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Telemedicine Device Using IoT for Health Monitoring

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Abstract

This project aims to develop a telemedicine system that enables patients to receive medical care from home using digital technology. The primary objective is to provide continuous monitoring of blood oxygen saturation (SpO_2) and heart rate (BPM) for timely medical intervention without the need for clinic visits. The system uses a MAX30102 optical sensor to measure SpO_2 and BPM in real time. The collected data is transmitted directly to healthcare professionals, allowing remote assessment and decision-making. From May 23rd to 29th, recorded values showed BPM ranging from 60 to 125 and SpO_2 from 92% to 99%, demonstrating the system's ability to detect both normal and abnormal conditions. This method improves healthcare accessibility and ensures patients can receive treatment from their own homes.

1. Introduction

Early detection of abnormal physiological conditions is crucial in preventing severe health complications. However, many individuals neglect to monitor basic health parameters such as heart rate and blood oxygen saturation (SpO_2) until symptoms become severe. Misconceptions that irregular heartbeats or brief dyspnoea are harmless can delay necessary medical intervention, particularly in areas with limited access to healthcare. To address this, the proposed system utilizes the MAX30102 optical sensor to provide continuous, non-invasive measurement of SpO_2 and heart rate, with real-time data transmission via Internet of Things (IoT) technology to enable remote clinical assessment. [1].

The smart system is a multipurpose tool that tracks the patient's weight and amount of time spent sitting in addition to measuring vital signs, encouraging proactive health management [2]. Effective remote patient vital sign monitoring is still a major difficulty, even with the tremendous improvements in telemedicine and remote healthcare technologies. To assess vital health indicators like SpO2, and heart rate current solutions frequently rely on several platforms and sensors. Furthermore, many existing systems struggle with accuracy, reliability, and usability, particularly in non-clinical situations. This makes it challenging for patients, particularly the elderly or non-technical users, to operate several devices. Data interoperability is another important concern since it is challenging to connect electronic health record systems due to a lack of consistent standards and communication protocols. Prompt medical intervention can also be hampered by delays in data gathering or analysis, and many individuals cannot afford or use these systems because of their costly and complex setups, particularly in low-resource regions. A cohesive system that integrates various sensors into a single device is essential for improving the efficiency of remote patient monitoring [3].

In recent years, the integration of Internet of Things (IoT) technologies in telemedicine has gained significant traction, particularly in Malaysia, where healthcare accessibility remains a challenge. One study focuses on the development of an IoT-based healthcare monitoring system employing an ATmega328 microcontroller in conjunction with multiple sensors, such as temperature and cardiac sensors, to collect patient vital signs [4]. The collected data are transmitted to a cloud-based server (ThingSpeak), enabling healthcare practitioners to access real-time information via a mobile application. A GSM module is incorporated to send notifications during emergency events, thereby facilitating continuous patient monitoring and enhancing communication between patients and healthcare professionals. The system also leverages open-source hardware and software, which supports rapid prototyping and flexible modification. Sensor selection is based on affordability and durability, with examples including the LMT70 for temperature measurement, the MP3V5050 for blood pressure measurement, and the MAX30100 for pulse oximetry.

Additional system features include SMS alerts to doctors during emergencies and data transfer to patients' mobile devices through a dedicated Android application. IoT-enabled devices, such as smart home appliances and wearable health monitors, are capable of tracking vital indicators including blood pressure, heart rate, and glucose levels [5]. Real-time transmission of these data to healthcare providers enables continuous monitoring without the need for in-person visits [6]. Nevertheless, challenges such as infrastructure expenses, security concerns related to sensitive medical data, and scalability issues must be addressed. By overcoming these barriers, healthcare providers can enhance telemedicine services, thereby improve patient outcomes and increase accessibility to care [8].

2. Methodology

The methodology section provides a detailed description of the project's execution, including a system block diagram, circuit design schematic and prototype design. These techniques enhance accountability and ensure the project's reproducibility, ensuring the project's success.

This Figure 1 illustrates how the telemedicine system works, from sensing vital signs to displaying them. First, the MAX30102 Sensor measure the patient's body blood oxygen (SpO2), and heart rate (BPM). This raw data is then sent to the ESP32, which acts as the main brain, processing these readings. After processing, the information data is sent wirelessly via ThingSpeak on the internet. This database securely patient's health data. Finally, this data can be viewed and monitored by medical teams through a display ThingSpeak, providing a simple and effective way to keep track of a patient's health from anywhere.

