A SYNOPSIS OF MACHINE LEARNING BASED PATIENT MONITORING SYSTEMS ON THE INTERNET OF THINGS

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Abstract - **Patient monitoring systems are among the many applications that make extensive use of the Internet of Things (IoT). Healthcare systems are designed to keep an eye on patients in order to identify potential risks, respond swiftly to urgent situations, and facilitate long-distance contact for remote treatment. Long-term effects of the Internet of Things include physiological data, critical care, patient monitoring, and patient management. In order to gather data, sensors are attached to the patient. System controls receive the data first, then healthcare providers receive it on their own. Numerous biosensors use wireless networks to transmit medical data to websites or mobile applications. As a result, the Internet of Things allows healthcare providers to monitor patients and manage therapy outside of hospital boundaries.**

Keywords - IOT, Machine Learning, HealthCare, WBAN

I. INTRODUCTION

The Internet of Medical Things (IoMT) or Healthcare Internet of Things (H-IoT) represents a paradigm shift in the evolution of medical industry information systems. These systems are essential for determining a patient's current state of health and improving their quality of life. These are intricate systems that encompass systems from different disciplines, including computer science, medicine, microelectronics, and other systems.

The IoMT applications are in their growth phase, which runs from 2017 to 2022. As more beneficiaries show interest in these applications, these developments will quicken and enhance the medical sector overall. It follows that the Internet of Things (IoT) will undoubtedly redefine medical devices, applications, and integrated networks of healthcare solutions, thereby transforming the healthcare sector. IoT regularly.

II. HEALTHCARE SYSTEMS

Healthcare systems are a complicated network since they include: doctors, nurses, employees, healthcare providers, insurance companies, laboratories, and pharmacies. The parties involved are all located in and ongoing observation; particularly for ICU patients. These patient monitoring systems employ sensors to gather physiological data, which they subsequently analyze and store on the cloud. The patient's online caregiver group, which consists of the patient's family and the nurse, receives this data for additional analysis. A large team of medical experts collaborate based on individual specialties to evaluate the analysis that IoMT has performed using its data collection. As a result, high risk patients (those in need of urgent surgery, cardiac patients, etc.) can identify medical emergencies more easily.

Nevertheless, regardless of where they are, they can all start transactions on the healthcare systems, and the outcomes of those transactions will be saved on the device for everyone to view on the integrated system. At the moment, these transactions are kept on various, unintuitive platforms that take a long time to process and are prone to mistakes. A global ledger contains all of the transaction data for IoT healthcare systems. This implies that test results, insurance coverage, benefits and eligibility, medications, allergies, and medical records are all kept in a safe database that is accessible and safe (much like blockchain technology). The same database may be used to manage and track the requirements for medication, supplies, and other consumables, making healthcare management easier.

IoT can be evaluated in a number of ways, but the three most crucial factors to take into account are context awareness, remote patient monitoring, and care quality. The automated medical data collecting in IoMT reduces the possibility of human error, which could be detrimental to the patient's health. It also improves patient health and raises the standard of diagnosis. The many elements of clinical care will be reviewed in the sections.

2.1 Clinical care

Hospitals need to have access to round the clock, continuous monitoring in order to respond quickly and save lives in an emergency; this is especially important for patients in the intensive care unit. These patient monitoring systems employ sensors to gather physiological data, which they subsequently analyze and store on the cloud. The patient's online caregiver group, which consists of the patient's family and the nurse, receives this data for additional analysis. A large team of medical experts collaborate based on individual specialties to assess the analysis that IoMT has performed using its data collection. As a result, high and ongoing observation; particularly for ICU patients. These patient monitoring systems use sensors to gather physiological data, which they then process, store in the cloud, and send to the patient's online caregiver group, which consists of the nurse and the patient's family, for additional analysis.

To assess the study that IoMT has performed with its acquired data, a large number of medical professionals collaborate depending on their individual areas of expertise.

