Journal of Trends and Challenges in Artificial Intelligence

ASPUR PUBLISHING

Vol. 02, No. 03 (2025) 89-94, DOI: 10.61552/JAI.2025.03.004 - http://jai.aspur.rs

ARTIFICIAL INTELLIGENCE OF THINGS-BASED INTENSIVE CARE UNIT PATIENT MONITORING SYSTEM

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Received 19.07.2024.
Revised 17.08.2024.
Accepted 22.09.2024.

Keywords:

Artificial Intelligence, Internet of Things, Artificial Intelligence of Things, Intensive Care Unit, Patient Monitoring System.

Original research

A B S T R A C T

Monitoring patients in Intensive Care Units (ICUs) is essential for ensuring safety and delivering optimal care; nevertheless, the Philippines may be deficient in the adoption of new technologies. This research study investigates and aims to improve ICU patient care. The system utilizes Artificial Intelligence and the Internet of Things for continual monitoring, emphasizing ICU patients, particularly vegetative ones. The development process encompasses circuit diagrams and utilizes a variety of programming languages, including JavaScript, HTML, PHP, and Python, to create artificial intelligence APIs. The system has been evaluated by various medical professionals to guarantee that the study conducted adheres to the ethical norms of medical practitioners in the Philippines. Obtaining confidential AI training datasets was one of the challenges faced while doing this research. The system effectively oversees access control, administrative activities, and patient monitoring, demonstrating improved care and reduced nursing effort, thus improving ICU care quality. In conclusion, this study provides an intriguing possibility to enhance ICU care through innovation and technology, resulting in better outcomes for both patients and healthcare providers.

1. INTRODUCTION

Medical operations use more advanced technologies to diagnose and cure illnesses and improve patient outcomes (Vatandoost & Litkouhi, 2019). Patient monitoring systems, which use advanced technologies to measure vital signs and detect anomalies continually, have been deployed in Intensive Care Unit (ICU) settings across the globe, including the United States, United Kingdom, Germany, Australia, Canada, and Japan. These systems are important in closely monitoring patients, comprehending early warning signs, and delivering timely interventions. As a result, additional healthcare providers are motivated to improve patient care and results in Intensive Care Units (ICU) (Banda et al., 2022). In comparison, the Philippines' existing patient monitoring systems may be inferior to those in the United States, United Kingdom, Germany, Australia, Canada, and Japan. While some hospitals in big cities may have installed fundamental patient monitoring systems, the utilization of motion and gesture detection technology may still be limited (Acampora et al., 2013). This is especially noticeable in rural areas, where medical professionals continue to use traditional methods of patient monitoring, which can be time-consuming and susceptible to errors (Galle et al., 2021; Haleem et al., 2021).

Concerning the high risk of complications alongside Intensive Care Unit (ICU) patients, nurses must regularly track them, frequently every 15-30 minutes or at least once per hour across a 24-hour shift; small lapses in monitoring can have significant implications, even death (Kim et al., 2021; Vai et al., 2021).

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2. CONCEPTUAL FRAMEWORK

This section provides a theoretical foundation for understanding the complicated relationships between the variables and concepts being studied. The study's paradigm, illustrated in Figure 1, defines the project's development into three stages: input, process, and output.

Figure 1. Paradigm of the AIOT-based Intensive Care Unit Patient Monitoring System

Figure 1 highlights the first phase of the project, which entails obtaining inputs for the AIOT-based ICU Patient Monitoring System. This step entails reviewing previous research on motion and gesture detection, applying technical skills and expertise, and collecting the appropriate tools and equipment. These inputs provide the basis for creating a monitoring system based on information gathered with regard to motion and gesture detection.

The second frame, on the other hand, presents a set of procedures for formulating requirements, identifying necessary tools, and establishing testing protocols for the AIOT-based ICU Patient Monitoring System. This step entails producing conceptual designs, circuit diagrams, and flowcharts, which serve as models for system development. These visual representations help to grasp the logical flow and linkages of system components, resulting in effective implementation. Furthermore, identifying the necessary tools allows researchers to select appropriate hardware and software solutions that are consistent with the project's objectives. This phase focuses on the planning, design, development, testing, and evaluation procedures.

