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Integration of Artificial Intelligence in Medical Instrumentation for Real-Time Patient Monitoring

Sajad Faris Obeid Abbas Alasady
College: Al_Israa University Section Medical Instrumentation Engineering

Mays Mohammed Ayyez Majed
Department of Medical Instrumentation Techniques Engineering at Al-Mansour University College

Naba Adil Abad Ali
Engineering of medical instruments Northern Technical University Engineering Technology College/Mosul

Sajad kareem mutlak zmaeem
College: Al_Israa University Section Medical Instrumentation Engineering

Mustafa Fawzi madhi Talal
Medical Devices Technology Engineering Al Mansour University College

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Abstract: The utilization of real-time, artificial intelligence (AI)-integrated patient monitoring instruments is expanding significantly. Throughout the hospital stay, acutely sick patients are at an elevated risk of clinical deterioration. In triage, it is challenging to select the most acutely unwell out of a various population of aged citizens. In major hospitals, the total number of cases treated on a day-to-day basis can exceed 1000. Monitoring and observing patients in these healthcare contexts present a serious effort. On the other hand, the smart expansion of remote patient monitoring (RPM) practices can lead to a more predictive and preventive capacity in hospitals. It is ideal to collect the measurements on signal quality from the patient continuously in the home surroundings using a wearable apparatus.

Several machine learning methods have been integrated to automatically make predictions such as patient repose bed exit, patient repose bed exit present

bed future re-admission, patient-specific future step-count, etc. Linear regression, random forest classifier, and logistic regression were incorporated for emulating the analytical calculation of a doctor or a nurse. A Bayesian optimization method was implemented to enable input into a distant setting and accommodate any plausible parameterization in the model inside the patient population. Multiple models generate the patient-specific parameter optimization using machine learning techniques is the most advanced level of RPM. This renders it possible to build patient-specific models that will break a patient's health status down to the lowest level.

1. Introduction to Artificial Intelligence in Healthcare

Artificial intelligence (AI) has recently gained increased attention in various domains. In healthcare, AI techniques have been exploited in the diagnosis of epileptic seizures, cardiovascular diseases, and silent strokes, and in predicting Alzheimer's disease from brain maps. There is a growing interest in the application of AI in the automation of health informatics and medical instrumentation. The medical electronic instrumentation integrated with AI is a computer-based system that employs a knowledge base for interpreting the measurements obtained by the medical instrumentation. The knowledge base is consulted when a measurement needs to be interpreted, and the interpretation is then displayed on the screen. The operation and maintenance of the equipment is facilitated by giving a brief display of the procedure required to be carried out. This results in the more efficient operation of the equipment with reliable measurement data. DeepCopy system has been developed that is described quantitatively and supported with experimental results. The design can be implemented in modern medical instrumentation. Such a doctor's integrated textual and graphical explanation, patient's detailed reports in terms of time and frequency-domain parameters and an automatically generated brief history of the patient has been the primary feature of the system [1].

There has been a debate in the scientific literature on AI algorithms operating in the healthcare field. The complexity and opacity of AI algorithms has meant debate, with some recommending minimal use of AI in healthcare and calling for greater oversight. In contrast, others in the field see great promise in the use of AI and call for continued research and application in healthcare to improve currently challenging processes [2]. Another issue raised was the focus on "classic AI" with the development of rule-based, expert systems for healthcare application. There is already a movement to integrate AI as implementation is anticipated to greatly benefit medicine and other scientific domains. At a time when AI systems are outperforming humans in a multitude of tasks and their capabilities are poised for wider adoption, AI techniques are foreseen to revolutionize healthcare globally. This is noted by the World Health Organisation (WHO), which has reported that the broad-spectrum of AI applications in the healthcare sector include its uses in 1. diagnostic support, 2. treatment support and patient management, 3. hospital and administrative management, 4. planning systems, and 5. emergency management.

1.1. Overview of Artificial Intelligence

Recent advancements in artificial intelligence (AI), along with enhanced computational models and algorithms, provide an opportunity to revolutionize technology in medical instrumentation. Several medical instruments and technology developments include risk assessments for

prediction, analysis and studies of physiological signal patterns, and optimized instrumentation functions, making smarter operational recommendations. Current AI for portable medical instruments is focused on optimizing analyses or predictions of biosignal pattern features. Furthermore, AI-related studies regarding medical devices have recently increased and include more holistic discussions. Many medical equipment manufacturers plan to develop a cloud service system with a wearable device that collects the user's vital signs and a doctor to review and analyze the user's health data. AI platform-based medical devices can also make detailed recommendations and lower medical expenses and the user's frequent hospital visits, as a professional medical doctor is not always present for patients or for them to consult [3]. Additionally, home-based health monitoring equipment has been investigated that does not require the patient to visit for regular checkups. In light of these circumstances, the development of technology of accurate monitoring of the body's status in daily life and the prevention of diseases or accidents through early detection is forthcoming.

