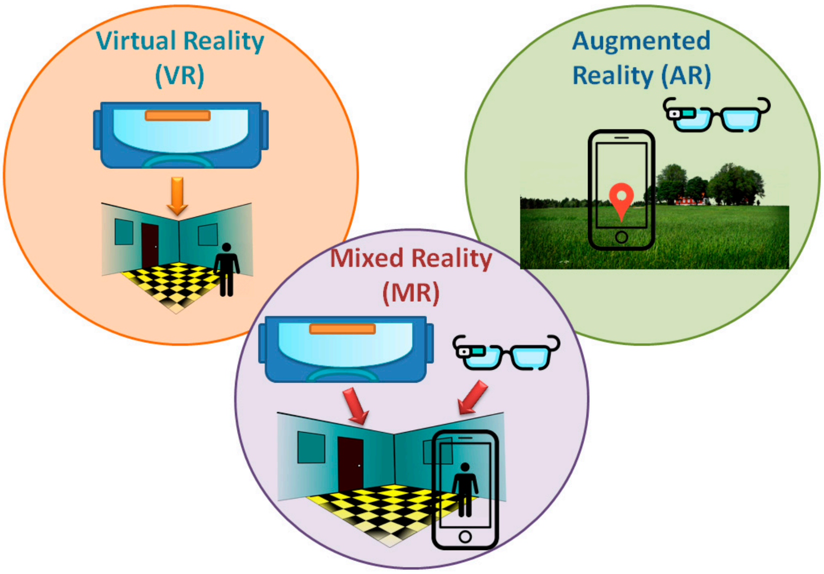

Figure 7. Virtual Reality, Augmented Reality, and Mixed Reality.

5. System Architecture

The main goal of a smart health care system is the successful combination of the emerging technologies for the enhanced medical detection, diagnosis, and treatment of an illness or disease. Such a system integrates the benefits delivered by WSN and the immediacy of the data produced by IoT, with the computation power offered from a CC server, established in a 5G wireless network, due to the high transmission data rate and low latency that could offer, in order to provide immediate disorder detection. VR, AR, and MR can offer access to volumetric data in a 3D environment, which may help with a medical diagnosis. Furthermore, the system could manage and control the BD produced by sensors and analyze it through ML and DL algorithms and DNN to propose both accurate medical diagnosis and treatment. Through the aid of haptics, a potential surgical operation could become less painful for the patient and more convenient for the surgeon, while the use of AI could go a step forward such an operation, which could be contacted wholly unsupervised by robotic devices.

In order to transfer the exaggerated amount of data produced by different devices such as sensors and cameras, the Extensible Messaging and Presence Protocol (XMPP) has been chosen. This protocol is an open standard and has been used and tested widely. The publish/subscribe model of XMPP is presented in Figure 8 [68].

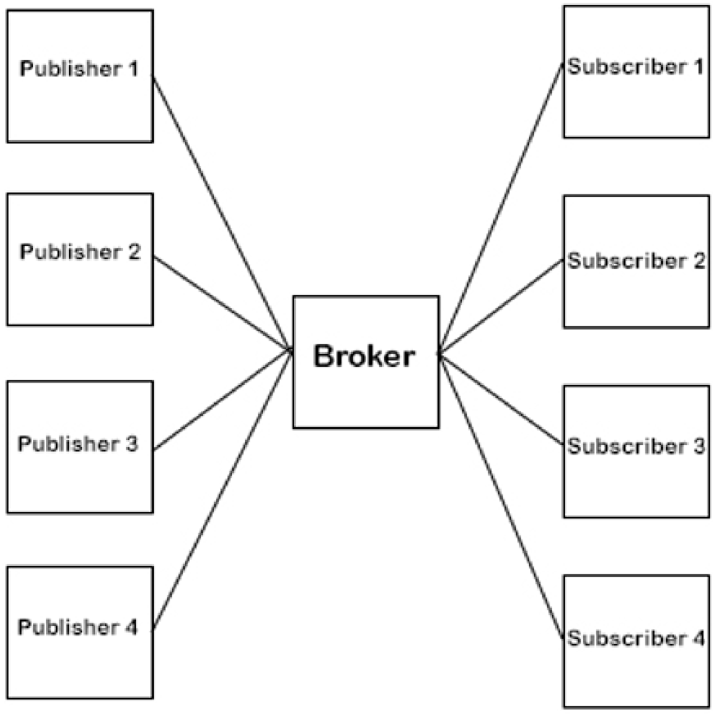

Figure 8. Publish/Subscribe communication model.