In the third frame, the study's findings show that the implemented AIOT-based ICU Patient Monitoring System has proven useful in assisting ICU nurses during working hours, particularly when monitoring critically ill patients. This device intends to attenuate unforeseen changes in the health status of comatose patients while also reducing the requirement for ICU nurses to remain physically inside the ICU facility room, hence decreasing potential dangers.

3. MATERIALS AND METHODS

The researchers surveyed several ICU nurses from the CALABARZON region in the Philippines to get appropriate information for looking into the current patient monitoring system. The researchers analyzed a variety of technical elements, including the design, operation, and safety measures for detecting movements and gestures in comatose patients. The researchers' goal with this study was to discover techniques for developing an AIOT-based ICU Patient Monitoring System capable of recognizing the mobility and gestures of vegetative state patients.

3.1 Layout of the microprocessor device

Figure 2 illustrates the construction of the Orange Pi One Board within the transparent acrylic case enclosure. The researchers began the assembly procedure by taking rigorous precautions to ensure that the Orange Pi One board was free from static charge.

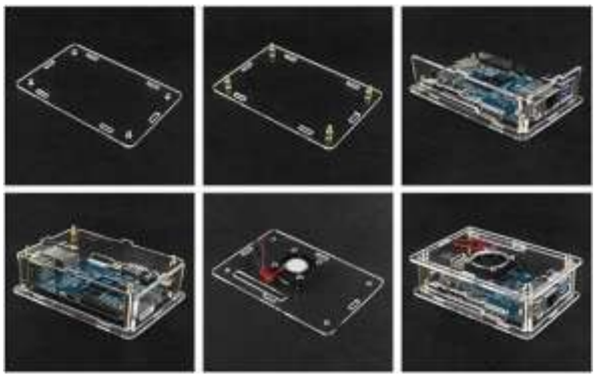

Figure 2. Layout of the Orange Pi One Board

After identifying the mounting holes on the board, the researchers placed screws into the base of the clear casing. The Orange Pi One Board was then carefully secured onto these screws within the acrylic case, and to improve stability, brass hex standoffs were strategically positioned in the corners, especially near the ports.

To prevent overheating, a small cooling fan was mounted in the server, and its wires were attached to pins 2 and 3 on the right side of the 40-pin header. The fan's red wire was attached to pin 2 to provide 5V power, while the black wire was connected to pin 3 for grounding.

The researchers completed the installation by covering the top of the case with the attached minuscule fan and fastening the screws for a snug fit. This thorough assembly technique not only eliminated static charge but also included stability measures and temperature management by integrating the small fan into the transparent acrylic box.

3.2 Development of the AIOT-based ICU Patient Monitoring Device using Orange Pi One

The researchers configured up the Orange Pi One using the PuTTY platform and created a PHP module library to handle API backend calls at /API/(additional endpoint). The researchers configured the Orange Pi One as the system's local server and uploaded PHP and Python scripts to handle incoming and outgoing queries.

To transmit SMS messages using the SIM 800C USB module, a PHP script was written. The researchers also updated the Orange Pi's kernel packages. The Orange Pi was connected to an internet-connected network via a

Local Area Network (LAN) connection to ensure system connectivity.

Figure 3 depicts the setup process for the developed AIOT-based ICU Patient Monitoring System, which includes connecting the GSM Module and LAN Cable to their respective ports before connecting to any power source, such as a system unit.

Figure 3. Actual Set-up of Developed AIOT-based ICU Patient Monitoring Server

This system is plug-and-play, which means it will activate automatically when plugged in. When started on, the Orange Pi One server produces a yellow light on its circuit board, the fan begins to rotate, and the LAN port's LED flashes yellow and orange, indicating a successful internet connection over LAN. The slow red light on the GSM module shows signal reception. The presence of these functionalities indicates a properly running server.