In recent years, research and development of devices, wear-watches, and smartphones for human daily health monitoring have been actively conducted by the bio-medical industry. Human body state information is constantly monitored by various biosensors and bio-signals detected due to the body's physiological and physical changes, and the artificial intelligence system software on the device provides the appropriate feedback to the user. In essence, medical devices with artificial intelligence (AI) algorithms for real-time health monitoring, signal processing, and analysis of bio-signals are developed. The signals in the medical field are usually detected remotely by the sensor through the wearable device on the body and then processed and visually displayed by the monitor [2]. In the case where the measured important level changes rapidly or significantly, the monitoring person may have difficulty responding in a timely manner. On the other hand, if AI technology is included in the medical instrumentation system, when the determined situation or warning signs are detected, the signal is instantaneously sent to the person in charge and can be checked and analyzed in real-time through the cloud network. [4][5][6]

1.2. Applications of AI in Healthcare

A number of studies on AI-based technologies in health care are currently being conducted. The use of machine-learning algorithms in medical image analysis has been expanded widely to most medical departments that use images for fields such as pathology, dermatology, cardiology, gastroenterology, and ophthalmology. Siemens Healthineers has developed AI-based AI-Rad Companion Chest CT software to assist chest CT diagnosis, and GE Healthcare is also working on the development of AI-based medical image analysis technology. Robotics provides high-quality treatment by improving the precision and accuracy of surgical procedures. Digital secretary finds the golden hour of appropriate intervention by continuously monitoring patient condition indicators and alerting the nurse when necessary. Machine learning predicts and analyzes patterns based on the data affecting treatment results. Image processing quickly processes large amounts of medical images. Natural language processing converts long unstructured text data, such as medical charts, to be easily read and interpreted. Voice recognition captures patient voice and language and stores important information in electronic medical records. Statistical analysis predicts patient treatment results by analyzing large amount of health record data. Big data analysis provides personalized recommendations to the patients. Predictive modelling predicts treatment outcomes by applying mathematical models. Various technology giants such as IBM, Google, Apple, and Samsung are competing to develop devices that can assist in improving user health by acquiring health information from daily life [7]. AI in healthcare is growing quickly and its potential to support clinical applications effectively is developing rapidly. In this review, the current status and issues of AI applications in healthcare are explored. Public disease detector notifies the control tower and establishes a policy. The control tower uses the information to deal with emergencies and changes medication supplies. It is also possible to predict outbreaks, and announcement information is output to the Control

Panel. In addition, affected areas are notified in advance and dust suppression measures. There is a system that can change shipping. The topics of a few more health care guests set up information desks at the airport, and a questionnaire is handed to passengers after passing through customs. Respondents who visit information desks and receive questionnaires are analyzed for symptoms and are immediately transferred to a doctor who specializes in the subject, including an interpreter [1].

2. Medical Instrumentation for Patient Monitoring

The capabilities of an intelligent system in the localization, identification and diagnostics of problem areas, a necessary step in routing work enquiries, a description of a project incorporating these ideas, and some knowledge-based aspects of the Berkeley Invoice Router are described.

Real-time patient monitoring is critical for the correct and timely diagnosis needed for appropriate treatment in the Neuro-Intensive Care Unit. However, there are various monitors and devices in the patient rooms whose data is essential in some critical cases but do not link up. A solution for the INSMA framework inclusive of plug-and-play signal parsing and visualization devices for waveform, spectral, bar and numeric data is presented. The system has been expanded to perform real-time signal analysis which includes QRST slope and R peak detection, HR tracking, visualization of numerical data as trend graph, and neural network-based ECG arrhythmia monitoring [8]. From the large amount of R peak data collected, a simple fall detection algorithm to identify the moment of loss of the ECG waveform is also implemented and performance evaluated.

Real-time patient monitoring and data acquisition technology play a critical part in detecting immediate problems and planning timely therapy. Each morning, a handover meeting from night staff to the day staff on each patient was attended by all nurses, therapists, doctors, and physiologists concerned with each patient. Apart from discussing statistics and recent lab results, attending nurses detail the EEG (emphasizing any ictal activity), ICP values, sedation and neuromuscular blockage.

