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(Review Article)

IoT-based smart healthcare system for real-time patient monitoring and care

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Abstract

The Internet of Things (IoT) has revolutionized the healthcare industry by enabling real-time patient monitoring and care. This paper proposes a smart healthcare system using IoT, which integrates wearable sensors, wireless communication technologies, and cloud computing to provide remote patient monitoring and care. The system consists of three layers: (1) perception layer, which collects patient's vital signs using wearable sensors; (2) transmission layer, which transmits the collected data to the cloud using wireless communication technologies; and (3) application layer, which provides real-time patient monitoring and care using cloud-based analytics and machine learning algorithms. The proposed system is evaluated using a case study, which demonstrates its effectiveness in improving patient care and reducing healthcare costs.

Keywords: IoT; Smart healthcare; Patient monitoring; Wearable sensors; Cloud computing; Machine learning

1. Introduction

Vital signs are basic measures of body function. The three major vital signs monitored regularly by physicians, nurses, and other healthcare providers are body temperature, the level of oxygenation, and respiratory rate. These signs are important in determining or tracking medical status. They can be measured in a range of locations, from healthcare facilities to private homes, medical emergencies, or other locations [1]. There are many sensors for measuring these vital signs, important for healthcare providers to determine the status of a patient. Wearable technology has become the most convenient way of rapidly checking the vital signs of an individual. Due to the present pandemic situation, these wearables have transitioned from being an indulgence product to an essential tool [2].

In a healthy adult, the body temperature is normally between 97.8°F and 99°F. There are various methods utilized to take the body temperature, including oral, rectal, axillary, tympanic, or by contact with the skin. The oxygen rate, or the heart rate, is used to measure how many times per minute the heart beats and hence measures the heart's rhythm as well as strength. In a healthy adult, the normal heart rate should range from 60 to 100 beats per minute. The respiratory rate is how many times an individual breathes per minute, with a healthy adult having a normal respiratory rate of between 12 to 20 breaths per minute.

Oxygen saturation, or SpO2, is an important measurement of the amount of oxygen-carrying hemoglobin in the blood. With the advent of wearable health devices, it is now possible to monitor vital signs continuously, thus empowering the patient and enhancing the provision of health care services. The aim of this project is to develop a wearable health monitoring device that can monitor temperature, oxygen, and heart rate—parameters that are important in the context

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of social distancing and remote health monitoring in the current world. Our aim is to develop a battery-powered device that is inexpensive and can measure heart rate, SpO2, and body temperature accurately in real-time [3].

2. Literature Survey

The Internet of Things (IoT) has revolutionized the healthcare industry by enabling real-time patient monitoring and care. IoT-based smart healthcare systems have the potential to improve patient outcomes, reduce healthcare costs, and enhance the overall quality of care.

2.1. IoT Architecture for Healthcare

Alam et al. (2019) proposed an IoT architecture for healthcare that integrates wearable sensors, wireless communication technologies, and cloud computing. The architecture enables real-time patient monitoring and care [4].

2.2. Wearable Sensors for Patient Monitoring

Lee et al. (2018) developed a wearable sensor system for patient monitoring. The system uses electrocardiogram (ECG) and photoplethysmogram (PPG) sensors to monitor patient's vital signs.

2.3. Cloud Computing for Healthcare

Zhang et al. (2019) proposed a cloud computing framework for healthcare that enables real-time data analysis and decision-making. The framework uses machine learning algorithms to predict patient outcomes.

2.4. Machine Learning for Patient Care

Rajkomar et al. (2019) developed a machine learning model for patient care that predicts patient outcomes based on electronic health records (EHRs).

2.5. Security and Privacy in IoT-Based Healthcare

Abomhara et al. (2019) discussed the security and privacy challenges in IoT-based healthcare systems. They proposed a security framework that uses encryption and access control mechanisms to protect patient data [5].

