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A new framework to enhance healthcare monitoring using patient-centric predictive analysis

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ABSTRACT

In the contemporary healthcare landscape, various intelligent automated approaches are revolutionizing healthcare tasks. Learning concepts are pivotal for activities like comprehending acquired data and monitoring patient behavior. Among patient-centric concerns, addressing data heterogeneity, extraction, and prediction challenges is crucial. To enhance patient monitoring using care indicators like cost and length of stay at healthcare centers, many researchers found a model for automated tools, but do not have the artificial intelligence (AI) based models as of now. Therefore, this research study will propose an AI and internet of things (IoT) integrated automated approach with smart sensors called the "PatientE" framework with heterogeneity and patient data. Employing certain rules for data extraction to form a distinct representation, our model integrates pre-treatment information and employs a modified combined random forest, long-short term memory (LSTM), and bidirectional long-short term memory (BiLSTM) algorithm for predictive post-treatment monitoring. This framework, synergizing AI, IoT, and advanced neural networks, facilitates real-time health monitoring, especially focusing on breast cancer patients. Embracing pre-treatment, in-treatment, and post-treatment phases, our model aims for accurate diagnosis, improved cost-efficiency, and extended stays. The evaluation underscores scalability, reliability enhancement, and validates the framework's efficacy in transforming healthcare practices.

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1. INTRODUCTION

Several healthcare monitoring systems and technologies have been developed to monitor and improve patient health, streamline healthcare delivery, and enhance overall well-being. Some existing healthcare monitoring systems are electronic health records, telemedicine and remote patient monitoring, health information exchange systems, clinical decision support systems, medication management systems, and population health management systems. This study investigated the effects of remote patient monitoring with modern technologies. While earlier studies have explored the impact of stand-alone and local or physical communication-based treatment methodologies, they have not explicitly addressed its influence on remote patient monitoring. It is important to note that the adoption of these technologies may vary across regions and healthcare systems. Additionally, ongoing developments and innovations are likely to bring new monitoring systems and improvements to existing ones [1]. In the other hand, existing technology in wearable health devices like fitness trackers, smartwatches, and medical-grade devices can monitor various health parameters, such as heart rate, sleep patterns, physical activity, and in some cases, even blood glucose levels. These devices can provide continuous health data and enable proactive healthcare with limited distance monitoring between patients and healthcare experts [2]. Therefore, this research study proposes remote monitoring with artificial intelligence (AI) and internet of things (IoT) related technologies. For this Patient-centric monitoring is needed for large-scale healthcare centers [3]. Patients are not able to get admission due to heavy crowds during heavy healthcare requests like the coronavirus disease (COVID) period and other critical-care situations, even with a few unconditional climate changes. Therefore, this research study contributes to a new approach to solving these kinds of cases. In day-to-day, artificial intelligence-based products with the IoT are being utilized in healthcare to better monitor and care for patients by connecting various devices and sensors. Healthcare practitioners receive data from these devices and use it to make informed decisions.

The healthcare industry has been profoundly affected by IoT. The World Health Organization (WHO) found that IoT can help save lives by facilitating early disease identification and management, as well as increasing access to care and decreasing medical errors. Rapid expansion and increased importance in terms of both income and employment have been characteristics of the healthcare sector in recent years [4]. Just a few short years ago, medical professionals needed to perform a thorough physical examination of a patient to diagnose illness or abnormalities. Through their therapy, most of the patients had to remain in the hospital. Because of this, healthcare spending rose and strain was placed on facilities in more outlying areas. Miniaturized devices, such as smartwatches, can now be used for illness detection and health monitoring, thanks to advances in technology. The healthcare system's emphasis has shifted from hospitals to individuals as a result of technological developments. Many clinical studies can be performed at home without the intervention of a healthcare professional. In addition, thanks to modern communication technologies, clinical data can be transmitted from faraway locations to hospitals and other healthcare facilities. More and more people can get the medical treatment they need thanks to advancements in communication technologies like the IoT, wireless sensing, mobile computing, and the cloud.