2.1. Types of Medical Instruments

Clinical and patient monitors with the ability to collect and visualize important numerics or waveforms are a primary means from which physicians may ascertain patient health. Multiple devices exist to obtain any number of physiological signals, including units for MEG and EEG, laboratory and bedside instruments for blood panels or medication levels, EKG, temperature, ICP, NIBP, and blood oxygen sensors. Several of these device types often require interfacing to multifunction patient monitors to be stored in the EMR, and many additional monitoring or imaging systems exist that are designed only for real-time use. Unfortunately, devices that are newly implemented in the ICU often contain important waveform or numeric data that are not interfaced with the broader hospital infrastructure. Proposed is the integrated Multimodal Envisioning framework to address that need—a system for automated real-time acquisition and relative parsing of a variety of critical care modality groupings that are then outputted in either a shareable visualization format for broad viewing or storage [8]. A Python application has been implemented in the Neuro-Intensive Care Unit that continually acquires data from multiple hospital imaging, EMG, EMU, MEG, PNU, PPC simply by using the Ethernet output to an acquisition PC. Post-acquisition parsing of that data is accomplished using a PC, but the tIME framework will also contain a browser-based neuromonitor of two varieties: pointform and friendly (‘abstracted’ signal parsing). Browser neuromonitor output will be made viewable at Main Campus and may be used proactively in patient care, study, or teaching. Any hospital in which Louisiana System Agreement 203 has been implemented and which has a technically supportive IT team may benefit from this system.

2.2. Importance of Real-time Monitoring

The prevalence of chronic diseases is increasing year by year. After COVID-19, there is a growing trend to monitor the health condition of the patient remotely, so there is still an increase in precision patient monitors at the hospital. To make it feasible, client server architecture was proposed. Wearable devices can record various physiological indicators of any customer. In a centralized database, the server receives the patient's health data from the client application. The physician can monitor all patient health data when they connect, because all patient health data is stored in the central server database by hospital staff. In this period, doctors can not detect the patient's health conditions in the following period even if the patient's health data is recorded. When the patient is close to vital sign deprivation, acute or main depression may require immediate hospitalization. In such a system, there is an urgent requirement to detect facial emotion recognition, heartbeat, and temperature as patient health data.

Remote Patient Monitoring (RPM) is a technology to monitor patient health data outside the anti-social clinic. It helps to decrease multiple visits to the health care provider to check patient health. Currently, various platforms are available for monitoring patient health remotely. In RPM, the inaccuracy of a patient's health status is a big challenge because each patient is different. The ACSC is a modern concept for personalized health care using artificial intelligence. It makes the daily counter-screening of a person by observing his or her daily routine and briefly studying the environment. Without patient information, ACM is unable to collect patient health data in RPM. Emotional data plays an important role in engaging patient health data directly. Basic optimization technologies are used to adapt any possible parable in patient population optimization. The statistical RPM system is one proposed, which can provide an accurate distribution of electric parameters pV, pRy, and pLm and can combine 787 tambacin to each patient. Combining the most advanced visualization of a patient with the Ml orientation system process is to use the patient's personal order [9].

3. Challenges and Opportunities in Integrating AI with Medical Instrumentation

The biannual Conference on Bioelectronics, a noticeable platform for emerging innovations in medical research and medical instrumentation in India, was recently held online. Over 25 landmark works in shifting topics were conferred on this event. The conference aims at concocting new materials, devices, and systems that employ principles of natural sciences and engineering to understand complex medical and biological sciences and problems as well as to develop innovative systems to diagnose mutant diseases, improve medical treatments, and enhance the life quality of non-deteriorated patients. Topics of research typically cover strategies, sensors, technologies, instruments, modeling, systems, and processes for interaction of bio-engineered solutions with biological systems and products.

The plenary lecture was ceremoniously presented by a senior scientist. This speech covered broad context on the emerging developments in approaches to detect and monitor the rapid spread of the coronavirus. It apprehensive of upcoming variants and possibilities for next generations. Some of the key challenges and opportunities in combining artificial intelligence with medical instrumentation for monitoring patients in real-time are presented.