3.3 Convolutional Neural Network for AI development of the system

The researchers collected data from multiple healthcare facilities and places throughout the CALABARZON region to train an AI system capable of detecting the movements and gestures of critically ill patients. The researchers used the CNN model for the neural network and trained for sixty (60) epochs to achieve optimal learning. Convolutional Neural Networks (CNNs) are very well-suited to picture recognition and analysis, making them an excellent candidate for detecting small motions or gestures inpatient data. By using convolutional layers, the system can detect crucial spatial hierarchies and features in the input data, improving its capacity to recognize complicated motion patterns relevant to the target domain.

To integrate machine learning into web-based application, the researchers used TensorFlow.js, which allowed researchers to build and deploy models directly in web browsers or Node.js environments.

TensorFlow.js is a robust machine learning toolkit that enables TensorFlow-trained models to operate on the web, providing flexibility and scalability. One of its primary advantages is the ability to use hardware acceleration, such as GPUs, to boost computing efficiency. This ensures that complicated machine learning tasks, such as gesture detection, may be completed in real-time even in a browser-based setting.

The system's accuracy criterion was established at 75% for minimizing false-positive detections while maintaining a balance of sensitivity and reliability. For detection to be regarded as legitimate, the prediction score must be greater than 75%; otherwise, the system stops and returns to motion detection mode. Furthermore, the researchers established a set of motions linked with seizures, which is critical for validating detection requests and guaranteeing that the system can effectively discern between different levels of patient activity. This combination of CNN-based identification and TensorFlow.js integration allows the system to deliver accurate and efficient monitoring of comatose patients across multiple web platforms.

4. RESULTS AND DISCUSSION

This section provides the actual result of the developed prototype and how the web application system works during an actual operation (Dullabh et al. 2020).

4.1 Developed AIOT-based ICU Patient Monitoring System

In the software development phase of creating the ICU Patient Monitoring System, the researchers identified the software requirements critical for the system's functionality. To align the system with the hospital's brand identity, the researchers strategically integrated the color orange and green within the system's design. This meticulous process involved exploring various platforms to determine the most fitting programming languages and resources for the task at hand.

Figure 4. ICU Patient Monitoring Portal

Initially, the ICU Patient Monitoring System's front end was developed using Python and HTML5, while the back end was developed using a combination of Tensorflow.JS and PHP, each chosen for its specific functionality. MySQL was used to facilitate the database design, ensuring that the system's data administration is resilient. JavaScript was used as the programming language, enabling dynamic and responsive user interactions. The developed monitoring portal is shown in Figure 4.

4.2 ICU Patient Monitoring Dashboard

The developed ICU Patient Monitoring Dashboard is illustrated in Figure 5, It features a stats card interface divided into Total Patients, Total Nurses, Recent Admitted Patients, and Patients Discharge categories. These cards display essential information such as patient count, nurse availability, recent admissions, and discharged patients.

Figure 5. ICU Patient Monitoring Dashboard

To aid the head nurse in report generation, a filter option allows specifying the target month for reports on admissions, ICU occupancy, and discharges. corresponding analytics graph provides visual representation, utilizing color coding for easy interpretation. Additional features include a pie graph showing gender distribution among patients and a search bar for retrieving details of recently admitted patients based on name, admission date, or status. These features streamline data access and facilitate efficient patient monitoring and management (Zainuddin et al. 2020, Jiménez & Martínez 2021).

4.3 SMS Notification System

Figure 6 displays the developed Notification Message that the assigned nurse receives once motion and gesture are detected by the ICU Patient Monitoring System (Azizulkarim et al. 2017).

