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Trends in Telemedicine Utilizing Artificial Intelligence

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Abstract. With the growth and popularity of the utilization of artificial intelligence (AI) in several fields and industries, studies in the field of medicine have begun to implement its capabilities in handling and analyzing data to telemedicine. With the challenges in the implementation of telemedicine, there has been a need to expand its capabilities and improve procedures to be specialized to solve specific problems. The versatility and flexibility of both AI and telemedicine gave the endless possibilities for development and these can be seen in the literature reviewed in this paper. The trends in the development of the utilization of this technology can be classified in to four: patient monitoring, healthcare information technology, intelligent assistance diagnosis, and information analysis collaboration. Each trend will be discussed and presented with examples of recent literature and the problems they aim to address. Related references will also be tabulated and categorized to see the future and potential of this current trend in telemedicine.

INTRODUCTION

The continuous development of technology that paves the way towards the expansion of connections through the internet and the growth of the capacity to process data has created greater possibilities of the development of the global health industry especially telemedicine. Information sharing, data analytics, internet of things, wearables, cloud technology, and robotics are currently rising as some of the drivers for innovation for the next decade. With these aspects steering towards the responses to the large amount of data used in healthcare, the requirement of consistent accuracy in complex procedures, and increasing demand in service for healthcare, it becomes is evident that the use of artificial intelligence (AI) has a major role in the operation and implementation of the technology. There is a need to develop the efficiency in allocating time and delivering healthcare needs and operations by automating hospital logistics [1].

Telemedicine is the application of transferring medical information in through interactive digital communication to perform consultations, medical examinations and procedures, and medical professional collaborations at a distance [2]. It is often highlighted that the telemedicine is an "open and constantly evolving science as it incorporates new advancements in technology and responds and adapts to the changing health needs and contexts of societies" [3]. The main objectives of telemedicine are bridging the gap of accessibility and communication in the medical field reducing delays and the cost logistics. Wireless technology applied to sensors and application to case studies related to electronic patient records and home monitoring and have been developing during the past decade, including studies on the cost-effectiveness and acceptance of the medical community to this technology [4]. It is mainly established to provide services using information and communication technologies (ICT) to four fields namely teleradiology, which transmits digital radiological images (e.g. X-ray images) from one location to another, telepathology, which transmits digitized pathological results, teledermatology, which transmits medical information concerning skin conditions, and telepsychiatry, for psychiatric evaluations and/or consultation via video and telephony, all of which are for consultation and interpretation through video and telepresence [3]. But with the

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growing knowledge in artificial intelligence and data analytics can further expand its scope and capabilities. It is the objective of telemedicine to increase productivity and organize expertise, knowledge, and man power based on demand and urgency while providing.

This paper will discuss the importance and both the current and possible future application of various concepts of AI to the objectives of telemedicine. Each concept and application to be discussed will be classified according these objectives namely patient monitoring, healthcare information technology, intelligent computer diagnosis, simulation and training systems, and information analysis and collaboration.

Application of Artificial Intelligence

Artificial intelligence technology has been around for decades and it has been vastly applied in various industries. The technology can be applied in various aspects of healthcare, such as providing a system to analyze medical information to determine sources of errors and develop solutions using existing results from procedures and enhancing procedures by adding computerized intelligence to medical devices and tools. Detecting patterns with speed and computed accuracy is a great advantage in finding the best practice and decisions for medical procedures. Discovery of patterns in the outputs of medical procedures can lead to optimization and prediction of impending problems. According to Dr Yulun Wang, the CEO of Santa Barbara-based InTouch Health, "Hospitals are now using this type of technology in order to leverage the specialists that they have even better and more efficiently" [5]. Several applications of artificial intelligence were used in the studies conducted in the references such as neural networks, machine learning, fuzzy logic, and the like.