This model provides a safe and efficient data exchange, where a publisher sends the data to the broker device. Then, the broker device forwards the updated data to any subscriber device that asks for a specific topic. For example, a temperature sensor will publish the temperature data to the broker under the temperature topic. These data will be available to anyone who requests the temperature topic. The XMPP is a protocol that fits the cloud and storage systems' needs. Moreover, a framework was applied for the implementation of the system and the communication of all devices, servers, and databases providing an abstraction of the network devices. This framework simplifies the interaction between the Application Programming Interface (API), which is hosted in the user's device, and the IoT devices. Specifically, the framework was used for data fetching, data visualization, and authentication of the users.

Firstly, the IoT devices should be installed and programmed in order to produce data over time. Most of the data usually are in a form and volume that many times are unmanageable. In addition, to make the data have a valuable meaning, suitable ML algorithms should be integrated. Then, the data should be published into a database, the Redis database, where they can be stored and manipulated. Redis can also be used as a broker device. Thereafter, the application used and connected to the system via 5G connectivity will be responsible for the visualization of the data, for the real-time update of the API, and for the valuable notifications. Finally, for the more complex outcomes, a cloud server should be used that provides deep learning techniques to have a better insight of the data collected and stored in the database.

Regarding the detection phase of an illness or disorder, the cloud server is responsible for the supervision of each surveillance infrastructure. Additionally, the cloud server may accept data from an installed infrastructure that is not directly connected to it. All the data collected from the system should be then managed and preceded in the cloud server in order to export the necessary conclusions via BDA for each monitoring area.

Thermal-IR cameras help to detect the temperature of the environment, and more specifically, from the individuals when entering or moving into the surveillance space. The images captured from each camera are sent to the cloud server via 5G networks. In the cloud, a server that runs a data analysis algorithm, checks if the measured temperature of each camera is above a determined threshold. Afterwards, if it is detected a temperature over this specific threshold, a notification signal appears in the monitoring system.

Air condition-quality sensors detect for a high rate of air pollution in the area's atmosphere. The detection data send via the wireless network to the cloud server. In the cloud server, an AI-based algorithm can detect and inform about the condition of the area monitored. This ML algorithm manages and controls the data shared from the WSN (both cameras and air sensors) and after a number of computations and rounds, it is able to export automated conclusions about whether an area is at risk or not. Thus, depending on the data shared from the WSN, it will notify the local surveillance and control personnel. The aim of the ML algorithm is to be in charge in order to detect without necessarily the supervision of a person and subsequently to notify correctly about the detection that it found.

Moreover, the cameras of the system can record 3D video resolution, and export visualized medical results as 3D models. This system utilizing VR, AR, and MR technologies gives the opportunity to the medical staff to access volumetric data in a 3D environment. Thus, medical professionals can have an effective tool that visualize humans' body and examine it in a 3D space. Enhancing VR, AR, and MR with TI offers an interactive solution for doctors to examine patient's body without coming in physical contact. This solution could be exceptionally suitable when patients suffer from infectious diseases, eliminating the possibility of spreading them. With the advancement of DL algorithms, it is feasible to analyze the 3D volumetric data in order to conclude in a precise diagnosis in a timely manner.

Finally, the medical data can be analyzed by DNN through repeated model retraining. Compared to the conventional approach, this AI approach is capable to analyze in detail over a hundred million of BD. DNN offer about 100 times higher processing accuracy compared with the conventional approach. Thus, this technology revolutionizes the discovery of vaccines and antibiotics, allowing scientists to efficiently handle much more data with considerably better predictive accuracy. The proposed system architecture is depicted in Figure 9.