In addition to fostering greater autonomy, IoT has broadened the individual range of possible interactions with the world around them. By utilizing cutting-edge protocols and algorithms, IoT has become an integral part of international communication. Numerous gadgets, wireless sensors, and electronic equipment can now be linked to the web [5]. IoT has several uses, including in farming, transportation, the household, and medicine [6]. Improved accuracy in quality, lower prices, and better predictive capabilities are just a few of the reasons why the IoT is becoming increasingly popular. The ubiquitous availability of wireless technology, the maturation of software and application development, and the rapid growth of the digital economy have all contributed to the IoT revolution. IoT devices (sensors and actuators) can monitor and share data with other physical devices thanks to the incorporation of various communication protocols, such as Bluetooth, Zigbee, IEEE 802.11 (Wi-Fi), and so on. Patients' vital signs, including temperature, blood pressure, and electrical activity of the heart and brain, are recorded with the help of sensors in hospital settings [7]. Temperature, humidity, date, and time are just some of the environmental details that can be stored. We found that this research study will predict earlier healthcare monitoring using IoT and artificial intelligence technologies to monitor the patient's health and report to healthcare experts for treatment correlates with remote sensing technologies. The proposed remote sensing-based treatment process in this study tended to have an inordinately higher proportion of the "PatientE" framework for patient-centric predictive analysis to monitor patients as a new innovative method for the benefit of patients and doctors.

2. RESEARCH METHOD

Traditionally wearable device-based medical practice is limited to IoT-based healthcare studies involving the use of internet of things (IoT) devices for monitoring and managing patients with many medical complications or treatments like chronic respiratory conditions [8]. However, the objective of this study is to assess the effectiveness of an IoT-based remote monitoring system in improving the management and outcomes of patients with many healthcare frequent conditions such as chronic respiratory conditions like chronic obstructive pulmonary disease (COPD) or asthma [9]. In other studies, wearable devices equipped with sensors to monitor respiratory rate, oxygen saturation levels, and physical activity are provided to participants. Home-based spirometers connected to the IoT platform for measuring lung function are distributed, but limited to patients and healthcare expert distances [10].

Medical practice can now take advantage of IoT and cloud computing thanks to the internet of things framework utilized in healthcare applications. It also details the procedures for interfacing with a healthcare network and the sensors and medical devices that will be utilized to monitor the patient's nature of cases and related diagnostic and admissions procedures. The topology of a healthcare internet of thing (HIoT) is the configuration of its constituent pieces and their interconnections. In Figure 1, we can see the basic building blocks of an IoT system: the publisher, the broker, and the subscriber. It refers to a network of sensors and other medical devices that can collect data alone or in tandem to paint a comprehensive picture of a patient's health. Examples of such data include electrocardiograms, electroencephalograms, electromyograms, and other physiological measurements [11].

This data can be continuously transmitted from the publisher to the broker through a network. The data provider collects information and then stores it and processes it on the cloud. The subscriber can view the patient's data at any time from any location using any internet-connected mobile device (phone, tablet, and computer). In the event of a physiological deviation or decline in the patient's health status, the publisher may examine these records and offer commentary. The HIoT combines many components into a hybrid grid, each of which performs a specific task in the healthcare system's internet of things (IoT) network and cloud. Due to variations in healthcare needs and uses, it is challenging to develop a standard HIoT framework. An HIoT system has previously incorporated several structural alterations [12].

The ease with which the authorized node (sensor) may access the patient's data, from wherever it may be located, is an important factor to keep in mind while planning an HIoT system. To accomplish this, it is necessary to accurately identify the healthcare network's nodes and sensors. An authorized entity may be quickly recognized and data can be exchanged without any ambiguity provided a unique identification (UID) is assigned to it. In the modern healthcare system, a unique identifier (UID) is assigned to every component (patient, hospital, doctor, nurse, carer, and medical gadget). That way, everything in the digital realm may be properly identified and linked together. Several sets of identifying criteria have been documented in scientific literature. The open software foundation (OSF) produced two different kinds of identifiers: universally unique identifiers (UUIDs) and globally developed identifiers (GUIDs). Distributed computing environment (DCE) employs a technique called universally unique identifier (UUID), which does not rely on a single administrator [13].