TRENDS IN THE UTILIZATION OF ARTIFICIAL INTELLIGENCE IN TELEMEDICINE

Patient Monitoring

Patient monitoring is one of the first and most common application of telemedicine. This allows a faster and cost- efficient way of conducting regular doctor-to-patient consults to assess the patient's current state and clinical results at a distance. This has been developed to resemble face to face consultation through video conferencing and the connection of digital medical devices to take and record the patient's clinical data. The objective of this trend is to provide accessibility, ease, efficiency, and reduce costs compared to physical patient monitoring.

Recent designs of telepresence robots are designed to be able to autonomously move around hallways and rooms by being remote-controlled using a software interface connecting the user to the robot through a Wi-Fi connection [6]. This concept has been recently developed by adding the use of the combination artificial intelligence and vision systems for navigation and obstacle detection. An example of this is the Dr Rho Medical Telepresence Robot, which is composed of a mobile body and screen for patient-doctor communication. It features an intuitive vision system that instructs the cameras to follow the movements and gestures of the doctor and a micro-projector for collaborative examinations and procedures [7]. This robot, as well as other designs or telepresence robots, have already been deployed in several hospitals. The application of artificial intelligence will fit in the concept of machine learning equipped with simultaneous mapping and indoor navigation using sensors will allow the software to program a path for the robot having the only the destination as the input of the user. The same technology may be used to have the robot adjust its physical set up such as the height and angle of the screen or camera lens for the convenience of the patient.

FIGURE 1. Ankle rehabilitation system with subject's foot mounted to footplate and smartphone wireless gyroscope platform [8]

An application of AI and telemedicine for monitoring and gathering data on a patient's progress without the use of video communication or consultation is the study on an Ankle Rehabilitation System with Feedback from a Smartphone Wireless Gyroscope Platform and Machine Learning Classification. This study proposes the use of a device composed of a wireless gyroscope platform on a 3D printed frame (See FIGURE 1. Ankle rehabilitation system with subject's foot mounted to footplate and smartphone wireless gyroscope platform) connected through a smart phone to record the number of use and effects of ankle therapy and using "measure the efficacy of the rehabilitation strategy using" a machine learning algorithm [8]. This is an example of the importance of wireless vital sensors to telemedicine with its capacity to easily transmit data to devices which is vital in continuous monitoring [9] [10]. Another is the use of a web-based management system with machine learning techniques for real-time and faster data collection directly from patients with sickle cell disease [11]. The system is mainly used for management, accommodation of the patient, and monitoring but the AI feature adds the capability to predict the amount of medication based on previous data [12]. Through the current developments in patient monitoring, there is a support for self-diagnosing techniques and application of telemedicine not only in hospitals but also in homes [13]. As the capacity expands with telemedicine being applied on devices outside the hospitals, each device should be designed with a standard data architecture [14]. Majority of the patient monitoring devices and technology that are utilized outside the hospital are commonly to monitor the status or behavior of elderly patients or patients with chronic ailments [15] [16] (See Table 1).

Healthcare Information Technology

With the large scale of healthcare data being recorded in hospitals not only through manual registration but also through the developing use of self-diagnosing technology, medical information will be difficult to retrieve and store. Also, considering the goal of telemedicine connect medical professionals and patients from around the world, there is a need to create a universal record system for all participating institutions [17]. The trending technology of using the concept of big data analytics and neural networks to manage and properly retrieve electronic health care records.

The trend of applying AI in systemizing the retrieval and analysis of data also addresses the difficulties encountered in hospital procedures. A study by the American College of Physicians state that doctors spend 50 percent of their time on EHR and desk work so they came up with Remedy. This is a system that manages patient records effectively by replacing the manual process of examining the patients vitals with a chat interface questionnaire, recording it in storage, and sending the results to the doctor, speeding up the process [18]. This allows faster sending of prescriptions and other information directly to the patient as they can send photos or videos directly for examination.