Such a system could be established in various indoor buildings, such as hospitals and universities or outdoor places such as parks. This could become feasible due to the advanced wired and wireless networks that are expected to be launched soon. Specifically, 5G networks are considered as the next communication technology that will offer a great boost in many sectors, including the medical one. In cooperation with optical fiber, which is a recent technology with many benefits versus coaxial cables, the era of industry 4.0 and beyond is rapidly evolving.

ML and DL techniques can support a DNN to offer powerful ways for developing accurate antibiotics against diseases and viruses. The timely and effective cure is the main aim of pharmaceutical companies. Hiring scientists from the field of informatics or collaborating with research centers, the pharmaceutical industry would be able to provide the most effective antibiotics or vaccines in time.

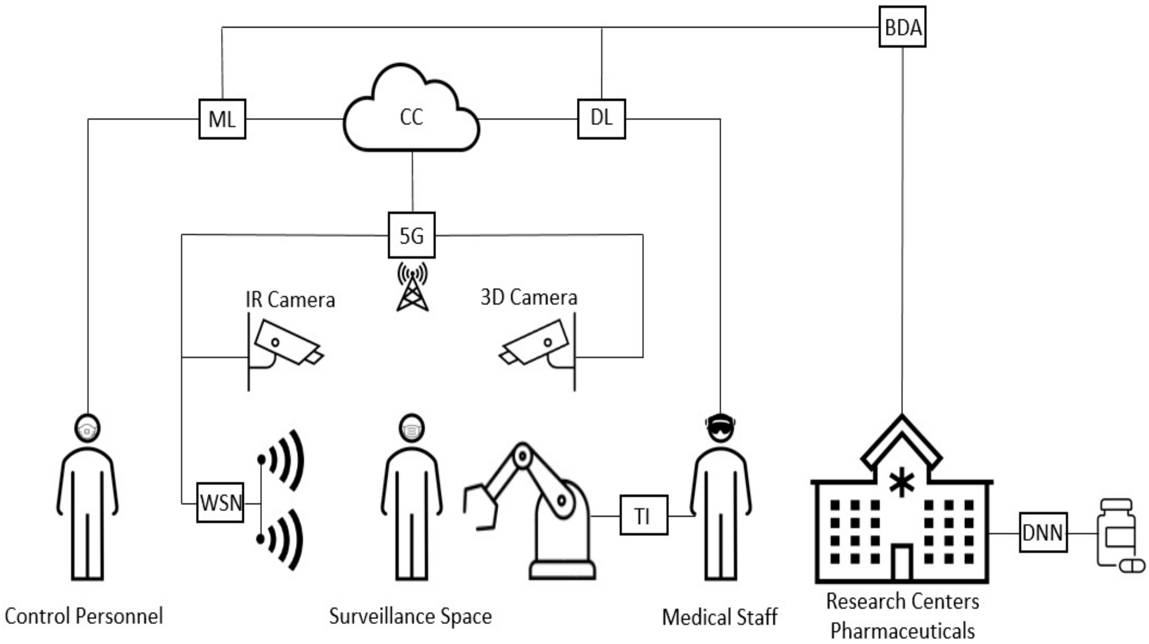

Figure 9. Proposed smart healthcare system architecture.

The application of a shared virtual 3D display system amongst doctors and surgeons worldwide in combination with the haptic models, can lead to a more accurate treatment of the patients, without the physical presence of them in the operation room. The power of the 3D viewing and haptic interaction is unquestionable, and they are considered as emerging technologies that will be widely used in the medical industry. The advantages of interaction in a 3D environment and realistic visualization of the results that VR and AR technologies could provide will enhance the medical profession. These technologies are presently being extensively applied in certain sectors and especially in the industrial one. Soon enough its development will be rolled out to many more sectors, and one of them will unquestionably be the medical one.

System Evaluation

In this paper, an attempt was made to simulate the proposed system in the Cooja Emulator and more specifically in the Contiki software. Thus, the data transfer through the proposed system was studied. The simulated data are mainly related to the temperature and humidity levels of the hospital room.

Figure 10 shows the simulated scenario with the sensors in the hospital room, which collect the biometric data of the room related to the patient's health. Sensor communication is based on the technology of the 5G wireless network that is installed in the building, in order to have directness in communication and data exchange.