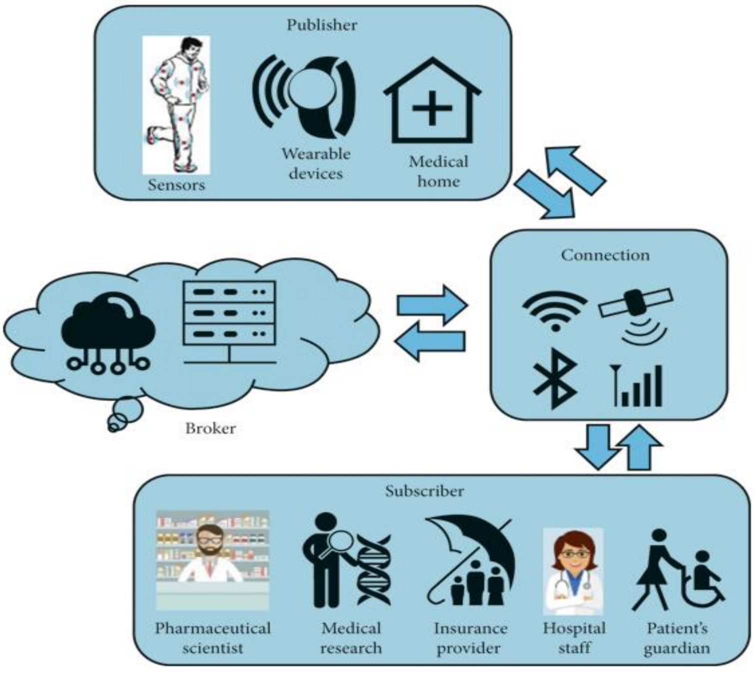

Figure 1. Architecture of an HIoT framework [8]

3. RESULTS AND DISCUSSION

The internet of medical things (IoMT) is a subset of IoT that aims to improve healthcare monitoring by connecting and coordinating disparate pieces of medical technology across a network. IoMT, or healthcare IoT, uses AI-powered machine learning, robotics, and biosensors to replace the need for human engagement in healthcare monitoring. The IoMT allows for medical data to be collected, processed, and transmitted remotely between patients and clinicians through a secure network. By enabling wireless monitoring of health parameters, IoMT technologies can cut down on costly, avoidable hospitalizations. The IoT comprises both wearable, at-home personal, real-time health monitoring devices and point-of-care (POC) devices used in hospitals and clinics [14]. Wearable personal health monitoring devices include electronic textiles and clothing, smartphone-integrated gadgets, and sports watches, as depicted in Figure 2.

Traditional healthcare monitoring is disrupted by the widespread availability of automated detection technologies and integrated cloud solutions made possible by digital healthcare. As a result of this digital revolution, more individuals, including those in rural areas, have easier access to high-quality medical care than ever before. Now, devices used at the POC can connect to the internet and save user data in the cloud. This includes ultrasound machines, thermometers, glucose monitors, and ECG readers. The development of such technologies is essential for the improvement of healthcare in areas such as insulin dosing and the creation of direct patient-clinician links. In modern hospitals, smart beds are becoming more common since they can be adjusted to accommodate a variety of sleeping positions. The IoMT is also transforming more conventional forms of home healthcare. For instance, a smart home drug distribution system routinely syncs patient health records to the cloud. It notifies both the clinician and the patient when a patient is not taking their prescribed prescription [15].

Artificial intelligence is the overarching field, machine learning (ML) is a subset of AI focused on learning from data, and deep learning (DL) is a specialized subset of ML using deep neural networks for representation learning. These fields are interconnected and contribute to the development and advancement of intelligent systems as shown in Figure 3 and shows that the majority of AI systems employ ML to anticipate outcomes based on historical data.