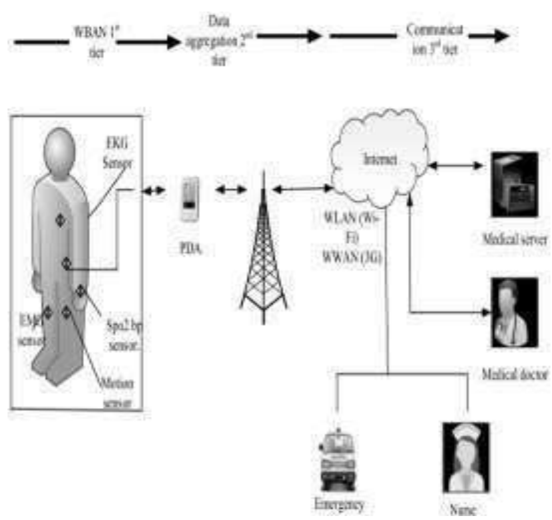


Figure 1. Real time remote monitoring systems

As a result, high risk patients (cardiac patients, patients in need of emergency surgery, etc.) have an easier time being identified as medical emergencies.

2.2 Remote patient monitoring

For numerous practical applications, remote patient monitoring, or RPM, is a crucial paradigm.

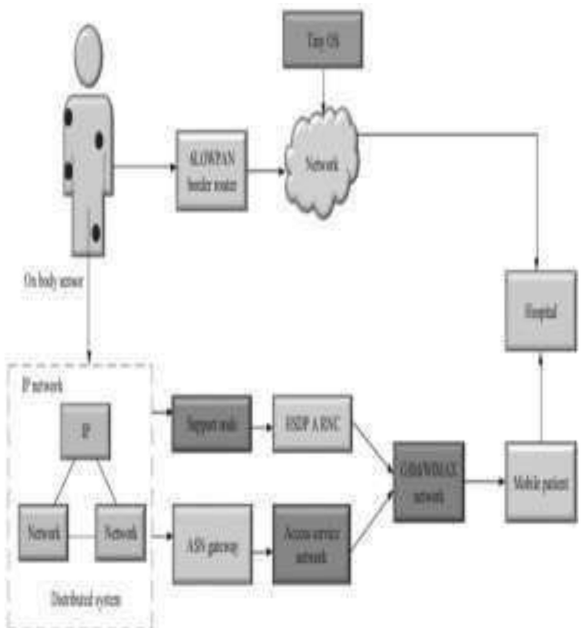
Consequently, the system furnishes details on the patient's health condition and gives prompt therapy, thereby mitigating subsequent difficulties and adverse effects. As a result, the technology enables real-time patient monitoring in the medical field. Additionally, it facilitates quicker diagnosis using input sensors, thus saving patient lives

Context awareness

One important requirement for IoMT applications is context awareness. Because IoMT can track both the physical surroundings and the health status of individuals, it can assist healthcare workers in understanding abrupt changes that may impact their condition. Changes in the environment might raise risk factors and a person's susceptibility to illness, putting them at risk. The numerous specialized sensors collect valuable information that aids in comprehending the condition of the patient at the time of hospitalization, at home, or wherever the patient may be. These data include a variety of physiological status indicators, such as the patient's ability to walk, run, or sleep, as well as information about the patient's physical surroundings, including temperature, humidity, and other factors, and the relationship between the awareness.

2.3 Healthcare networks in IoT

To increase the effectiveness of the health care system, a variety of devices and systems must function in the framework of the Internet of Things. One of the key components of the Wireless Body Area Network (WBAN) is the Internet of Things (IoT) healthcare network. The WBAN facilitates general system communication and the effective transfer of data. Network topology, a platform, and an architecture make up IoMT.



2.3.1 IoT network topology

Figure 2. IoT network topology in remote patient monitoring [3]

With the use of this technology, caregivers may keep an eye on patients from a distance and react based on the data that is sent. The healthcare data pipeline, which makes use of an interconnected network with WiMAX, Internet Protocol Network, and Access service networks, is shown in Figure 2.