As depicted in Figure 11, at time 5:22 the sensor activated the thermostat and then the temperature system started operating, in order to increase the room temperature in an automated way (Machine Learning scenario). Furthermore, as shown in Figure 12, at time 5:19, where high levels of room humidity were observed, the sensor was activated to control and reduce the room humidity. In addition, based on the automated proposed scenario, as illustrated in Figure 12, there is a constant control of room humidity over a range of values over time.

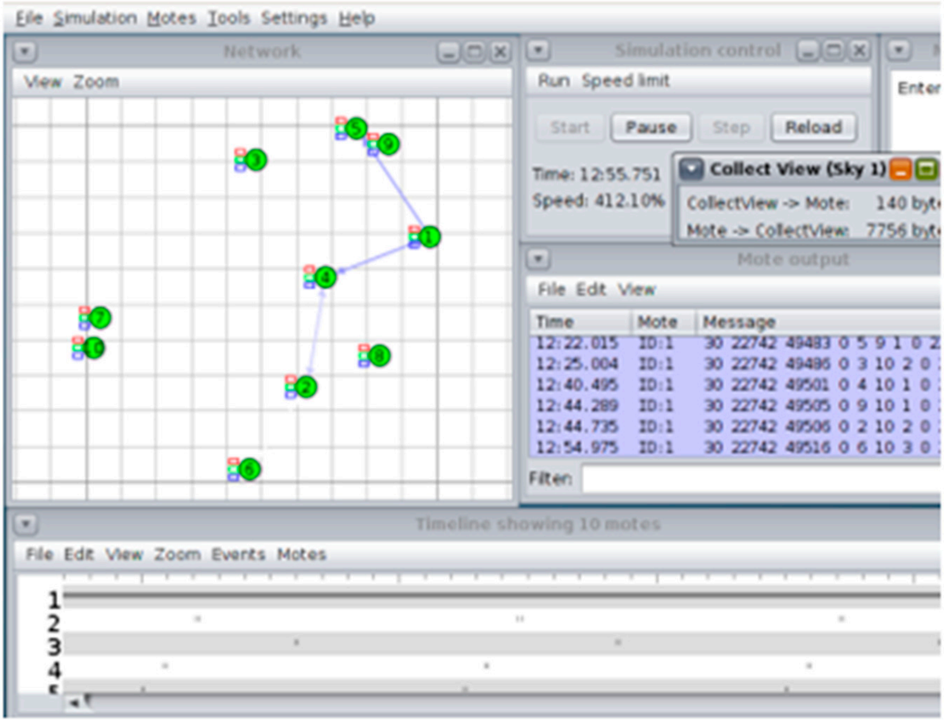

Figure 10. Wireless Sensor Network of the proposed system.