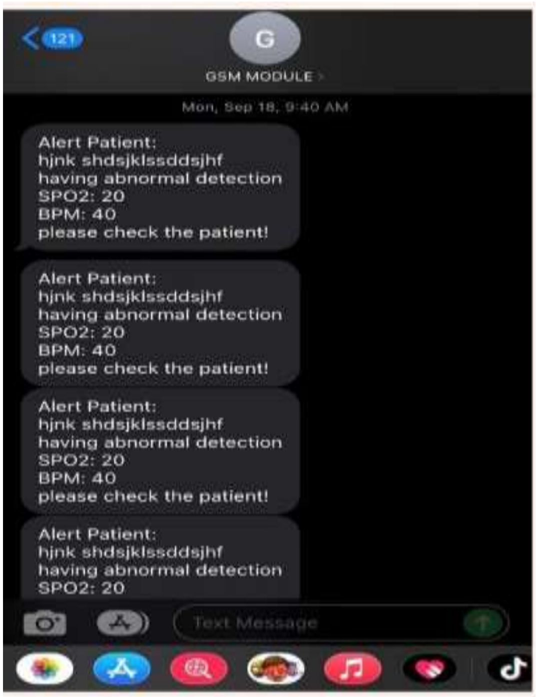

Figure 6. SMS Notification

A notification is sent by the GSM Module to the designated nurse assigned to monitor the patient (Poncette et al. 2020). The message contains an alert notification, stating that the system has detected an abnormality in the patient's condition (Dziadzko et al. 2016, Aditya et al. 2020, Ele et al. 2020.). A notification system is a critical component of the ICU Patient Monitoring System, designed to ensure timely and effective responses to potential patient distress or changes in condition (Babu et al. 2020, Bhavani et al. 2020).

5. CONCLUSION

Analysis on the developed system yielded the following conclusions.

- The AIOT-based ICU Patient Monitoring System notably progressed in integrating cutting-edge approaches in healthcare, especially the intricate process of identifying movements and gestures in comatose patients.
- The AIoT-based ICU Patient Monitoring System's design effectively incorporates an Orange Pi One board housed within an acrylic case, guaranteeing secure placement and optimal cooling, with additional provisions for a mini fan. Additionally, the utilization of JavaScript and HTML for creating interactive websites, PHP for handling server-side tasks, and Python for extending functionality from web development to machine learning was successful.
- The AIoT-based ICU Patient Monitoring System integrates multiple technologies to monitor comatose patients effectively. JavaScript and HTML create a user- friendly web interface, while PHP manages server- side operations for efficient data handling. Python aids in web development and enhances machine learning capabilities, crucial for interpreting patient movements and gestures. TensorFlow.js enables real-time, hardware-accelerated machine learning within the web application. This combination forms a robust and responsive platform, ensuring efficient and adaptable patient monitoring in ICU settings.
- The AIoT-based ICU Patient Monitoring System enhances patient care by detecting the motion and gestures of coma patients, thereby reducing the workload of nurses through real-time notifications. With individual devices assigned per patient, the system efficiently stores and manages information about both nurses and patients, optimizing the delivery of healthcare. Furthermore, the system aids in identifying any prior medical history, allowing for more informed and tailored treatment plans.
- The AIoT-based ICU Patient Monitoring System was found to be highly effective and reliable, offering robust functionality by securely authenticating users and managing distinct profiles. It provided smooth

interactions through intuitive interfaces for nurses and patients. Crucially, it accurately detected patient motions, triggering timely SMS alerts without generating unnecessary notifications. Overall, the system demonstrated reliability, accuracy, and user-friendliness, making it ideal for critical healthcare settings.

Acknowledgement

We would like to acknowledge all medical professionals and hospitals in the CALABARZON region in providing us support and suffice dataset to fully develop this research.

We would also like to acknowledge all the moral and financial support of our beloved family and friends.

Lastly, we would like to offer this research to our Almighty God, Jesus Christ, by providing us wisdom and proper understanding before, during, and after the development of this research.

References:

Acampora, G., Cook, D. J., Rashidi, P., & Vasilakos, A. V. (2013). A survey on ambient intelligence in healthcare. *Proceedings of the IEEE*, *101*(12), 2470-2494.