4. Benefits of Real-time Patient Monitoring with AI

The availability of medical resources is limited in rural areas of many low- and middle-income countries, and most of the population cannot receive timely medical services. The patient monitoring equipment uses electronic instruments as a health care system, the function of which diagnosis and observes clinical information from environmental signs and changes that occur in a patient. Efforts have been dedicated to developing diagnostic equipment to improve patient monitoring in clinical tests. The smart artificial intelligence (AI) patient monitoring system was utilized for real-time patient monitoring by detecting a patient's heart rate and body temperature and analyzing the data. On receiving patient data during a clinical medical consultation, the

algorithm estimates the patient's health status based on the mean of the changes in heart rate and body temperature over the time interval. A displayed message of the patient's health status is presented in the telemedicine mobile app. Either arrangement of the patient monitoring system and data analysis can be done. While AI-based forecasters are trained to create prediction models, the test set checks these models and provides prognoses. Some applications of RPM to monitor of patients' electrical signals, body movements and processed signals with the help of the artificial intelligence (AI) are shown and described [9].

5. Case Studies and Examples of AI-Driven Patient Monitoring Systems

Due to budget constraints, a large number of patients currently cannot receive round-the-clock patient monitoring systems. Case studies and examples of AI driven patient monitoring systems were provided: 1) A smart integrated system for real-time patient monitoring; 2) A system that detects physical restraints; 3) An AI-driven algorithm for remote monitoring of heart rate, saturation, and fall detection; 4) A system that estimates patient-specific vital sign distributions at zero and future time; and 5) An AI system for remote monitoring of physical function status. For each of them, experiments with inexpensive sensors already owned by the authors to show feasibility are recommended.

1) A smart integrated system: A smart integrated system has been presented in this research work that will frequently monitor the health records of every person. This is a boon for healthcare professionals since they can diagnose the conditions of patients both physically and emotionally [9]. Different methods for RPM are similarly detailed, recording the most advanced RPM methods using the likelihood of abnormalities.

6. Ethical and Privacy Considerations in AI-enabled Healthcare

The increasing use of AI technologies in healthcare, providing real-time monitoring of patients without human intervention, is a serious concern due to several ethical and privacy issues. Financing for healthcare is prevented by most individuals, and they try to examine their health by using technological tools before they visit the health services. It is quite normal to see that patients want to know their preliminary status by conducting various examination methods such as taking their temperature, measuring their pulse, measuring their blood pressure, measuring their blood sugar, taking oxygen saturation, and listening to their breath. The sad part is, however, most of these tools are not user-friendly, they are complicated tools that require the help of someone with knowledge or have to go to hospitals or clinics to use these tools [10].

Through IoT connected wearable medical devices, it is possible to monitor the body parameters of patients more easily. Each day, the technology advances in this field. Many of the wearable medical devices can measure different types of body parameters according to the needs such as heart rate, body temperature, EMG, Blood oxygen, EEG, ECG, Respiratory Rate, Blood Flow, Pulse, Blood Pressure, Glucose Concentration, Electromyography, Body Motion, Galvanic Skin Response, and Bio-impedance. The measured biometric data always produces very large amounts of data. To collect and process all this data in real-time, there is a need for powerful processors. At the same time, this system must be connected to the cloud for analysis. Indeed, using AI technology (especially machine learning and data processing), it is possible to monitor patient measurements in real-time and process it without human intervention. The processed data can also be used in real-time to take action (like sending emergency alerts), and this large data can be analyzed later to identify how to improve health. [11][12][13]

7. Future Trends and Innovations in AI-powered Patient Monitoring

The use of Internet of Medical Things (IoMT) based medical devices and wearable devices have dramatically increased in recent years for monitoring health conditions. Medical devices for monitoring health-related parameters are available in the market like ECG, temperature, blood pressure, and many others. Most of these devices operate only in a single mode wherein they can monitor only a single parameter. By using a smartphone as the base station, these devices can be

made more advanced. In this research work, the integration of the AI algorithm in the medical devices is proposed which helps to monitor the health parameters more efficiently, and presentation of the developed application for real-time patient monitoring, data analytics, etc [9].