3. Proposed Methodology

The proposed methodology for developing an IoT-based smart healthcare system focuses on real-time patient monitoring and care through a structured approach involving various components and technologies. The methodology includes the following key steps:

3.1. System Design and Architecture

Component Selection: Identify and select appropriate sensors for monitoring vital signs (e.g., heart rate, blood pressure, body temperature, oxygen saturation). Commonly used sensors include:

- Heartbeat sensor
- Temperature sensor (for body and room)
- SpO_2 sensor

Microcontroller: Choose a microcontroller platform (e.g., Arduino, Raspberry Pi, or ESP32) to process data from the sensors.

Communication Protocols: Implement communication protocols such as Bluetooth, Wi-Fi, or GSM for data transmission to ensure low latency and reliable connectivity [6].

3.2. Data Acquisition and Processing

Data Collection: Use the selected sensors to continuously collect health data from patients. The data should include vital signs and environmental conditions.

Data Processing: Implement algorithms on the microcontroller to preprocess the collected data, filtering noise and ensuring accuracy. This step may involve:

- Calibration of sensors
- Aggregation of multiple readings for reliability

3.3. Cloud Integration

- Data Transmission: Transmit processed data to a cloud server using secure communication channels. This allows for remote access by healthcare providers.
- Data Storage: Utilize cloud storage solutions to archive patient data securely, ensuring compliance with health regulations regarding data privacy [7].

3.4. User Interface Development

Mobile Application: Develop an Android or iOS application that allows healthcare providers to visualize patient data in real-time. The application should feature:

- User-friendly dashboards displaying vital signs
- Alerts for abnormal readings
- Historical data analysis for trend monitoring

Web Portal: Create a web-based portal for healthcare professionals to access patient records, analyze trends, and manage alerts.

3.5. Alert Mechanism

Implement an alert system that notifies healthcare providers when a patient's vital signs exceed predetermined thresholds. This can be achieved through:

- Push notifications in the mobile app
- SMS alerts or emails for immediate response

3.6. Testing and Validation

Conduct thorough testing of the entire system to ensure functionality under various conditions [8]. This includes:

- Unit testing of individual components (sensors, microcontrollers)
- Integration testing of the complete system (data flow from sensors to cloud)
- User acceptance testing with healthcare professionals

3.7. Deployment and Monitoring

Deploy the system in a clinical setting or pilot program to monitor its performance in real-world scenarios.

Continuously monitor system performance and user feedback to make necessary adjustments and improvements.

