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Patient Monitoring System Used Smart Sensor Technology Internet of Things and AI

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Abstract: In recent years, advancements on the Internet of Things (IoT) and Artificial Intelligence (AI) have significantly transformed the healthcare sector, particularly in patient monitoring and management. This research presents the development of a smart patient monitoring system that utilizes IoT-based sensor technology integrated with AI for real-time health data acquisition, processing, and analysis. The system is designed to continuously monitor vital signs such as body temperature, heart rate, blood pressure levels either Systolic and Diastolic, and patient movement using a network of wearable and non-invasive smart sensors. These sensors transmit data wirelessly to a centralized cloud platform, where it is stored, visualized, and analyzed using AI-driven algorithms. The AI components are implemented to detect abnormal patterns and generate alerts for healthcare providers or caregivers in case of emergency or irregularities in a patient's condition. The system is particularly useful for remote patient monitoring, chronic disease management, elderly care, and post-surgical recovery, reducing the need for constant physical supervision and hospital visits. It also supports early diagnosis and timely medical intervention, potentially improving treatment outcomes and reducing healthcare costs. The proposed system was tested in a simulated environment and demonstrated high accuracy in data collection, anomaly detection, and timely notifications. The results indicate that integrating IoT and AI technologies can enhance patient safety, increase monitoring efficiency, and support better healthcare decision-making. This study highlights the potential of smart sensor-based IoT and AI systems as scalable, reliable solutions for modern, connected healthcare services.

Keywords: Patient Monitoring, IoT, Smart Sensor, AI

1. INTRODUCTION

The rapid advancement of digital technologies is reshaping the healthcare landscape, particularly in the way patients are monitored and treated. With the growing demand for high-quality, real-time, and remote healthcare services, especially in the wake of global health crises such as the COVID-19 pandemic, the need for smart, connected, and intelligent patient monitoring systems has become more urgent than ever. Traditional patient monitoring methods are often resource-intensive, rely heavily on manual oversight, and are not scalable for large populations or remote care. These limitations highlight the importance of leveraging modern technologies to transform conventional healthcare into more proactive and personalized systems. IoT has emerged as a game-changing technology in healthcare, enabling the development of systems that connect various medical devices and sensors to the internet. This connectivity allows for real-time data acquisition, remote monitoring, and better communication between patients and healthcare providers. When coupled with smart sensors, IoT systems can continuously track vital physiological parameters such as body temperature, heart rate, blood pressure levels either Systolic or Diastolic, respiratory rate, and movement. This seamless data collection helps build a comprehensive profile of a patient's health condition over time. AI, on the other hand, adds an intelligent layer to this data-rich environment. Applying machine learning algorithms and pattern recognition techniques, AI can analyze vast amounts of health data to detect anomalies, predict health risks, and support clinical decision-making. AI can also help reduce false alarms and optimize alert systems, making monitoring systems more efficient and reliable [1].

This research introduces a patient monitoring system that integrates IoT-based smart sensor technology with AI-driven data analysis. The proposed system is designed to improve the quality of patient care by providing real-time monitoring, early detection of critical health events, and timely alerts to medical professionals. It is especially beneficial for monitoring patients with chronic illnesses, elderly individuals, and those in remote or underserved areas who require continuous care but may not have immediate access to healthcare facilities. Developing a scalable, low-cost, and intelligent monitoring solution, this study aims to address current challenges in healthcare delivery and contribute to the evolution of smart health systems. The integration of IoT and AI not only enhances the efficiency of healthcare services but also empowers patients to take a more active role in managing their own health.

2. LITERATURE REVIEW

The convergence of IoT and AI has opened new frontiers in the healthcare industry, particularly in patient monitoring systems. Numerous studies have explored the potential of these technologies to improve healthcare delivery, patient outcomes, and operational efficiency. Several researchers have proposed IoT-based health monitoring systems that utilize wearable sensors to collect physiological data. For instance, [2] highlighted the role of IoT in healthcare for continuous monitoring and emphasized the need for cloud-based data analysis and decision-making tools. These systems typically collect vital signs such as heart rate, temperature, and oxygen saturation and transmit the data to remote servers or mobile applications for real-time access by healthcare professionals.

Further developments have incorporated smart sensors with wireless communication protocols such as Wireless Fidelity (Wi-Fi), Bluetooth, and Zigbee to enhance mobility and reduce wiring complexities [3-4]. These sensor nodes are often embedded in wearable devices, allowing for unobtrusive and continuous health tracking. However, the reliability of data and the ability to interpret it meaningfully remain key challenges, especially in critical care environments. To address these challenges, AI has been introduced to complement IoT frameworks. According to [5-6], machine learning algorithms can be trained to detect anomalies, classify diseases, and even predict critical health events before they occur. For example, supervised learning techniques such as decision trees, support vector machines (SVM), and deep neural networks have been used to analyze electrocardiography (ECG) signals, respiratory patterns, and other bio signals for early detection of medical conditions.