Another trend in the development of patient monitoring is the use of cloud computing to solve electronic infrastructural issues in the bandwidth of some areas and the difficulty of implementation. This development aims to improve the efficiency of collecting and distributing the patient's information by applying the services in data-centers and using remote servers to store and manage the information. This has been applied in a study entitled "A Cloud Computing Based Telemedicine Service" to enhancing the speed of medical analysis by transferring ECG wave signals to a varied number of locations, such as a mobile phone, through the cloud [19]. Cloud computing has also been applied to linking "classical healthcare information system architecture and emerging eHealth consumer electronics technology". An example of this is the Microsoft Band 2 (See **Error! Reference source not found.**), which is equipped with blood pressure sensors and possess an associated and documented application program interface [20]. Applying cloud computation to this will improve the speed of data retrieval and improve transactional processing capacity. This can be a step towards the standardization of medical information and records throughout regions which will not only be important in processing data and collaboration but also to the overall application of an automated system in facilities throughout the region [21]. This will lead to faster telemedicine procedures and consistency in the implementation of new programs.

FIGURE 2. e-Health smart wearable: Microsoft band 2 [20]

Considering that the process of telemedicine utilizes wireless connections and constant transferring of patient's information, there was a risk in the security and confidentiality of the patient's information [22]. This was one of the common issues related to the reluctance of some facilities to implement telemedicine. Although certain studies involving the use of image processing and AI have presented ways to secure data using Wavelet Based Watermarking. This is a study conducted in India that proposes the use of an algorithm for digital watermarking of medical images to secure confidentiality of the diagnosis [23]. The development of device-to-device communications for robust security-aware process of transmission by adding authentication and analyzing the demonstration of the device [24]. This

Intelligent Assistance and Diagnosis

Another trending feature for the robotic technology is the addition of assisting mechanical components and the use of collected medical information and results for intelligent diagnosis. Both features aim to assist patients either physically or by analyzing initial patient evaluation to aid the current hospital system. These tools can operate under the programmed application of neural networks and machine learning. This will allow the technology to continuously develop using the information and results introduced to the system. There are existing technologies launching the use intelligent diagnosis applied in various types of software and smart phone applications for self-diagnosis technology in telehealth [3].

With the known trend in medical devices, there has been a development of self-diagnosing applications and devices in the market that is for quick evaluations of vital signs such as pulse, heart rate, breathing, and the like. An example is a start-up company called Lemonaid Health which developed and AI model of screening and evaluation of a patient through a questionnaire and fulfillment to a few requirements [25]. The patient will then be categorized after screening based on the complexity case of the case [26]. Doctors will evaluate the situation accordingly and may conduct phone call consultations or prescriptions can be sent directly. A triage examination process using a chatbot interface has also been developed by Carbon Health. This process will summarize the patient's information and schedule the consultation if needed. The program will also monitor and follow up patients on medication or signs of recurring symptoms [26].

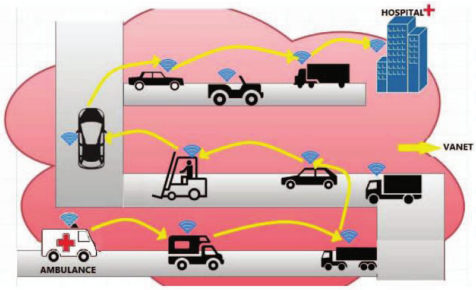

FIGURE 3 Architectural diagram of the telemedicine system and the types of vehicular ad-hoc networks used [27]

There is also an application of wireless telemedicine application in emergency situations such as the exchange of medical data of ambulances with nearby healthcare centers or facilities to collaborate and deliver fast quality service to the incoming patient as seen in the structure in Figure 3. A study has been conducted to analyze the feasibility and evaluate the performance of the implementation and will be very useful in other application such as calamities [27].