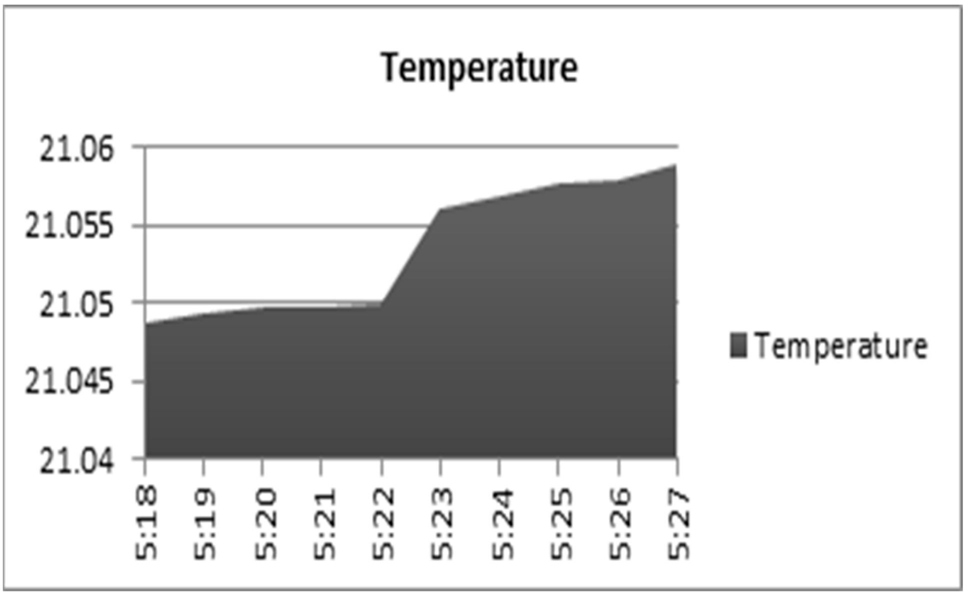

Figure 11. Room temperature level over time.

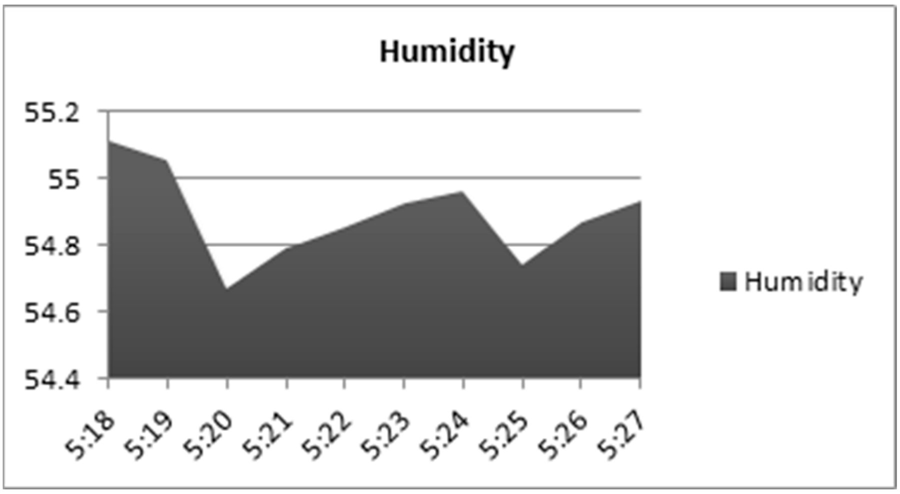

Figure 12. Room humidity level over time.

6. Discussion

Digital transformation is defined as a process aimed at improving an entity through a combination of technologies and making a significant change in its attributes information, computer, communication, and connection. As such, digital transformation is facing changes associated with the introduction of new information technologies into the current organizational structure. The digitization of healthcare involves the use of new technologies. These new digital technologies offer the potential for explosive expansion of the potential of a variety of diagnostic and therapeutic tools and systems to minimize the risk of contracting the virus for primary care physicians and medical staff. In healthcare, digital transformation aims to answer the question of how technology can improve the quality of care and related services, and both are based on accurate, relevant, complete, and rapidly accessible information. That is, it demonstrates the potential of health information technology to reduce costs while improving assessment, treatment, and patient management. In fact, their implementation could provide the public with greater healthcare access and flexibility.

The proposed smart healthcare system could offer many benefits in the detection, diagnosis, and treatment of illnesses, diseases, and viruses. The upcoming technologies can be applied to both indoor buildings and outdoor areas, in order to identify potential disorders. A system that combines the BD that a WSN produces with CC data processing can mostly have application in hospitals and medical centers for immediate medical detection, as they are buildings with high traffic and mass attendance. Hence, it can have application in universities, entertainment halls, and outdoor parks, providing effective disorder detection. In addition, such an architecture can be adopted by research centers where the researchers, with the use of DNN, will be able to extract valid information about the medical diagnosis.

The objective of a system architecture that combines the aforementioned technologies is the enhanced clinical picture of patients on medical centers and hospitals, providing to the doctors a better evaluation of the clinical results. The doctors can work in a safer environment and make improved decisions for their patients. Thanks to 3D visualization and the use of haptic interfaces, the doctor has the ability to see the patients' clinical data in a better resolution and higher quality, such as Ultra High Definition (UHD). The doctor may consult other doctors from different medical centers and hospitals using a shared virtual 3D dimensional display system which offers simultaneous real-time visual feedback monitoring collaboration.