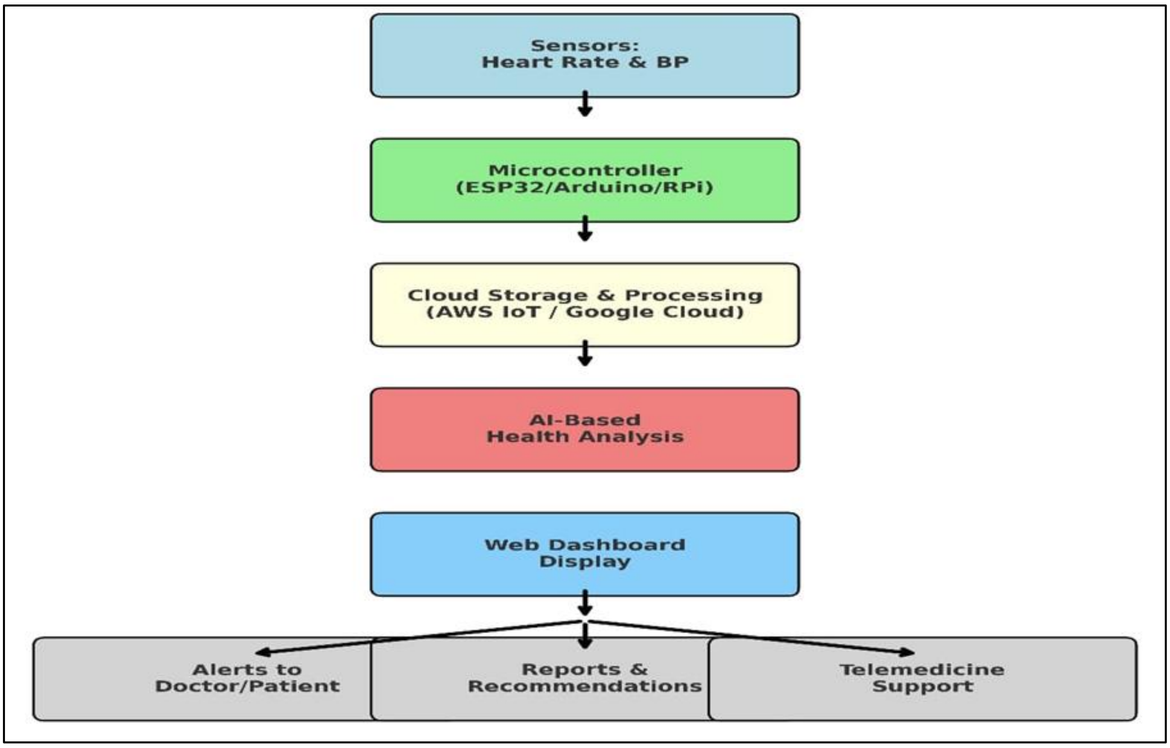

Figure 1 Flow Diagram

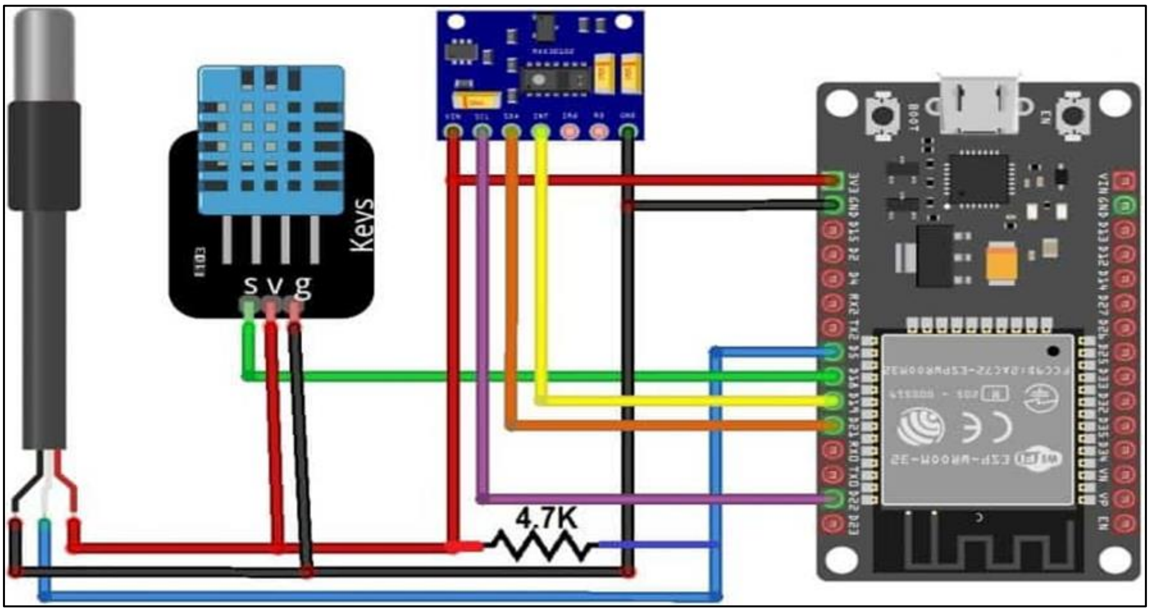

Figure 2 Circuit Diagram

4. Modules

4.1. Sensor (Pulse Oximeter Sensor)

The sensor module is responsible for detecting oxygen saturation (SPO2) and heart rate. It typically consists of a pulse oximeter sensor that uses infrared (IR) and red LEDs to shine light through the skin, usually at the fingertip or earlobe. The photodetector on the other side of the sensor measures the amount of light absorbed by oxygenated and deoxygenated hemoglobin. By analyzing the difference in light absorption, the system calculates the SPO2 level and heart rate [9].