Information Analysis and Collaboration

This is the application of telemedicine in medical research and academic trainings or consultations. Using the technology to connect medical experts from other countries will encourage not collaboration not only on perspectives and information for diagnosis but also medical data. This will revolutionize the ways of pharmaceutical research with regards to the use of big data analytics in consolidating clinical test results as well as the use of genetic neural networks in recognizing patterns and analyzing data. This portion of the paper presents the trends in the use of artificial intelligence to use clinical data to determine the value of products in pharmacy and treatment outcomes. This trend will largely utilize the pattern detection feature of artificial intelligence as healthcare information is not only to be stored and easily retrieved but also to be analyzed. Using computer analysis will eliminate bias and opinions with regards to results since the program will be based only on the results.

An example is a Predictive Model for Assistive Technology Adoption for People with Dementia, which uses neural networks to determine the patient's potential to adopt to technology by considering and analyzing characteristics, behaviors, and other factors through an algorithm. The objective of the research is to provide predictive tools for better understanding and interpretation to be applied to home based care [28].

One of the most significant applications of neural networks is establishing connections in patient records or medical diagnoses stored in electronic healthcare records (EHR). This may be sourced from a combination of several hospitals or facilities in one region or country to make use of larger sums of data for the analysis. The success of this implementation can lead to revelations on insights on connection of the patients' records individually and generally as an area or district based on practices and changes in the environment.

The table (TABLE 1) below show the recent related references of utilizing artificial intelligence to various areas of telemedicine that are related to the discussed categories.

TABLE 1. Summary of References on the Trends in Telemedicine

Journal Article	Year	Trend Category	Summary
A Predictive Model for Assistive Technology Adoption for People With Dementia [28]	2014	Information Analysis and Collaboration	This study uses a k-Nearest-Neighbor and data mining algorithms and analyze behaviors of people with dementia when adapting to technology to provide a suitable predictive tool that could be used by healthcare professionals
A Telerehabilitation Application with Pre-defined Consultation Classes [29]	2014	Healthcare Information Technology	This focuses on addressing the issue of telemedicine under low-bandwidth network conditions using customized consultation classes demonstrating rehabilitation practices with preset parameters and a bandwidth adaption algorithm
A Wireless Continuous Patient Monitoring System for Dengue: Wi-Mon [30]	2017	Patient Monitoring	This presents *"a wireless monitoring system for patients who need continuous monitoring, using the Wireless Body Area Network (WBAN) concept"*
An Effective Telemedicine Security Using Wavelet Based Watermarking [23]	2016	Healthcare Information Technology	This paper proposes an algorithm that embeds and reads digital wavelet watermarks on medical images to secure confidentiality
Ankle Rehabilitation System with Feedback from a Smartphone Wireless Gyroscope Platform and Machine Learning Classification [8]	2015	Patient Monitoring	This study uses a smartphone application, a wireless gyroscope platform, machine learning, and 3D printing to record usage and effects of therapy on an ankle and measure the efficacy of the strategy.