Aditya, T. R., Pai, S. S., Bhat, K., Manjunath, P., & Jagadamba, G. (2020, July). Real time patient activity monitoring and alert system. In *2020 International Conference on Electronics and Sustainable Communication Systems (ICESC)* (pp. 708-712). IEEE. DOI: 10.1109/icesc48915.2020.9155602

Azizulkarim, A. H., Jamil, M. A., & Ambar, R. (2017). Design and development of patient monitoring system using Android application. International Journal of Modern Trends in Engineering & Research, 4(5), 38-44. DOI: 10.21884/ijmter.2017.4150.cvmfn

Babu, D., Sitaram, K., Reddy, V. A., Kumar, P., Ramki, & Rajesh Kumar, T. (2020). Remote monitoring of COMA patients using Zigbee. *IOP Conference Series: Materials Science and Engineering*, 993(1), 012082. DOI: 10.1088/1757-899x/993/1/012082

Banda, Z., Simbota, M., & Mula, C. (2022). Nurses' perceptions on the effects of high nursing workload on patient care in an intensive care unit of a referral hospital in Malawi: a qualitative study. *BMC nursing*, *21*(1), 136. DOI: 10.1186/s12912-022-00918-x

Bhavani, P. (2020). Patient monitoring system using beacon. *International Journal for Research in Applied Science and Engineering Technology*, 8(6), 547-551. DOI: 10.22214/ijraset.2020.6086

Dullabh, P., Hovey, L., Heaney-Huls, K., Rajendran, N., Wright, A., & Sittig, D. F. (2020). Application programming interfaces in health care: Findings from a current-state Sociotechnical assessment. *Applied Clinical Informatics*, 11(1), 59-69. DOI: 10.1055/s-0039-1701001

Dziadzko, M. A., Harrison, A. M., Tiong, I. C., Pickering, B. W., Moreno Franco, P., & Herasevich, V. (2016). Testing modes of computerized sepsis alert notification delivery systems. *BMC Medical Informatics and Decision Making*, *16(1)*, 1-7. DOI: 10.1186/s12911- 016-0396-y

Ele, B. I., Odey, J. A., Frank, N. E., & Ekinya, I. M. (2020). A web-based medical appointment scheduling with SMS alert notification system. *Transactions on Machine Learning and Artificial Intelligence*, 8(6), 28-38. DOI: 10.14738/tmlai.86.9098

Galle, A., Semaan, A., Huysmans, E., Audet, C., Asefa, A., Delvaux, T., ... & Benova, L. (2021). A double-edged sword—telemedicine for maternal care during COVID-19: findings from a global mixed-methods study of healthcare providers. *BMJ global health*, *6*(2), e004575.

Haleem, A., Javaid, M., Singh, R. P., & Suman, R. (2021). Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sensors international*, *2*, 100117.

Jiménez, A. C., & Martínez, J. P. (2021). Remote patient monitoring systems with 5G networks. *Advances in Science, Technology and Engineering Systems Journal*, 6(4), 44-51. DOI: 10.25046/aj060406

Kim, L., Garg, S., O'Halloran, A., Whitaker, M., Pham, H., Anderson, E. J., ... & Langley, G. E. (2021). Risk factors for intensive care unit admission and in-hospital mortality among hospitalized adults identified through the US coronavirus disease 2019 (COVID-19)-associated hospitalization surveillance network (COVID-NET). *Clinical infectious diseases*, *72*(9), e206-e214.

Poncette, A. S., Mosch, L. K., Stablo, L., Spies, C., Schieler, M., Weber-Carstens, S., ... & Balzer, F. (2022). A remote patient-monitoring system for intensive care medicine: mixed methods Human-Centered design and usability evaluation. *JMIR Human Factors*, *9*(1), e30655.

Vai, B., Mazza, M. G., Colli, C. D., Foiselle, M., Allen, B., Benedetti, F., ... & De Picker, L. J. (2021). Mental disorders and risk of COVID-19-related mortality, hospitalisation, and intensive care unit admission: a systematic review and meta-analysis. *The Lancet Psychiatry*, *8*(9), 797-812.

Vatandoost, M., & Litkouhi, S. (2019). The future of healthcare facilities: how technology and medical advances may shape hospitals of the future. *Hospital Practices and Research*, *4*(1), 1-11.

Zainuddin, A. A., Superamaniam, S., Andrew, A. C., Muraleedharan, R., Rakshys, J., Miriam, J., ... & Taufik, M. S. M. (2020, September). Patient monitoring system using computer vision for emotional recognition and vital signs detection. In *2020 IEEE student conference on research and development (SCOReD)* (pp. 22-27). IEEE. DOI: 10.1109/scored50371.2020.9250950

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