Recent research by [7-8] demonstrated the effectiveness of combining AI with IoT-based monitoring systems for chronic disease management. Their system employed real-time analytics and a rule-based AI engine to provide predictive alerts for diabetes and hypertension patients. Similarly, [9-11] reviewed various AI-IoT frameworks used during the COVID-19 pandemic for remote diagnosis and patient tracking, highlighting the importance of intelligent monitoring systems in public health emergencies. Despite these advancements, many existing systems still face limitations in scalability, data security, interoperability, and user-friendliness. There is also a need for more adaptive AI models capable of learning from individual patient histories to offer personalized healthcare services [12-14].

In summary, prior research underscores the significant potential of integrating IoT and AI for patient monitoring. However, further work is needed to develop systems that are not only technically sound but also practical for real-world healthcare settings. This study aims to build upon existing work by developing a smart, real-time, and intelligent patient monitoring system that addresses key limitations found in current solutions.

3. METHODOLOGY

This research follows a design and implementation methodology to develop a smart patient monitoring system that integrates IoT technology with AI for real-time health tracking and analysis. The methodology consists of several key phases: system design, sensor integration, data transmission, cloud infrastructure setup, AI model development, and system testing.

3.1 System Design

The system architecture is structured into three main layers:

- Sensing Layer – Responsible for data collection using smart sensors.
- Network Layer – Facilitates wireless data transmission using IoT communication protocols.
- Application Layer – Handles data storage, analysis using AI, and visualization for end-users e.g., healthcare providers or caregivers.

3.2 Hardware Components

The system utilizes a set of smart biomedical sensors to measure vital signs of heart rate and blood pressure. Measured using a pulse oximeter sensor e.g., MAX30100. Body temperature measured using a digital temperature sensor DS18B20. Motion and fall detection captured using an accelerometer and gyroscope MPU6050. All sensors are connected to a microcontroller Node-MCU with Wi-Fi module that processes and transmits the data.

3.3 Data Transmission and Cloud Integration

Sensor data is transmitted to a cloud platform Amazone Web Services (AWS) IoT Core via Wi-Fi. The cloud service handles which real-time data storage, data visualization dashboards, and push notifications and alerts.

3.4 AI Model Development

The AI component uses machine learning models to analyze incoming data for anomaly detection and prediction. The steps include of data preprocessing, cleaning and normalizing sensor data for consistency. Feature extraction deriving key health metrics such as average heart rate, temperature trends, and motion patterns. Model training classification and regression models which is a lightweight neural network using labeled datasets. Anomaly detection implementing real-time inference to detect abnormal health patterns and trigger alerts. Figure 1 shows the architecture block diagram of the proposed healthcare monitoring system.

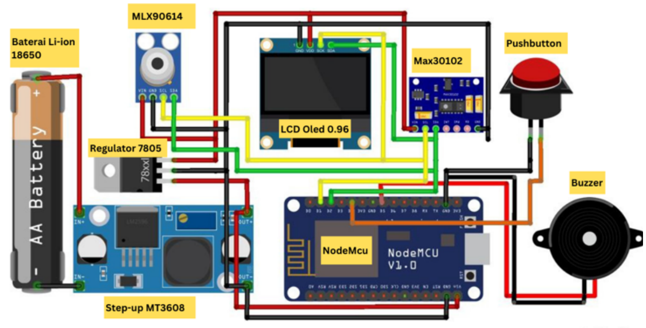

Figure 1. Architecture of block diagram monitoring system.

3.5 Software and Tools

Programming languages which is Python for microcontroller programming used in this research. Cloud services is AWS IoT used in this work. Development tools is Arduino IDE with Jupyter notebook application [15].

3.6 Testing and Evaluation

The system is tested in a controlled environment using both real-time and simulated patient data. The evaluation metrics include of the accuracy of sensor readings, latency in data transmission and response time, Precision and recall of anomaly detection, user feedback on interface usability and alert effectiveness. This methodology enables the development of a scalable, low-cost, and intelligent patient monitoring system suitable for remote healthcare environments. Figure 2 shows the use case of this monitoring system.

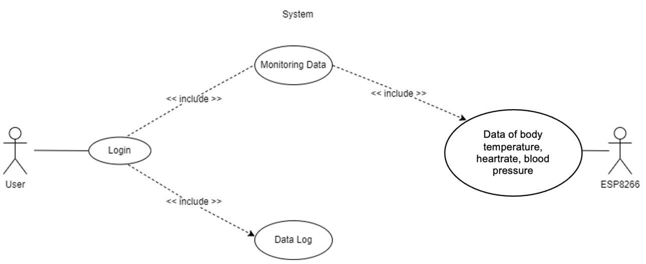

Figure 2. The use case diagram for monitoring.