COMPASS: an Interoperable Personal Health System to Monitor and Compress Signals in Chronic Obstructive Pulmonary Disease Thomas [31]	2015	Patient Monitoring	This presents a personal health system platform accessible to android devices that can analyze and send data for observation of chronic illnesses. This paper will also show compressed sensing techniques for the data and how it can be optimized through genetic algorithm
Detection of Fetal Electrocardiogram through OFDM, Neuro-Fuzzy logic and Wavelets Systems for Telemetry [32]	2016	Patient Monitoring	This study uses a neuro-fuzzy logic system to monitor the and detect the exact electrocardiogram and other signals of a fetus inside an abdomen.
Intelligent decision systems in Medicine -a short survey on medical diagnosis and patient management [33]	2015	Intelligent Assistance Diagnosis	The study presents "a short review of some current Machine Learning algorithms (neural networks, genetic algorithms, support vector machines, Bayesian decision, k-nearest neighbor, etc.) used for automated diagnosis of different major diseases, such as breast, pancreatic and lung cancer, heart attacks, diabetes"
Logic-Centered Architecture for Ubiquitous Health Monitoring [34]	2014	Patient Monitoring	This paper presents a logic-centered software for health monitoring and discusses how it can be shifted from software to hardware development with an application to smart wearable devices
Mobile Cyber Physical Systems for Health Care: Functions, Ambient Ontology and e-Diagnostics [35]	2016	Patient Monitoring	This paper proposes the use of a monitoring system embedded in wearable devices for the doctor or family members to receive updates on the status of the patient. An application of fuzzy systems was used to identify the best course of action for a given situation
Predictive Monitoring of Mobile Patients by Combining Clinical Observations With Data From Wearable Sensors [36]	2014	Intelligent Assistance Diagnosis	"This paper explores principled machine learning approaches to interpreting large quantities of continuously acquired, multivariate physiological data, using wearable patient monitors, where the goal is to provide early warning of serious physiological determination, such that a degree of predictive care may be provided."
Smartphone-Based Recognition of States and State Changes in Bipolar Disorder Patients [37]	2015	Intelligent Assistance Diagnosis	This paper proposes a system of using a smartphone-sensing wearable device to evaluate the behavior and recognize depressive and manic states of patients with bipolar disorder
Using CART for Advanced Prediction of Asthma Attacks Based on Telemonitoring Data [38]	2016	Intelligent Assistance Diagnosis	This study created an algorithm with data coming from a home-based telemonitoring system to predict asthma exacerbation

A novel biometrics method to secure wireless body area sensor networks for telemedicine and m-health [39]	2006	Healthcare Information Technology	"This article explores the use of this conduit in the security mechanism of BASN; that is, by a biometrics approach that uses an intrinsic characteristic of the human body as the authentication identity or the means of securing the distribution of a cipher key to secure inter-BASN communications."
Mobile phone messaging telemedicine for facilitating self-management of long-term illnesses [40]	2008	Patient Monitoring	The application of mobile phone telemedicine to monitor long term illnesses by evaluating the effects, changes in self-management, and cost of the intervention.

CHALLENGES IN IMPLEMENTATION

One of the greatest hindrances of the implementation of telemedicine programs and devices is the cost. Despite the development of cost-effective models, installation and training will require hospitals and facilities to invest time and expenses for full implementation [3]. There is also an issue with regards to the connection status or bandwidth to build a fast and stable delivery of quality telemedicine information as it may be necessary to make changes in infrastructure, which is very difficult to conduct especially in rural or underdeveloped facilities [41]. There has been a vast area of future directives of artificial intelligence in the area of healthcare information because of the current problems faced with its confidentiality and the security in conducting telemedicine consultation and operations. As it was mentioned in the under the category of healthcare information technology, there is still a risk in security and confidentiality in using connections such as satellites and the internet. Studies that aim to address this problem have not yet been fully refined may still take time to be implemented to the actual telemedicine technology.

Just like other medical procedures and devices, another issue is the malpractice issues which have led to the requirement of training and licenses to properly operate telemedicine devices. This may hinder facilities from implementation as it adds to the cost and time of completion. Malpractice and lack of education can also affect the consistency and preference of patients, which can lead to disregarding the use or development of the technology.

CONCLUSION

In conclusion, we are at the age of development of computer intelligence, a technology that can exceed the capabilities of and can greatly enhance manual procedures and even existing technology. The simplicity of being able to apply this technology allowed it to be of great use in several fields and this paper shows importance of its implementation to the field of medicine. Telemedicine is a versatile process and it has endless possibilities of development, an application can mean accommodating more patients or discovering the best practice for a medical procedure, which will impact many lives. It can be considered that telemedicine was able to catch up with the trends in using artificial intelligence but there are still some challenges to be solved. The implementation of these researches will be the most important contribution, which is why it is also important to begin researching on how this technology can be made more cost effective so it can be used in rural areas and underdeveloped hospital facilities.

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