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ELECTRONICS REVIEW REPORT

IoT-Based Heart Defect Monitoring Using a Pulse Sensor for Real-Time Health Management

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ABSTRACT

Increasingly prevalent cardiovascular diseases (CVDs) continue to be one of the leading causes of death worldwide, often complicated by the unnoticed development of critical heart rate irregularities. This study attempts to fill the gap in demand for constant and remote cardiac supervision by designing an IoT-based heart defect monitoring system using a non-invasive pulse sensor. The developed system offers a portable solution for real-time diagnosis and alerts of heart rate anomalies that is affordable and accessible, transforming patient monitoring as well as healthcare response times. The architecture of this system includes data acquisition with pulse sensor, signal processing with microcontroller Arduino UNO, anomaly detection, data transmission performed by ESP8266 Wi-Fi module, real time feedback on local LCD screen interfacing, visualization and analysis through the cloud platform Thing Speak, and remote access via Telegram Bot. Also, critical notifications can also be automatically sent without requiring prior request when abnormal pulses are detected. This makes it useful for health self-management systems, elderly care monitoring systems, and telemedicine systems.

Keywords: IoT, Heart Rate Monitoring, Pulse Sensor, Arduino UNO, ESP8266, Cloud Computing, Telegram Bot, Real-time Monitoring, Telemedicine.

1. INTRODUCTION

The burden of cardiovascular diseases (CVDs) continues to affect the health and wellness of people globally. Health complications and premature deaths associated with these diseases are on the rise [Citation needed]. A crucial part of CVDs requires managing cardiac events detection, and monitoring heart rate changes like bradycardia, tachycardia as well as arrhythmias as they usually occur silently in most patients. Most traditional cardiac monitoring devices used at hospitals often have challenges related to their cost, availability, and suitability for long-term use, especially in low resource environments and for domiciliary care.

This calls for the development of intelligent automated systems capable of real-time heart monitoring to solve these problems. The application of Internet of Things (IoT) technologies in medicine opens new avenues as it tackles patient engagement issues since it facilitates remote patient's evaluation via a combination of biomedical sensors, embedded microcontrollers, and wireless communication modules. Among the wide range of biosensors, pulse sensors are especially useful for detecting changes in heart rate non-invasively by observing minute alterations in blood flow volumetric [1]. This study carries out the design and implementation of an IoT-based system for heart defect detection that is pulse sensor based, reliable, scalable, and integrated within an IoT framework consisting of a local LCD screen for instant feedback, as well as, remote alerts and data access via telegram bot. The objective is to enable pre-emptive management of cardiac health with ease by users at minimal cost through this approach.

2. LITERATURE REVIEW

The recent years do consider the incorporation of IoT into the monitoring systems of one's heart, and many researchers have provided Frameworks that heuristically can shift the health care initiation from old interfaces to modern ones. Kumar et al. (2022) demonstrated through his research how wireless pulse sensors integrated with Wi Fi are able to provide precise heart rate tracking in real time and how early anomaly detection prevents emergency shifts during critical cardiac episodes [Citation needed]. Jain (2022) took these systems a step "further" investigating health notification user experience by creating an application interface aimed towards end users and providing them necessary updates as per the schedule [Citation needed]. Not only rural health infrastructure, but also Patel et al. (2021) focused on recommending Arduino based pulse rate amplifiers due also recalling elbow ointment limb physiotherapy equipment availing sophisticated medical assistance microwaves with rotary trainers on magnetic sleeves bone connected patients in scattered areas where rural medical facilities remain scarce improving access through divided advanced healthcare technologies [Citation needed]. Kaur (2020). These studies reinforce and emphasize the growing demand to realize responsive IoT plugged automatic systems at every phase of cardiac difficulties therefore, the system should be designed smartly for shut down within short intervals till more than three burst alerts are triggered immediately aiding expedient response detonations pre automating demanding external contacts able drastically cutting present wait periods during exposed extremely desperate circumstances potentially streamlining cardiac problem matching responding overwhelming retrieval's dynamics energy enabling Ei things.