4. RESULTS AND DISCUSSION

In this section presents the outcomes of the implementation and evaluation of the smart patient monitoring system. The system was tested in a controlled environment using a set of predefined scenarios to simulate real-time patient health conditions. The primary focus was on assessing sensor accuracy, data transmission efficiency, AI-based anomaly detection performance, and overall system responsiveness.

4.1 Sensor performance and data accuracy

The smart sensors MAX30100 for heart rate and blood pressure Systolic and Diastolic, DS18B20 for temperature, and MPU6050 for motion were calibrated and tested against standard medical-grade devices. The comparison showed, heart rate accuracy is ±2 bpm variance from reference monitor. Blood pressure accuracy is ±1.5% compared to clinical pulse oximeter. Temperature accuracy ±0.3°C compared to standard digital thermometer. These results indicate that the sensors provide reliable and clinically acceptable readings for continuous monitoring applications.

4.2 Data transmission and cloud integration

Using Wi-Fi-enabled Node-MCU microcontrollers, sensor data was successfully transmitted to the firebase real-time database with an average latency of <1.2 seconds per update. The system maintained stable communication for extended periods over 12 hours without data loss, demonstrating strong reliability for remote monitoring use cases. The cloud dashboard provided real-time visualization, with health metrics updating smoothly and triggering notifications when thresholds were crossed e.g., Blood pressure < 92%, HR > 120 bpm. Figure 3 shows how the interface of monitoring system with mobile application [16].

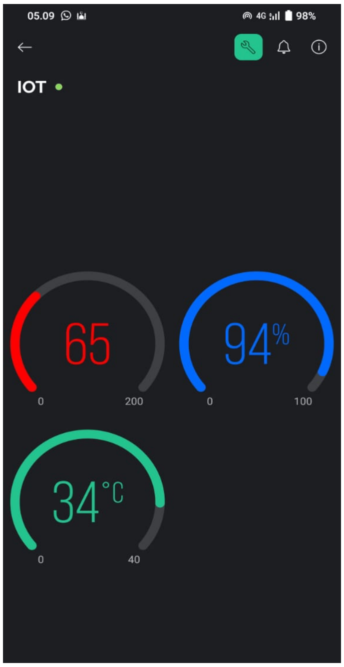

Figure 3. Mobile interface of patient monitoring system.

4.3 AI-Based anomaly detection

A model of AWS IoT was trained using labeled health datasets to detect abnormal patterns such as tachycardia, hypoxia, and fever. The model was integrated into the cloud backend and achieved the following performance with accuracy is 96.4%, precision is 94.7%, recall is 95.2%, and false alarm rate is 3.8%.

Table 1. Testing and calibration data of several sample patient.

Name	Heart Rate (bpm)	Error (%)	Temperature (°C)	Error (%)	Blood Pressure (mmHg)	Error (%)
Nurlisa Andriani	94	0	35.0	1.7	97/117	1.0
Chici Syafiliati	87	2.2	35,5	4.2	88/106	1.1
Widy Utami Adha	85	4.4	34.0	0	103/125	5.1
Via Saragih	89	2.2	34,3	0.8	98/118	2.9
Bagas Ocha	90	4.2	36.0	2.7	95/115	2.1
M Iqbal	98	2.9	36,5	1.3	96/117	3.0
Rizna Akmaliyah	77	3.75	34.0	0	95/115	2.0
Eka Mulyani	82	2.3	35.0	5.4	90/109	4.2
Erika Pendriana	90	5.2	34.0	2.9	97/116	2.0
Kelvin Prawira	85	3.4	34.0	2.9	97/117	1.0
Febri Ananda	87	3.3	36,0	2,7	88/105	2,2
Rata-Rata Error	3.0 %		2.2 %		2.4 %	

These results suggest that the AI model can effectively distinguish between normal and abnormal conditions, supporting timely intervention by healthcare providers. Alerts were generated in real-time and delivered via push notifications to mobile devices or email.

4.4 System usability and responsiveness

User testing with medical professionals and caregivers showed high satisfaction with the dashboard interface, alert system, and ease of use. Participants appreciated the ability to monitor patients remotely, especially in non-clinical settings such as homes or eldercare facilities. Feedback included suggestions for adding voice alerts and integration with hospital electronic medical records (EMR) systems, which are considered for future development. Figure 4 shows the captured data transaction during monitoring of patient health. Table 1 shows the testing have been done and calibration to the tested data for all indicator of patient data such as body temperature, heart rate, and blood pressure systolic and diastolic with error lower then 3%.