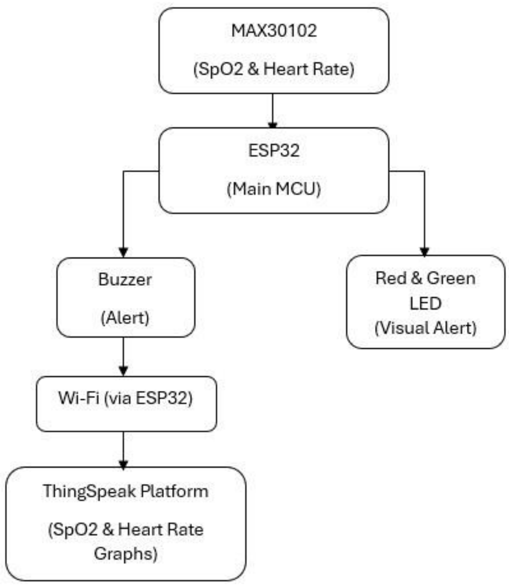


Fig.1: *Block Diagram*

2.1 System Flowchart

Figure 2 system flowchart for the telemedicine device using IoT for health monitoring.

Figure 2 illustrates the system flowchart for collecting SpO_2 and heart rate data. The process begins with the initialization of the sensor, followed by the acquisition of readings from the user. These readings are then validated to ensure accuracy and reliability. If validation fails, the system resets the sensor and repeats the measurement process. If validation is successful, the data is optimized or processed as required. The processed data is subsequently transmitted to the IoT platform ThingSpeak for storage and viewing. The results are presented in a clear format for users or healthcare professionals to interpret. The cycle of data acquisition, validation, processing, and storage continues until the monitoring session is complete.

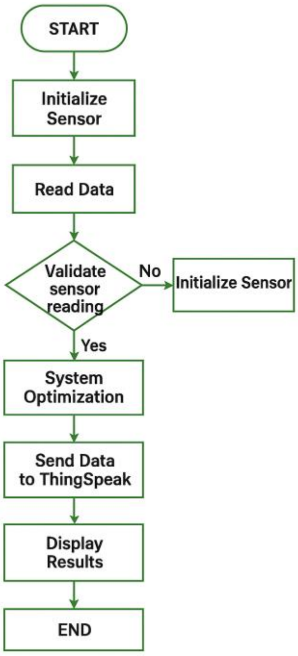


Fig.2 *System Flowchart*

2.2 Circuit Design

The Circuit design for automatic garbage sweeping systems illustrate in Figure 3.

The telemedicine device is controlled by an ESP32 microcontroller, which functions as the main processing unit for all data. It is connected to a MAX30102 sensor for precise measurement of heart rate (BPM) and blood oxygen saturation (SpO_2). Two indicator LEDs are incorporated: a green LED to indicate normal readings and a red LED to indicate abnormal readings. An active buzzer is also integrated to provide an audible alert in urgent situations. The ESP32's built-in Wi-Fi module enables wireless transmission of health data for remote monitoring, resulting in a complete system for real-time health assessment.

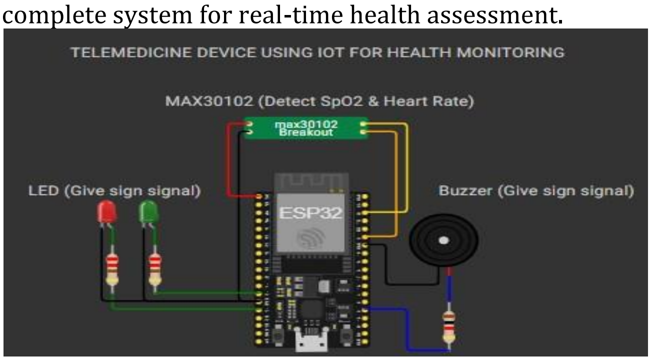
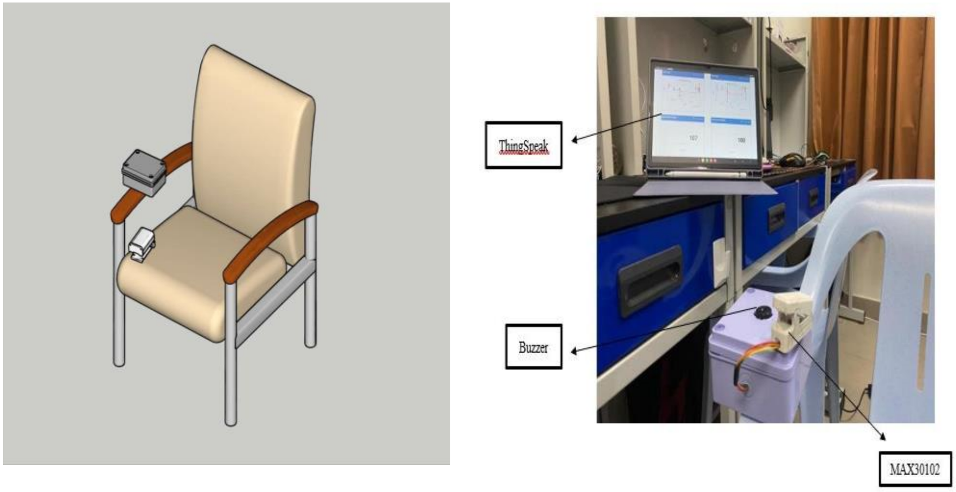