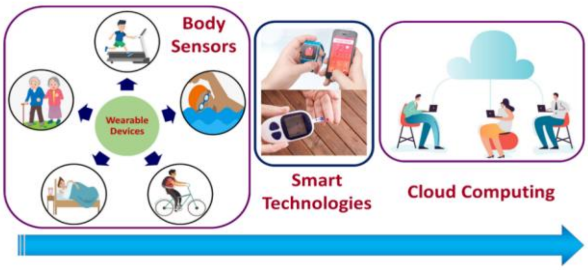

Figure 2. Schematic representation of IoMT devices and cloud data transfer

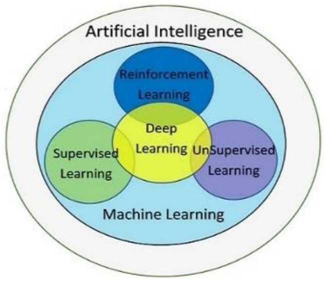

Figure 3. Schematic representation of relations between AI, ML, and DL

Supervised learning (SL), unsupervised learning (UL), and reinforcement learning (RL) are three major paradigms within the broader field of machine learning. While supervised learning focuses on learning from labeled data, reinforcement learning deals with learning from interaction and feedback. In some cases, they can be combined, such as in imitation learning, where an agent learns from both labeled data (supervised) and environmental feedback (reinforcement). On the other hand, unsupervised learning can be used in the context of reinforcement learning to pre-process or extract features from raw data. For example, unsupervised learning techniques like clustering might be used to segment states in a reinforcement learning environment. These two paradigms can be used together in semi-supervised learning, where a model is trained on a dataset containing both labeled and unlabeled examples. The model leverages the labeled data for supervised learning and the unlabeled data for unsupervised learning. Figure 4 depicts one possible subcategorization of ML based on algorithm structure and learning methodology. In practice, the boundaries between these paradigms are not always strict, and there is ongoing research into hybrid approaches that leverage the strengths of multiple learning paradigms for more effective machine learning systems.

In addition to the aforementioned categories, there are also the sub-categories of supervised learning, unsupervised learning, and reinforcement learning. The algorithm in supervised learning is taught using examples from the real world. Supervised learning is employed in contexts where past data can be used to make predictions. The training of these algorithms using historical data makes the resulting approaches both simpler and more precise. Regression algorithms and classification algorithms are two subsets of these [16]. When there is a correlation between the input and output variables, like in weather forecasting, regression techniques can be applied. Classification algorithms divide the results into groups based on the input variables, such as yes/no or true/false. Because of these characteristics, supervised learning can be used to anticipate the outcome of a real-world situation by analyzing the data at hand [16]. Unsupervised learning techniques can find a pattern in each dataset regardless of how the data are labeled or categorized.

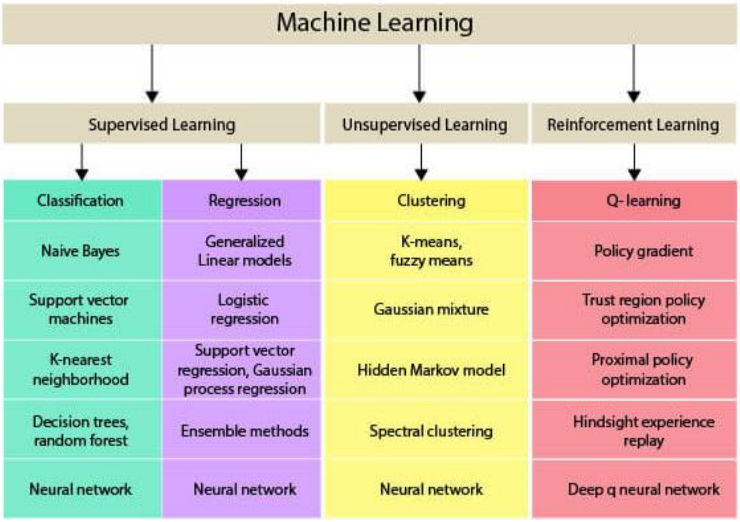

Figure 4. Schematic representation of relations between SL, UL and RL methodologies