	A	B	C	D
1	Time	Heart Rate	SPO2	Temp
2	05/16/24 08:26:00 PM	50.15555589	91	35
3	05/16/24 08:25:00 PM	69	102	34.4
4	05/16/24 08:24:00 PM	89	100	34
5	05/16/24 08:23:00 PM	75	100	34.09
6	05/16/24 08:22:00 PM	87	98	37
7	05/16/24 08:21:00 PM	83	100	33.98
8	05/16/24 08:20:00 PM	80	89	36
9	05/16/24 08:19:00 PM	67	0	36
10	05/16/24 08:18:00 PM	108	100	35.5
11	05/16/24 08:17:00 PM	81	88	35
12	05/16/24 08:16:00 PM	62	68	34.3
13	05/16/24 08:15:00 PM	93	90	34.23
14	05/16/24 08:12:00 PM	83.1	86	36.6
15	05/16/24 08:11:00 PM	82.15	100	33
16	05/16/24 08:10:00 PM	84	93	33.3
17	05/16/24 08:07:00 PM	87	98	35
18	05/16/24 08:06:00 PM	83	97.4	35.3
19	05/16/24 08:05:00 PM	69	68	35
20	05/16/24 03:02:00 PM	88.7	69	35.15
21	05/16/24 03:01:00 PM	93	79.9	31.5
22	05/16/24 03:00:00 PM	0	0	0
23	05/16/24 02:58:00 PM	0	0	0
24	05/16/24 02:56:00 PM	74	95	34
25	05/16/24 02:55:00 PM	98	81	33.6
26	05/16/24 02:53:00 PM	0	0	0
27	05/16/24 02:51:00 PM	67	0	32
28	05/16/24 02:50:00 PM	68	93	37
29	05/16/24 02:49:00 PM	2657777778	77.77778	34

Figure 4. Capture data monitored from the system.

4.5 Discussion

The results demonstrate that integrating smart sensor technology with IoT and AI can significantly enhance the capabilities of traditional patient monitoring systems. The real-time nature of the system allows for continuous observation without requiring patients to remain in clinical settings. The AI-driven anomaly detection adds a layer of intelligence, making the system proactive rather than reactive. Compared to existing solutions, the proposed system is low-cost, scalable, and suitable for both rural and urban healthcare environments. However, challenges such as data privacy, sensor calibration over time, and AI model generalization across different demographics remain and warrant further research. Figure 5 shows the sequence diagram of patient monitoring system.

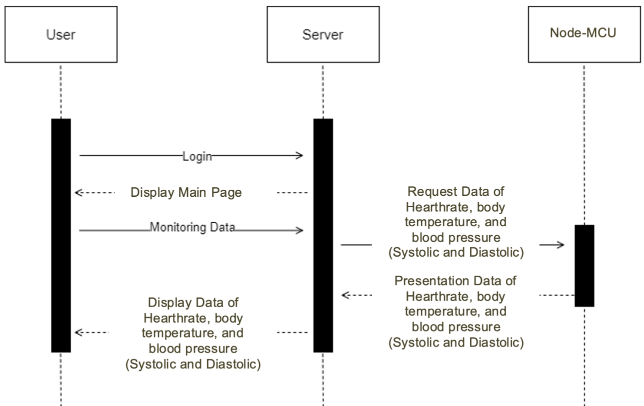

Figure 5. How the sequence diagram in the process.

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5. CONCLUSION

This research has presented the design, development, and evaluation of a smart patient monitoring system that integrates smart sensor technology with the IoT and AI. The system successfully demonstrates how real-time monitoring of vital health parameters such as heart rate, body temperature, blood pressure, and patient movement can be achieved using low-cost, non-invasive sensors connected to a cloud-based IoT infrastructure. The implementation of AI algorithms further enhances the system's capabilities by enabling early detection of abnormal health conditions, reducing false alarms, and supporting timely medical interventions. Experimental results have shown high accuracy in sensor readings, efficient data transmission, and reliable AI-based anomaly detection, confirming the system's potential for both clinical and remote healthcare applications. This approach offers significant benefits for healthcare providers, patients with chronic illnesses, elderly individuals, and those in rural or underserved areas. It reduces the dependency on in-hospital care, supports proactive treatment strategies, and contributes to improved patient outcomes through timely alerts and data-driven insights. In conclusion, the integration of IoT and AI in patient monitoring systems represents a major advancement in digital healthcare. The system developed in this study provides a scalable, cost-effective, and intelligent solution aligned with the future direction of smart healthcare services. Future work will focus on enhancing security, integrating with hospital information systems, expanding AI capabilities, and conducting real-world clinical trials to further validate the system's effectiveness.

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