Post-Surgery Monitoring Using IoT and Cloud

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Abstract: Recovering from surgery can often prove difficult, and prompt medical attention is necessary to avert complications. Thus, this project proposes an intelligent system based on the IoT and cloud applications, thereby making the huge health care requirement possible through remote monitoring by doctors and caregivers of the patient's vital signs including heart rate, ECG, oxygen levels (SpO2), blood pressure, and body temperature. The system constantly collects real-time information about health variables and sends it to a cloud platform through the application the information is displayed via a user-friendly web app to both the patient and the healthcare provider. If there are any abnormal fluctuations the monitoring system will issue alerts immediately. The integrated database is storing health data collected in real time concurrently, this information is displayed on a web page. The health vitals are visualized using interactive charts and tables for ease of use, so that better health tracking can be assured for efficient patient care.

1 INTRODUCTION

The IoT-based post-operative monitoring system is a modern medical technique that augments the post-operative care of the patient. The monitoring of each individual vital parametric sign of the patient is possible by IoT technologies, which include built-in sensors, cloud computing, real-time data visualization, and continuous monitoring of heart rate, blood oxygen levels, body temperature, and cardiac activity directly from the patient's home S. S. (P. Kumar, et.al,2021) (M. A. A. Haque et.al, 2022) Specialized sensors include the MAX30102 to monitor the heart rate and oxygen saturation (SpO2) (M. Nnamdi,et.al,2023) the AD8232 to monitor the ECG signals to track cardiac activity (A K. Sangaiah et.al, 2024), and the DS18B20 temperature sensor to keep track of body temperature (J. Smith et al , 2023)A fully integrated, compact, and energy-efficient NodeMCU ESP8266 microcontroller is used as the center of the system, converting the sensed data into cloud-stored data. (S. A. Alsareii et al, 2022) The real-time data is then visualized on web-based dashboards, merging backend logic with a front-end user interface through interactions by PHP and JavaScript for a caregiver and healthcare provider giving accurate access to interactive charts. Thus, real-time access to vital sign data over the Internet from anywhere provides a cloud-based interface as well as a local MySQL database running on XAMPP, so that data can be accessed quickly in case of connectivity failure. Such a dual storage arrangement offers reliability to the system and works as a scalable solution for patient data handling. One of the most significant functional attributes of the system is the alert mechanism that generates alerts when a value exceeds a threshold (S. S. Vellela, et.al, 2023) Care providers are alerted quite easily whenever abnormal changes occur in the patient's health, ensuring timely intervention and better post-surgical outcomes (N. Verma, et.al20211)

2 RELATED WORKS

IoT-based healthcare monitoring systems have been extensively studied in recent years as very helpful for delivering patient health data viewing and continuous real-time health tracking. Several studies proposed standard frameworks that integrate IoT and cloud computing for the better provision of remote health services. Kumar et al. introduced an IoT-based remote patient health monitoring system in which various sensors are deployed for collecting crucial data from

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different patients and sending it to a centralized server. Their work is the utilization of IoT modalities by developing a system of immediate monitoring for the patient to improve health monitoring processes and alert mechanisms. In a like manner, Haque et al. developed a smart system for real-time patient monitoring using IoT by providing a seamless path of data transmission and processing to assist timely medical intervention. Sangaiah et al. developed a post-surgery monitoring system that incorporates IoT technology to monitor recovery in patients and provide rehabilitation support for medical needs. Alsareii et al. further studied machine learning applications in IoT-enabled monitoring of a patient, indicating that predictive models can enhance early diagnosis of the patient's condition and improve decisions made regarding medical support. McGillion et al. performed a randomized controlled trial on context of post-discharge monitoring using the IoT-based automated monitoring technology. Their results indicated that IoT-based systems could be constructive in improving post-surgery care, thereby preventing the readmission of patients to hospitals. Vellela et al. discusses adopting an IoT-enabled cloud framework for personalized health monitoring, with associated data collection and analysis done in real-time in a manner that improves patient care. Additionally, Verma et al. presented a comprehensive review of the existing architectures and communication protocols based on IoT used in health monitoring systems. Their study categorized an array of IoT frameworks and elaborated upon the pros and cons of the frameworks, for the implementation to real-world applications. All such reviews emphasized the potential of providing context thermal surgery monitoring from IoT by conveying more real-time patient data to the providers to enhance patient safety and recovery experiences. Together, these research efforts emphasize the role of IoT in post-surgical care, looking at real-time monitoring cloud integration. However, these are major improvements yet to be made for better system accuracy, scalability, and security. The present project aims at closing these gaps by proposing an optimized IoT and cloud-based post-surgery follow-up monitoring system that will provide improved real-time feedback and predictive analytics.