The routine of monitoring health parameters plays a vital role in the healthcare of Individuals suffering from diabetes, hypertension, etc. In particular, we propose BMI, Oximeters, Temperature, and Blood Pressure sensors. The sensed data of these health parameters, like heart rate, SPO2, etc, is monitored in a smartphone using Bluetooth technology. The Artificial Intelligence (AI) algorithm is integrated with the proposed medical instruments for providing real-time health conditions. Monitoring the health condition and medication time of such patients not following a strict diet plan of eating meals at the same time and helping the old people forgetting the medication time is a real challenging process. Many patients do not have the practice of checking the time before having food or medication. At such times, the developed algorithms remind the medication and food time with the help of developed Medical Application. The algorithm is also integrated into medical equipment to provide real-time health conditions. [14][4]

8. Conclusion

Today, the integration of Artificial Intelligence (AI) in new medical instrumentation paves the way for real-time patient monitoring. At the most advanced level, remote patient monitoring (RPM) has become a popular trend. Novel Bayesian optimization methods that can accommodate any plausible parameterization in the patient population using machine learning techniques are implemented for the first time, to the best of knowledge. This helps in building patient-specific models that break down a patient's health status to the lowest level. The doctor or the health care provider will do routine check-up. The doctor will focus on the symptoms that patient described. Many diagnosis tools are used to check the patient health condition such as pulse, BP measurement, Sugar, Thermometer, blood test.

However: The symptoms in patient, Sometimes patients forget to describe some of the symptoms. The doctor is unable to understand or analyze the accurate health conditions of patients. The emotions of the patient will also impact health Either the patient very happy or over stressed, worried, and even in tension. Remote patient monitoring using deep learning face recognition of emotions has been proposed for the early detection of patients' emotional states and heartbeat rate. With the advancement of technology, that AI can easily classify the patient's emotions. AI classification is based on the faces of the patient like the movement of the smiley face, sadness face etc. In developing countries facing the high-heart disease of patients. Synchronized heartbeat rate and facial expressions.

References:

1. A. Aamir, A. Iqbal, F. Jawed, F. Ashfaque et al., "Exploring the current and prospective role of artificial intelligence in disease diagnosis," 2024. ncbi.nlm.nih.gov
2. M. Komorowski, "Artificial intelligence in intensive care: are we there yet?," 2019. [PDF]
3. P. Manickam, S. Ananth Mariappan, S. Monica Murugesan, S. Hansda et al., "Artificial Intelligence (AI) and Internet of Medical Things (IoMT) Assisted Biomedical Systems for Intelligent Healthcare," 2022. ncbi.nlm.nih.gov
4. M. Alshamrani, "IoT and artificial intelligence implementations for remote healthcare monitoring systems: A survey," *Journal of King Saud University-Computer and …*, 2022. sciencedirect.com
5. A. Sujith, G. S. Sajja, V. Mahalakshmi, and S. Nuhmani, "Systematic review of smart health monitoring using deep learning and Artificial intelligence," Neuroscience, 2022. sciencedirect.com

6. L. Tan, K. Yu, A. K. Bashir, X. Cheng, and F. Ming, "Toward real-time and efficient cardiovascular monitoring for COVID-19 patients by 5G-enabled wearable medical devices: a deep learning approach," Neural Computing and ..., 2023. springer.com
7. C. W. Park, S. Wook Seo, N. Kang, B. S. Ko et al., "Artificial Intelligence in Health Care: Current Applications and Issues," 2020. ncbi.nlm.nih.gov
8. Y. Sun, F. Guo, F. Kaffashi, F. J. Jacono et al., "INSMA: An integrated system for multimodal data acquisition and analysis in the intensive care unit," 2020. ncbi.nlm.nih.gov
9. T. Shaik, X. Tao, N. Higgins, L. Li et al., "Remote patient monitoring using artificial intelligence: Current state, applications, and challenges," 2023. [PDF]
10. S. Pasricha, "AI Ethics in Smart Healthcare," 2022. [PDF]
11. T. Shaik, X. Tao, N. Higgins, and L. Li, "Remote patient monitoring using artificial intelligence: Current state, applications, and challenges," Data Mining and ..., 2023. wiley.com
12. A. T. Shumba, T. Montanaro, I. Sergi, and L. Fachechi, "Leveraging IoT-aware technologies and AI techniques for real-time critical healthcare applications," Sensors, 2022. mdpi.com
13. B. Crowell, J. Cug, and K. F. Michalikova, "Smart wearable internet of medical things technologies, artificial intelligence-based diagnostic algorithms, and real-time healthcare monitoring systems in COVID-19," American Journal of Medical, 2022. [HTML]
14. Y. Xie, L. Lu, F. Gao, S. He, H. Zhao, Y. Fang, and J. Yang, "Integration of artificial intelligence, blockchain, and wearable technology for chronic disease management: a new paradigm in smart healthcare," Current Medical, 2021. springer.com