IoT topology network showcases the gateway systems in figure 2. It also points out iMedpack. Additionally, various sensors, and wireless network topology interfaces create essential gateways for healthcare applications. IoMT makesdiagnostics and analysis possible via connecting the different wearable devices to the healthcare gateway. IoMT is also able to store the collected data, analyze, review, and lastly: present them. All IoT networktopologies are recognized and their infrastructures areconnected with the integrated healthcare systems. Themain IoT network topology components provide essential medical care, and they are generally used to help healthcare service providers. These faculties are used for medical emergency services. Therefore, network topology becomes important in medical systems. [3]

2.3.1 IoT network platforms

Two important IoT platforms are the IoT platform for healthcare service model and the cloud computing IoMT model. The healthcare service model mostly focuses on residents' health data as shown in figure 2. The figure also depicts the structure of the IoMT network platform which shows the user how to access the database layer for healthcare support from thevery first layer of the application. This can ensure thatthe interoperability of the platform and its automated design, which are engineered for rehabilitation are employed suitably for their intended goals. The business layer, data persistent layer, support layer, and accessing layer make up the framework itself. To manage many users connected to sensors, you must have an activation method to access the IoT gateway.

This model makes the management of multiple users possible via the use of multiple sensors during the data collection process. The IoT database uses Multi- Tenant databases; and the source layer is mostly responsible for sharing the healthcare system's data and interpolation using the resource control mechanism. This systematic framework makes theuser interface and the IoT's capacities possible in the health sector.

2.3.2 IoT network architecture

IoMT architecture consists of the device's operational layers, physical parts, and stated operating principle. The compatibility of the Internet of Things gateway with the wireless local area network (WLAN), secure communication between the IoT gateway and caregivers, and multimedia streaming are some essential components that have been discovered for this kind of network design. The Internet of Things (IoT) network health system uses specific protocols to communicate wearable device and sensor data across a secure communication channel. The user Datagram Protocol (UDP) is used by the data transmission architecture to reply to the sensor nodes. This offers a safe, integrated communication method for the patient and the medical staff. [3]

2.3.3. IoT network architecture based on Wireless Body Area Network

Wireless Body Area Network (WBAN) is composed of three different layers. Figure 3 shows on-body sensors, and different sensor nodes. These sensors are known as on-body or wearable sensors which are embedded on the patient's skin, and can work via wireless networks. The sensors receive signals from the body, and then transmit the patient's vital signs such as blood pressure, heart rate, blood sugar, body temperature, and humidity.

The tags or low-level management system provide information about and/or forecast the capabilities and operations of the nodes. Using the nearby personal web server (PWS), the data gathered from the on-body sensor is transmitted to the master communication controller or the central controller system. As a result, it can transmit emergency data recovery, synchronization of time, etc. Thus, the user's health state can be ascertained by the personal web server using the health information that is now available.

Additionally, it offers input regarding the user interface and the sensors. Both the IP address and patient data are stored on a personal web server.

The second layer system uses restricted human bond communication (HBC) to allow the interfaces of the WBAN sensor nodes and personal web servers to communicate with other services via the information bank. PWS nodes are linked to mobile computers (PCs) and other computing devices. The primary purpose of this is to keep an eye on senior patients. A network coordinator maintains the stability of the link between the body area network and the personal web server. Initialization, sensor node customisation and registration, and an all- around safe and secure connection are all included in the network configuration.

Medical server:

The storing, processing, and analysis of medical data is the primary duty of the medical server. The storing, processing, and analysis of healthcare apps that deliver healthcare services are also included in this. An essential component of the medical server is patient authentication. Medical data is transmitted for testing by sensors that are based on IoT medical servers.If any deviation is observed in the patient's health, or any causes for concerns are raised; the medical unit will be immediately notified. Due to the aforementioned processes, patient authentication, secure connections, and the effective protection of the patient’s personal data are of the utmost importance, and are thoroughly considered in all aspects of healthcare systems. For this reason, and to also provide overall security in general communication, the range of wireless communication is limited. [3]

3. The main challenges of Healthcare systems

Regardless of the user's geographical location, IoT- based healthcare solutions link clinics, hospitals, and patients to an integrated system to coordinate medical care or services.. However, there are manyother issues to carefully consider in research beforethese systems can become viable for mainstream use.