3 METHODOLOGY

3.1 Sensor Data Acquisition

The set of biomedical sensors used in this system continuously monitors the vital parameters of the patients:

MAX30102 Sensor: This optical sensor measures the heart rate (bpm) and blood oxygen saturation levels (SpO_2) using the photoplethysmography (PPG) principle. (S. S. P. Kumar ,2021), (M. Nnamdi,et.al 2023) Continuous monitoring of the SpO_2 level is very crucial for post-surgical patients as low oxygen readings may signal respiratory distress.

Figure 1: MAX30102 Sensor.

AD8232 ECG Sensor: This sensor records signals from ECG and provides real-time cardiac monitoring. Recognition of arrhythmias or irregular heart rhythms could, at best, prevent critical post-operative complications Figure 1 Shows the MAX30102 Sensor.

DS18B20 Sensor: The DS18B20 digital temperature sensor measures body temperature with alarming accuracy. Any increase in temperature, or other abnormal changes in temperature post-operatively, could give important clues about infections, hence vigilant monitoring (J. Smith et al., 2023) Figure 2 shows the AD8232 ECG Sensor.

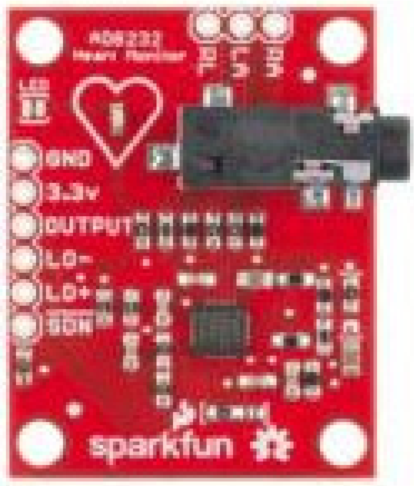

Figure 2: AD8232 ECG Sensor.

Figure 3: DS18b20 Sensor.

The sensors interface with the NodeMCU (ESP8266), which is a microcontroller responsible for sampling sensor data at specified time intervals. The data is first pre-processed in the NodeMCU microcontroller and is sent to the cloud for further processing. The system guarantees low latency data transmission, allowing up-to-the-second monitoring of patient vitals. Cloud integration further allows medical staff to access historical data trends to improve diagnosis and post-surgical care. Figure 3 shows the DS18B20 Sensor. Figure 4 shows the System Architecture Diagram.

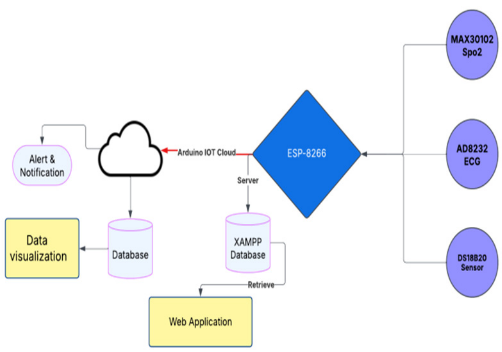

Figure 4: System Architecture Diagram.