3.1. Artificial intelligence and neural network applications for healthcare monitoring

Artificial intelligence-based models have already demonstrated their worth in the pharmaceutical and healthcare industries in a variety of settings, including therapeutic drug manufacturing, real-time health monitoring, and predictive forecasting. Artificial intelligence has proven useful in the drug development process and is now being used across the board, from medication design through drug screening. In 2020, a problem that had lasted for 50 years was finally solved when the DL model "Alphafold" correctly predicted the structure of a protein given its amino acid sequence. In a blind examination of protein structure prediction methods, Alphafold surpassed the competition by a wide margin, with TM scores of 0.7 or higher in 24 of 43 free modeling domains [17]. Carriere *et al.* [15] presented a comprehensive catalog of applications of AI algorithms and learning methods in the field of medicine. This analysis finds that supervised learning is the best approach to healthcare learning because it produces more practically relevant results. Support vector machines (SVMs) and neural networks (NNs) are the two most popular AI-based algorithms used in healthcare today, according to research by Carriere *et al.* [15], as shown in Figure 5.

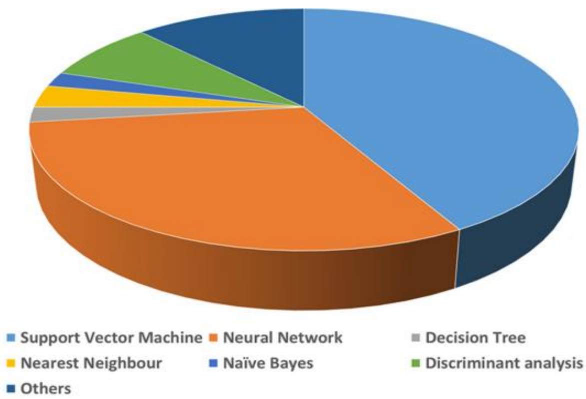

Figure 5. Use of various AI methods in medical applications

3.2. Proposed new framework PatientE

With the use of natural language processing (NLP), computers and machines can now evaluate, modify, and even synthesize human speech. The ability to do complicated jobs is greatly enhanced by combining NLP and ML algorithms [18]. Google Assistant, Siri, and Alexa are just a few examples of popular virtual assistants. Automatic clinical document encoding is another application of NLP. Recently at COVID-19, NLP methodologies have been put into action to translate clinical notes into a machine-readable manner [19], allowing for improved elucidation of the patient's health and medical history, subjective assessment results, and counsel delivered. The automated trained model for patient consultation with automated tools is available in past research works [20]. However, this paper proposes artificial intelligence-based patient-centric predictive analysis for monitoring patients at healthcare centers.

Therefore, Figure 6 shows the patient-centric predictive analysis system with an artificial intelligence-based approach. This framework first works with patient-centric applications accessed through a logical or physical approach. If the type of treatment procedure is chosen as a logical approach, this research study contributes the PatientE framework to function with AI and IoT modules [21], [22]. The logical approach continues with login credentials based on type of case for consultation procedure, depends on the user information as text or voice data, according to these data database from the healthcare centers decides the admission process, whether required or not [23]. If admission is required for the patient, then advice given to the patient to allocate a bed or prescription will be given to the patient for further medication procedure.