Because this scheme allows more close-up views of hidden areas that it is not easy to be revealed by using the current conventional medical methods, it ensures smaller incisions for minimal scarring, more accuracy in the prediction of the potential complications, and thus, enhanced and more effective treatment for the patients. On the other hand, such a system can offer patients the ability to receive shorter hospital stay with less pain and risk of infection, less blood loss and transfusions, faster recovery and return to the normal activities, as well as better overall clinical outcomes [14]. By establishing such a system, the interaction and relationship between doctor and patient is changed since the doctor can operate from a distance with more accuracy, eliminating long-distance travels and risks of injury from the patient side. Doctor and patient can have real-time communication with each other with almost zero latency, using all of the available technological means and the reliable communication networks.

However, there are some limitations and barriers of such application. It is fact that the initial economic cost of the supply, establishment, proper operation, and system maintenance should be taken into account. In some cases, this cost might be prohibitive, especially for countries facing economic crises [30]. Unlike other studies, this one differentiates as it describes a holistic approach and a fully effective system that can show its overall potential operating over 5G cellular networks.

7. Conclusions

The traditional medical approaches are still necessary for the healthcare sector, and they cannot be thrown away despite their limitations. Some of these limitations, such as the early detection and the accurate diagnosis, can be bowled over through the adaptation and integration of different cutting-edge technologies such as those aforementioned. Healthcare systems should intend to use emerging technologies, which can be valuable for several reasons. Patients are able to receive clinical care while lessening the physical crowding into hospital premises. The combination of IoT and WSN could provide instant medical detection. Furthermore, the exploitation of innumerable AI-based systems could probably alleviate the clinical load of physicians. An online medical system could help patients diagnose early symptoms, educate people on the importance of personal hygiene, and refer people for medical treatment should symptoms worsen. DNN with the collaboration of ML and DL algorithms are able to process the amount of data in order to provide accurate diagnosis Thus, while the world persists to rely on traditional public-health measures for tackling illnesses and viruses, there is now an extensive variety of technologies that can be used to reinforce and strengthen these public-health strategies.

Haptics in conjunction with MR technology can become a gem for the doctors since both technologies can offer a more efficient health complications discovery for patients. Due to that, the doctors and patients will be both benefited. On the one hand, the doctors can use haptics on a device that represents the clinical results of patients in order to meliorate the 3D images [69–71]. On the other hand, patients benefit from the efficient healthcare and thus, have a quicker and better treatment. Due to this advantage, medical beds will be available when needed. Moreover, the benefits of such a system for the medical staff are many since this system can assist them in order to have a more accurate diagnosis than the one gained with the use of traditional technologies. Furthermore, the conjunction and adaption of these technological advances allows monitoring and treatment of patients from a distance in case of an infectious disease. The potential deployment of a robust system which will exploit emerging technologies, advanced networks, and innovative and effective identification techniques could lead to the increase of healthy population. Unlike other studies, this one differentiates as it presents a robust system for medical prediction, diagnosis, detection, and treatment. Although, several studies describe many models/methods that are not robust, they have motivated the robust network-based techniques for large scale, high dimensional biomedical data [72,73]. These robust network techniques are critical for predictive modelling in complex diseases such as cancers.

As future work, an expansion of this model is planned to adopt a federated learning scenario in the local node of each sensor, aiming to extract immediate data at the sensors level. Moreover, the installation of humidity sensors will be a useful addition to the surveillance infrastructure, in order to achieve a better detection scenario. Moreover, a robust and accurate robotic system equipped with AI may be developed and have learning abilities thanks to ML and DL methods. This robotic system can also be equipped with particular IoT-based sensors that will detect epidemic viruses and infectious diseases spread amongst animals and humans. In addition, a haptics assisted model can be implemented and applied in an experimental center for the evaluation of its efficiency. Such a model is regarded to be a well-promising research field since it will support telemedicine applications in which a doctor can operate on a patient from distance. In parallel, industries and vendors that put effort on AI development should focus on the medical sector in order to train machines to operate medical procedures totally unattained. In the near future, robotics will be able to act as surgeons in human bodies, eliminating potential implications during the operating process.

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