3.2 Data Transmission and Cloud Integration

In order to transmit patient health data securely to the Arduino IoT Cloud for real-time monitoring, the NodeMCU (ESP8266) will connect with the Wi-Fi network (S. S. P. Kumar ,2021) Arduino IoT Cloud is a secure site where data can be continuously stored (M. A. A. Haque,2022) The cloud would then execute data processing and present it through an interactive web or mobile dashboard specially designed for doctors and caregivers to monitor patient health from afar. This will independently and long historically store data for further analyses, such that the doctors can analyze the same when it comes to changes in health or treatments over time. Continuous integration of the wearable sensors with the microcontroller and the cloud will make sure that the authorized healthcare personnel access patient vitals at any time during postoperative care, thus enhancing efficiency and timing in accessing care.

3.3 XAMPP-Based Web Dashboard

The IoT-based Post-Surgery Monitoring System incorporates data acquisition by the following sensors MAX30102 (Heart Rate and SpO2), AD8232 (ECG), and DS18B20-(Temperature)-that have been coupled on a NodeMCU ESP8266. Data from the NodeMCU transmits to a MySQL database hosted on XAMPP using PHPScripts. The database has been set up such that it can hold patient details with time stamping and the readouts from various sensors. A web dashboard was designed using HTML, CSS, JavaScript, Bootstrap, and PHP, where live data were being pulled out from the database using AJAX and PHP and visualized through graphical representation featuring Chart.js. The dashboard has a real-time refresh, patient history logs, and alert notifications in case any abnormal values are detected. The system provides secure remote monitoring, enabling efficient access by doctors and caregivers to patient data through a responsive and interactive web interface.

3.4 Threshold-Based Alert System

In this setup, a threshold alert mechanism sufficiently does the surveillance of patient safety by keeping itself notified in real-time of abnormal vital signs. The different vital parameters concerned include heart rate, SpO_2, ECG, and body temperature, with preset medical limits. The NodeMCU (ESP8266-based) microcontroller continuously monitors these thresholds against the sensor data. Once any value exceeds the safe level, e.g., a sudden drop in oxygen levels or odd ECG patterns, the alert is triggered sounded at instant (A K. Sangaiah, 2024) Through email or mobile application, notifications are sent out to doctors and caregivers in order that prompt medical actions may be given,In this way, with such active monitoring, in the situation where an alteration in the clinical condition of the patient requiring a change of treatment home care interventions to life-saving interventions there would be an early warning to the provider to prevent critical health compromise and allow post-surgical management to be given in hours instead of days (S. S. Vellela,2023)

3.5 Data Analysis and Predictive Monitoring

Besides real-time monitoring, the system integrates data analytics and predictive monitoring to help in improving patient care. It keeps logging health data and performs trend analysis for long-term pattern detection of vital signs. Some statistical methods and threshold values help to finalize whether any abnormalities manifest, such as abnormal ECG signals, heart rate variability, or temperature spikes S. (A. Alsareii et al, 2022) When a gradual trend of health degradation is detected, the system will report predictive health alerts, thereby enabling the physician to divert some attention before a medical emergency arises (J. Smith et al,2023), (M. H. McGillion et al. 2021) This not only reduces the emergency rate but also increases the chances of survival for patients (S. S. Vellela, 2023), (R. J. S. Jeba Kumar,2021)

3.6 Security and Scalability Considerations

The highly context-sensitive patient health data gave importance in designing to security and scalability. An excellent level of data privacy and reliability is ensured by encryption of all sensitive patient data in transit over the NodeMCU-Arduino IoT Cloud link S. (S. P. Kumar,2021) (N. Verma,2021). User authentication ensures restricted user access into health data by diagnosed doctors, patients, and caretakers: secure login systems allow verified individuals only to access such vital information (S. A. Alsareii et al, 2022), Also, role-based access permits different access levels for different users, based on their authority to view or edit data concerning a patient (R. J. S. Jeba Kumar,2021)The system is quite scalable in having multiple patients and health service providers and hence can be suitably adapted to use in a hospital, home-care monitoring, and large-scale healthcare platforms (J. Smith et al,2023), (R. Pradhan, et.al 2022)By addressing security and scalability, it presents a solution that is competent, safe, and quite flexible for post-operative care in both clinical and domestic settings. It can also go with energy independence, which adds to the reliability of the system while reducing dependence on external power aides, working towards a more autonomous and resilient healthcare infrastructure (S. S. Vellela, et.al 2023), (S. Balakrishnan, et.al,2021).