3.1. Interoperability, standardization, and regulations

Concerns regarding IoT standards exist. All parties involved in the Internet of Things manufacturers, consumers, and healthcare providers need operational consistency. IoT standardization can become a complicated problem since IoT producers want to enter as many different industries as they can, industries that are governed by various regulations. agencies, and regulatory boards, and all have a different set of standardization. This becomes even more complex with the strict guidelines that exist in the medical industry. For example, in the United States of America, the standardization of wireless medical devices requires a multi-agency regulatory collaboration including: the Food and Drug Administration (FDA), the Centers for Medicare and Medicaid Services (CMS), and the Federal Communications Commission (FCC). This means companies must carefully review and evaluate all the regulations, and policies set by these three agencies. IoT healthcare systems must also operate within a complicated structure of agencies to make IoTeHealth products available to the market. These complicated regulations and standardization processes are not limited to the US. Generally, eHealth faces the same issues and complications all across the globe.

3.2 Heterogeneity

IoT healthcare applications require a wide range of contextual data which are obtained through various heterogeneous sources. Heterogeneity is generally defined in two ways:

Data heterogeneity : Multimodal Data heterogeneity can be brought about by sensors with varying functions, formats, and structural characteristics. Since these gathered datasets lack explicit explanations, using or sharing them may be difficult or confusing.

Sensor heterogeneity : Interoperability issues might arise when many sensors are integrated, each of which operates at a different frequency and requires a different network protocol. Furthermore, these problems may get worse when medical equipment and sensors are combined. Interferences in the network's range and frequency overlap can have a major negative impact on the system and obstruct access to crucial data.

3.3 Interface and user compatibility

It is crucial to take into account additional aspects when using an application, such as human compatibility, user acceptance, and the degree to which a given technology facilitates human connection. The user-friendliness and interface of front-end technology, sensors, tablets, smartphones, and other devices are critical to the electronic well- being of the Internet of Things. It is critical that end users of IoT eHealth can receive on-the-job training on how to operate sophisticated medical equipment and all of its accessories. The end users typically don't know much about wireless networks, sensor synchronization, or other technical topics.

Therefore, it is vital that the IoT eHealth devicesmade for remote access be designed as self-sufficiently and simply as possible. For example, one of the largest IoT eHealth end users are senior citizens so the interface must be user friendly, and require minimal professional assistance. Participatory design can help the human compatibility of the interface via encouraging the end users to engage with the design team, and communicating their user experience so the ease of use, likes, dislikes, andcomfort levels in interaction can be devised.

3.4 Scalability

The more compact For the Internet of Things (IoT) to process user requests and guarantee that all medical services are available to users via personal devices like smartphones, portable devices with data-collecting sensors and centralized servers are necessary. By extending this procedure throughout the entire hospital, it will be possible to guarantee that every patient will get access to healthcare, be kept informed of their progress, and gain from ongoing observation. Given that the city's antennas and sensors are capable of gathering data, the Internet of Things can be expanded to include the entire city. Algorithms, Application Programming Interface all data through smartphones, and mobileapplications, and furthermore; send feedback topatients about their healthstatus, enabling everyone tohave access to test results, and integrated medicalservices. IoMT allows users a more straightforward access to their medical records, and test results which cuts out patient waiting- times significantly, and is therefore more time- effective for users.

Upscaling a small IoT network to the entire city can potentially improve overall efficiency, support relationship building between organizations, and promote trust between medical professionals, and patients.

3.5 Power consumption

Another important factor to consider for IoT is power consumption. The limited battery life of the sensors can negatively affect the lifecycle of the devices. Charging, or changing the batteries in IoT devices are extremely complicated, and often have little effect, especially if a system uses multiple sensors. The battery life of an IoT device will depend on varying factors such as the transmission range, the communication channel usage, overall time of use, and the complexity level of signal and data processing.

3.6 Disadvantages

Some IoT e-Health applications require the patient to constantly wear the sensors or carry them around, which can become tedious and inconvenient to the user. Thus, more efforts must be made in order not to decrease the quality of life for the subject, or cause unnecessary inconveniences to their daily routines.

4. Other studies

Many scientists and researchers are working in the field, considering the importance of the healthcare systems and their application in IoMT. Therefore, the rest of this section will focus on reviewing some of these studies. Azadeh Zamanifar, and her colleagues have introduced a system for IoT applications called DSHMP-IoT, whose function is the tracking of IP- based sensors - in smartphones - and their direction of movement in a multi-user environment such as a healthcare system. [5] This was the first time that an AI solution was used for tracking the direction of mobile nodes in an IP-based phone network. This design uses a Hidden semi-Markov Model (HSMM) to predict and track direction with high accuracy and low overhead.