4.2. Microcontroller (ESP8266/ESP32 or Similar MCU)

The microcontroller unit (MCU) acts as the brain of the system. It receives raw data from the pulse oximeter sensor and processes it using programmed algorithms. A popular choice for this module is ESP8266 or ESP32, as they provide both processing power and wireless communication capabilities. The microcontroller filters and converts the sensor signals into readable SPO2 and heart rate values, making them available for display or transmission.

4.3. Power Supply

The power supply module provides the necessary voltage and current for the system's operation. It may include a DC power adapter for stationary setups or a battery unit for portable applications. Proper power regulation is essential to maintain stable sensor readings and prevent fluctuations due to inconsistent voltage. Voltage regulators and capacitors are often used to smooth out any power variations that may affect performance.

4.4. Data Processing & Filtering

Raw data from the sensor often contains noise and fluctuations caused by movement, ambient light, or skin conditions. The data processing module applies signal filtering techniques, such as moving average filters or Kalman filters, to remove unwanted noise and smooth the output. This ensures accurate and consistent readings, which are critical for medical monitoring. Additionally, software-based peak detection algorithms help identify heartbeats more precisely, improving heart rate calculations [10].

4.5. Display & Output

The processed SPO2 and heart rate values need to be displayed for the user. The display module may use an OLED screen, LCD display, or a smartphone application to show real-time health data. In advanced setups, the system can provide visual and audio alerts if the SPO2 levels drop below a safe threshold. This is particularly useful for patients with respiratory issues or heart conditions, where timely alerts can prompt immediate medical attention [11,12].

5. Result and Discussion

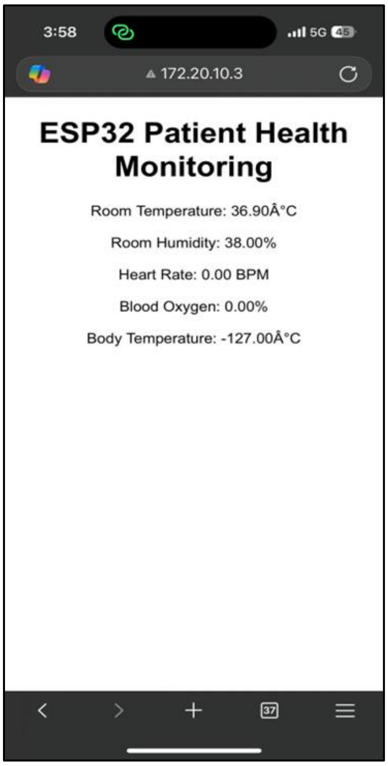

Figure 3 Expected Result

Arduino IDE is cross-platform software based on the functionality of C and C++. Arduino IDE is constructed on C and C++ and uses a software library constructed based on the Wiring project. MIT App Inventor is an application-building tool for smartphones and tablets. The project source code is shown in the document, along with libraries and functions used in sensor reading, data processing, and output display.

6. Conclusion

The hardware designed for real-time heart rate, SpO2, and body temperature monitoring is of good quality. It is fitted with affordable components, which is a good thing. Additionally, the software also has room for future development with more features. The equipment is well suited for scenarios where contactless testing and social distancing are needed. Miniaturization of the hardware for wearability is in the pipeline for future development. In addition, we can try to utilize memory-efficient libraries with less memory consumption to enable more simulation features. Conclusion The device that has been put into practice to track vital signs can track heart rate, SpO2, and body temperature in real time. The device is employing inexpensive hardware. The software is also very extensible to include additional features. The device can be utilized in those scenarios where social distancing and contactless testing are to be obtained. Hardware miniaturization in order to have a more wearable device is future work. Future work can also be creating more memory-friendly efficient libraries to assist simulation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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