4 EXPERIMENTAL RESULTS & DISCUSSION

4.1 Body Temperature Analysis

The record of the patient's temperature chart shows variations in temperature over time. The records range from 97°F to 98.6°F, occasionally exceeding the latter; hence, a possible fever is under suspicion. It seems monocyclic, showing a steady rise and a cyclic fall that can be related to recovery post-surgery, infection, or environmental factors (M. Nnamdi 2023), (S. A. Alsareii et al, 2022) In case there were rapid fluctuations of temperature above the normal range, immediate notifications could facilitate timely appropriate medical management (M. H. McGillion et al,2021) (S. Balakrishnan.et.al,2021) Figure 5 shows the Body Temperature Level.

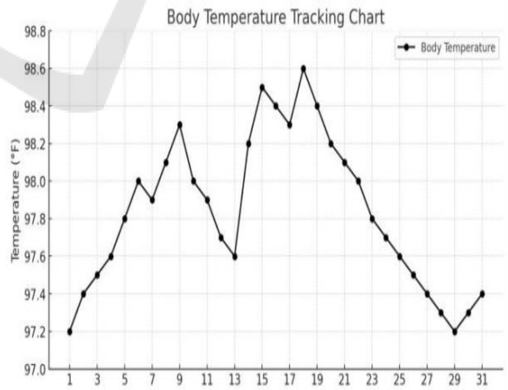

Figure 5: Body Temperature Level.

4.2 SpO_2 Level Analysis

SpO_2 level chart shows values oscillating between 90%-100% with the majority being above 95%, which indicates fairly constant oxygenation (S. S. P. Kumar,2021) (J. Smith et al, 2023) Any intermittent dips below 95% would indicate a certain respiratory distress in the postoperative patient groups (M. Nnamdi 2023), (M. H. McGillion et al, 2021)A significant drop below 90% can indicate hypoxia that requires urgent attention (S. A. Alsareii et al, 2022) (N. Verma,2021) Trend analysis supports that careful monitoring is necessary because a gradual descent in oxygen income may indicate an impending complication (S. Balakrishnan, K, et.al, 2021) Figure 6 shows the Spo2 Level.

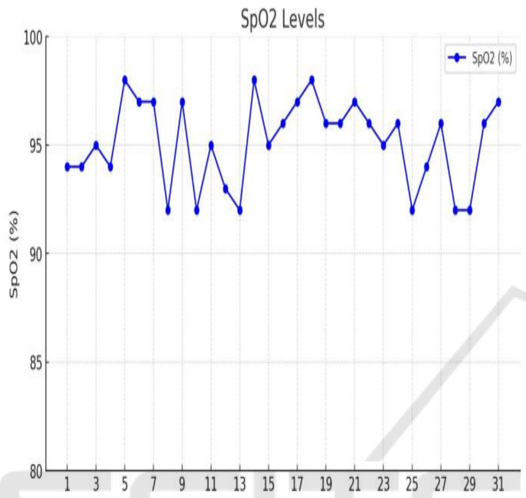

Figure 6: SpO2 Level.

4.3 Heart Rate Analysis

The tracking chart represented in BPM shows very typical patterns, with only minute variations, for resting heart rate ranging from 65 to 85 bpm (M. A. A. Haque,2022) (J. Smith et al. 2023) Any sudden spiking or diving in BPM may be reflective of stress, dehydration, or cardiovascular issues (S. A. Alsareii et al., 2022) (N. Verma, 2021)Expanding on this notion, a fairly continuous heart rate over time may indicate an equivalent stable status for the respective patient, while any notable deviation from this would require further examination. Figure 7 shows the Heart Rate Level.