They also proposed a method to predict the ECG sensor data, and in addition, the patient’s health status which would not require a jointanalysis. [6] This method uses mobile sensors, and a HSMM to predict a patient's overall health status and has two prediction outputs.

They also introduced a design named DMP-IoT, which predicts the new distributed direction ofmobile sensor nodes in healthcare applications to reduce the operation costs of the mobile sensor nodes. They have customized the Hidden-Markov second-order to achieve this. DMP-IoT includes a detection mechanism that identifies incorrect predictions, and avoids disconnecting the sensor nodes from the network in cases of false movement prediction. This mechanism prevents misprediction and losing the network connection. Zamanifar also emphasizes the importance of IoMT in predicting patient health status in a chapter of her co-authored book titled:“Remote Patient Monitoring: Health Status Detection and Prediction in IoT-Based Health Care, in IoT in Healthcare and Ambient Assisted Living.” [8] They have used cloud computing and mobile edge computing to communicate between different Healthcare subsystems.

Mobile edge computing is a distributed computing paradigm that moves computing and data storage to optimized positions in order to improve response time, and save bandwidth. Healthcare systems based on mobile edge computing are more effective since their computing is done near the patient. Thus, the patient’s health status predictions are done in real-time, which is a vitalfunction to have in healthcare systems. The same chapter presents IoT- based healthcare devices and methods which are used to identify or predict a patient’s health status.

In their book“A new machine learning-based healthcare monitoring model for student’s condition diagnosis in Internet of Things environment,” Alireza Souri and his colleagues present an IoT- based student health care system that continuously monitors students via their vital signs to detect physiological and behavioral changes through IoMT devices. In this method, vital signs are collected through IoT devices and analyzed with Machine learning methods to detect possible risks or changes in the students' physiology, or behaviors. Khizra Saleem and her colleagues have invented a system to monitor and analyze sleep patterns using environmental parameters in their book titled:"IoT healthcare: design of smart and cost-effective sleep quality monitoring system." The proposed system is effective enough to monitor the patient's sleeppatterns using Commercial Off the Shelf (COS) sensors, and to furthermore; predict the results using the random forest model. The patient's physiological data including physical body movement, heart rate, SPO2 level (oxygen saturation level in the blood),and snoring patterns are monitored through this system, and the collected data can be sent tocomputer systems. This real-time system is made of two parts. One part consists of the behavioral data analysis collected through random forest and decision-rules in real-time. This system notifies the caregiver in cases of any changes to the sleeping participant's status. The second part enables batch data processing which establishes the condition of the patient at a given period of time through statistical methods. This cost-effective suggested method can easily analyze the sleep pattern of a patient and provide better treatments.

CONCLUSION

In a world that is changing quickly, most individuals, such as energy conservation, water supply management, traffic control, delivery management, agribusiness, home automation, and navy management. Thanks to the management. The integration of IoT with emergency services, smart homes, and smart hospitals is the Internet of Things, wearable sensor technology has grown to be a profitable industry in the healthcare industry. More detection gateways are needed when IoT penetrates the medical field in order to facilitate data ultimate goal of this new technology.

Real-time patient monitoring can be aided by the data that smart hospitals and smart equipment gather. This can be beneficial.if not all of them, now need remotely accessible, networked devices with data analysis capabilities. IoT has been developed in response to this need. IoT is a mechanism for internet-to-device connectivity. This is the process by which smart lights, watches, etc. "smart." The Internet of Things makes people more independent, an us learn more about diseases, medicines, and vaccines.

Healthcare systems are a huge part of the IoT applications. The large data collections in these systems need to be extracted so they can be analyzed for the information hidden in them. An important function of IoMT is its precise prediction of a patient's health status remotely, especially in intensive care.

Various health applications are increasingly including predictions of patient movement, and health status changes in their interfaces; and due to the IoMT's significant contribution to disease study, and gathering intelligence about the physical environment of the patient, pervasive systems, and assistive technologies, it has become an outstanding field of research.

An overview of healthcare systems in the Internet of Things was done in this article and the many challenges, and benefits of the field were examined. Also several methods in predicting patient health's conditions using machine learning were analyzed.

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