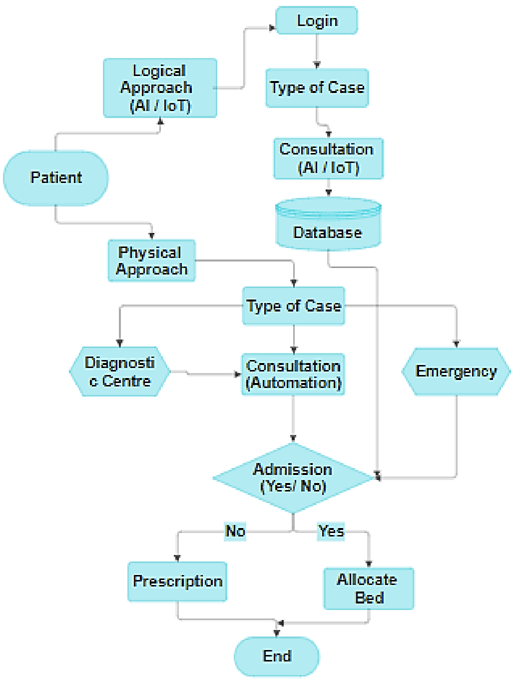

Figure 6. Framework "PatientE" architecture for patient-centric predictive analysis to monitor patients

Our study suggests that a higher remote patient monitoring system is not associated with poor performance in traditional treatment processes by healthcare experts and is limited to transportation from various places of hospitals to healthcare centers. The proposed method may benefit various regions of the patients to connect an intended network-based treatment consultation and medication process without adversely impacting social beings, technologies, and quality of treatment standards. This is a limitation in the existing studies. However, this proposed framework uses HIoT and AI techniques for regular practice of treatment for any patients in and around the corner of the country. On the other hand, the physical approach will continue with traditional procedures with types of cases like diagnostic center process doctor consultation or emergency bookings [24]. Based on this, admission required or not will be decided and, later allocated bed for the patient, if required. However, many automated applications in existing models have similar procedures to the physical approach. The sensor-based radio frequency identification (RFID) tags [25] are used to identify the monitor the patient's movements during the treatment on the remote side of the patients, this will control and advise the patients with this proposed framework-based application using a logical approach. Also, this proposed "PatientE" framework with heterogeneity and patient data, employs certain rules for data extraction to form a distinct representation. Our model integrates pre-treatment information and employs a modified combined random forest, long-short term memory (LSTM), and BiLSTM algorithm for predictive post-treatment monitoring. The CNN-based LSTM and BiLSTM algorithms are working in the patient's data-based analysis to suggest the exact status of the patient's procedure. Later, based on this information, patients are advised by healthcare experts.

This study explored comprehensive remote patient monitoring with IoT and AI technologies. However, further and in-depth studies may be needed to confirm its various obstacles in communication barriers on network protocol standards, especially regarding national network standard policies. Our study demonstrates that remote patient monitoring systems are more resilient than traditional patient treatment system. Future studies may explore all types of networks policies on various types of communication system with feasible ways of producing higher order communications reliability systems.

4. CONCLUSION

Recent improvements and innovations, especially those related to IoMT devices backed by AI for early disease identification, are reported here. There is enormous promise for remote health monitoring and disease prediction when IoT and deep learning technologies are combined. By applying these concepts, internet of things technology has helped the medical community monitor and diagnose more illnesses, measure more health data and expand diagnostic services to areas that were previously inaccessible. Personalized treatment for diseases like diabetes and cancer has taken a giant leap forward because of AI interfaces. Artificial intelligence results aid in early prediction and risk assessment of disease diagnosis. To enhance patient monitoring by using care indicators like cost and length of stay at healthcare centers, this research work proposed a new framework "PatientE" by having artificial intelligence and internet of things-based models. Hence, this research study required an AI and IoT-integrated setup at healthcare centers to use this proposed "PatientE" framework with heterogeneity and patient data. This is the limitation of this work. Employing certain rules for data extraction to form a distinct representation, our model integrates pre-treatment information and employs a modified combined random forest, long-short term memory (LSTM), and BiLSTM algorithm for predictive post-treatment monitoring. Recent observations suggest that the PatientE framework, synergizing AI, IoT, and advanced neural networks, facilitates real-time health monitoring, especially focusing on breast cancer patients. Our findings provide conclusive evidence that this phenomenon is associated with remote patient treatment process change, not due to elevated numbers of patient requests, it is due to technological advancement, to avoid patient appointment fixing. In the future, these results will be useful to encourage young researchers to push for and investigate novel ways to integrate nano-enabled sensing, AI, and the IoMT into biosensing to enhance individual-level disease treatment.

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