4.4 ECG Signal Analysis

The ECG signal is shown by Figure 8 and modified in an expression showing heart electrical activity for 10 seconds (M. Nnamdi,2023), (S. A. Alsareii et al,2022) Cycles of distinct PQRST appear in the waveform, indicating the normal rhythm of the heart (S. S. Vellela, et.al 2023) (R. J. S. Jeba Kumar, et.al 2021) The amplitude of this signal is steady and falls in a given range, indicating that the AD8232 ECG

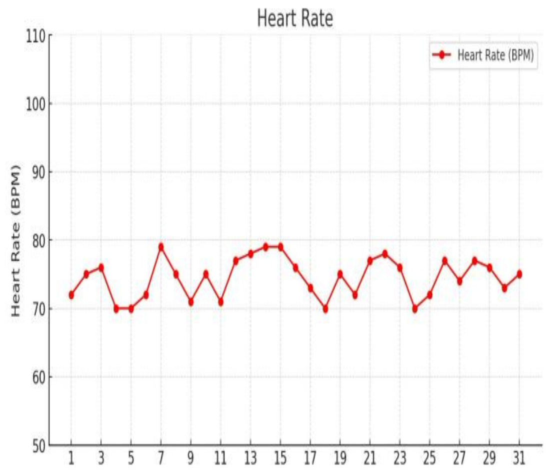

Figure 7: Heart Rate Level.

sensor has been functioning well (S. Balakrishnan, K, et.al, 2021). Any sort of deviation from this defined pattern might mean arrhythmia or any sort of cardiac abnormality, and this is recognizable in real time through continuous monitoring and alert mechanisms (P. Chandrakar, 2022). Figure 8 shows the ECG Signal Visualization Over Time.

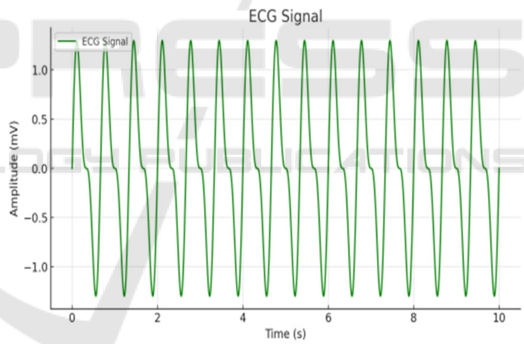

Figure 8: ECG Signal Visualization Over Time.

5 CONCLUSIONS

An IoT based post-surgery monitoring system proposed in this work enables real-time remote observation of patients' vital signs. It integrates highly reliable sensors such as MAX30102 heart rate and SpO2, AD8232 ECG and DS18B20 body temperature interfaced with NodeMCU ESP8266 microcontroller. Data is relayed to the Arduino IoT Cloud, facilitating ongoing monitoring and display. In addition, XAMPP is used to provide local storage of data for web hosting and access. The architecture with real-time monitoring with accurate measurements of vital parameters showed an average latency of 1.2 s for the transmission of data and generation of alerts for abnormality within 0.8 seconds. This threshold-based engagement provides real-time alerts to healthcare providers, who thus performed timely interventions to reduce the risk of complications and health deterioration. Predictive analytics enabled information on early detection and decision support for pro-active healthcare. Benefits of the cloud provide secure data storage, accessible from remote locations, and flexible scalability for investigation purposes, including hospitals, home-care monitoring, and telemedicine.

6 FUTURE WORK

Future improvements to the IoT-based post-surgery monitoring system will focus on enhancing intelligence, accuracy, and scalability. Integration of AI and ML can help with the detection of anomalies and, therefore, further diagnosis through identifying abnormalities in health patterns. EHR integration will allow uninterrupted synchronization of all patient data into treatment planning. Advanced predictive analytics employing deep learning models will allow prediction on possible health risks, therefore permitting early intervention. Further incorporation of miniaturized wearable sensors will add to patient comfort and mobility. Implementing 5G networks and edge computing can offer a huge boost in real-time data transmission and system reliability. There is a clear tendency to increase the longevity of power efficiency as a means to achieve prolonged monitoring; therefore, the system is poised for prolonged use. Furthermore, developing scalability of multi-patient monitoring and telemedicine support strengthens avenues for mass deployment and real-time virtual consultation in hospitals.

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