Fig.3 *Circuit Design*

2.3 Prototype Design

This section presents the development of the prototype and the 3D model for the telemedicine device, as shown in Figure 4(a) and Figure 4(b). The design was developed using engineering principles to create an accurate visual representation of the project concept. Computer-Aided Design (CAD) software, specifically SolidWorks, was used to model both the functional and aesthetic aspects of the device. The figures also include the actual prototype to illustrate the correlation between the 3D design and the physical implementation.



(a) **(b)**

Fig.4: *Prototype Design1*

3. Result and Discussion

The results section presents the outcomes of the development and testing of the telemedicine device system. It focuses on evaluating the system's performance based on key functional parameters, including the MAX30102 sensor's accuracy in detecting Blood Pressure (BPM) and Blood Oxygen Saturation (SpO2). The analysis results are to determine whether the device meets the project's objectives for vital sign monitoring.

3.1 MAX30102 Sensor (Detect BPM and SpO2)

To assess the MAX30102 sensor's performance in detecting SpO2 and BPM, the sensor will be utilized to facilitate testing on patients. This measure would allow for easier calibration of the sensor for accurate SpO2 and BPM detection. Figure 5(a) shows a patient using the MAX30102 sensor, while Figure 5(b) displays the patient's data being sent to ThingSpeak. This data clearly indicates whether the specified SpO2 and BPM values are accurately detected and displayed. The accuracy measurement described in this project is crucial, and therefore it represents a significant aspect of the system's performance and functionality.

(a)

(b)

Fig.5 *Patient's using the sensor*

3.2 Analysis of Data Health Monitoring

The analysis of the telemedicine device, utilizing the MAX30102 sensor, was evaluated based on its efficiency in detecting and monitoring the BPM and heart rate of patients in real-time. The selected test scenarios involved various patient conditions, allowing for a thorough evaluation of the device's capability to accurately capture and transmit vital signs. This real-time data collection is crucial for effective telemedicine applications, ensuring prompt assessment of a patient's physiological status.

A recent experiment was conducted on a patient in figure 6(a) to evaluate the effectiveness of a project designed to collect data BPM and SpO2. Initial start around May 23rd, the BPM at the beginning of the monitoring period, specifically around May 23rd, the heart rate readings were the highest throughout the entire chart, ranging from 110 to 120 BPM. This indicates a fast heart rate or an active state at the start. The SpO2 simultaneously, the oxygen saturation (SpO2) level on May 23rd was exceptionally good, reaching 100% or very close to 100%. This signifies optimal blood oxygenation. Around May 24, at BPM the graph shows a slight and steady decrease from the peak on May 23rd. The heart rate might have dropped a bit but remained in the higher range. The SpO2 levels remained very high, indicating stability in oxygenation. Around May 25th, BPM the heart rate showed temporary stability. Readings were still at a high level, possibly around 100-110 BPM, but already a slight decrease compared to May 23rd. SpO2 levels continued to show stability at a healthy level, likely around 97% to 98%.

(a)

Fig.6 *Data by day Patient's*

4. Conclusion

Overall, there is significant potential to enhance the efficacy and efficiency of remote healthcare services through the integration of ESP32 and health monitoring sensors in Internet of Things (IoT)-based telemedicine systems. Combining these technologies enables the real-time collection and tracking of vital health information, including blood oxygen levels (SpO_2) and heart rate (BPM), allowing medical personnel to monitor a patient's condition remotely. The system's sensors play a critical role in providing accurate and continuous data, supporting the early detection of abnormal medical conditions. Alerts can be triggered instantly upon detection of abnormal values, enabling prompt medical intervention or guidance. Receiving care at home not only helps prevent severe health issues but also increases patients' sense of safety and comfort. In the long term, such systems can reduce hospital admissions, save time and costs, and improve the overall quality of healthcare, particularly for elderly patients and those with chronic illnesses.

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