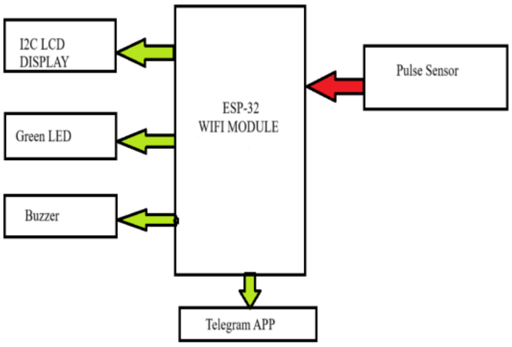
3. PROPOSED METHODOLOGY

The proposed IoT-based heart defect monitoring system is designed around a modular architecture comprising several key components that work in concert to achieve real-time data acquisition, processing, communication, and alerting. The core elements of the system are detailed below:

1. Pulse Sensing Unit: A non-invasive pulse sensor (specifically, the Pulse Sensor Amped) is employed to detect the pulsatile changes in blood volume at the fingertip. These variations, synchronous with the heart's contractions, are converted into an analog electrical signal proportional to the heartbeat.
2. Microcontroller and Processing: The Arduino UNO microcontroller serves as the central processing unit of the system. It receives the analog signal from the pulse sensor, digitizes it using its Analog-to-Digital Converter (ADC), and processes the data to calculate the Beats Per Minute (BPM). Furthermore, the Arduino is programmed to implement algorithms for signal filtering to minimize noise and to identify potential heart rate anomalies based on predefined threshold values.
3. Communication and Cloud Interface: An ESP8266 Wi-Fi module is integrated with the Arduino UNO to establish wireless network connectivity. This module facilitates the seamless transmission of the processed BPM data to a cloud-based IoT platform, in this case, Thing Speak. Thing Speak enables secure data storage, visualization through customizable charts and dashboards, and the potential for further data analysis. The system is also configured to trigger automatic notifications based on detected anomalies, leveraging features within Thing Speak or through integration with external services like IFTTT or dedicated mobile applications (e.g., Blynk).
4. User Interfaces: The system incorporates two distinct user interfaces to provide both local and remote access to the monitoring data and alerts. A 16x2 LCD display is directly interfaced with the Arduino UNO to provide a real-time visual display of the current BPM readings. This allows for immediate feedback to the user.

Additionally, a Telegram bot is integrated to provide remote access to the data and to deliver alert notifications directly to the user's smartphone or a caregiver's device. The Telegram bot communicates with the cloud platform or directly with the Arduino (depending on the implementation) to relay the current BPM values and any detected anomaly alerts.

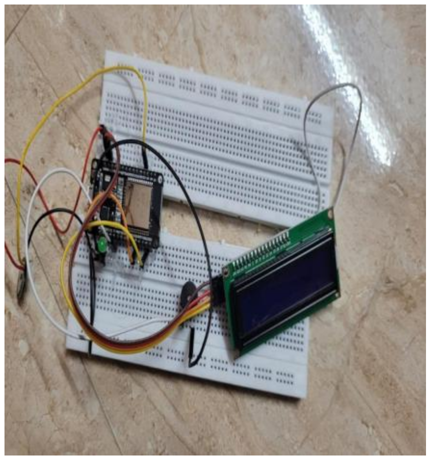
4. BLOCK DIAGRAM & WORKING PRINCIPLE



The heart of the system lies in its ability to accurately detect and interpret the pulsatile changes in blood volume. The pulse sensor emits infrared light into the fingertip, and a photodetector measures the amount of light reflected back. With each heartbeat, the blood volume in the finger increases, leading to a change in the amount of reflected light. This variation is sensed by the photodetector and converted into a fluctuating analog voltage signal. The Arduino UNO reads this analog signal through one of its analog input pins. The raw analog data is then processed using digital filtering techniques (e.g., a moving average filter) implemented in the Arduino code to reduce noise and smooth the signal. The processed signal is analyzed to identify the peaks corresponding to each heartbeat. By measuring the time interval between successive peaks, the Arduino calculates the Beats Per Minute (BPM). A common approach involves counting the number of peaks within a specific time window (e.g., 15 seconds) and then extrapolating to obtain the BPM. The calculated BPM value is then compared against predefined threshold values. Based on medical literature [Citation needed], a normal resting heart rate for adults typically falls between 60 and 100 BPM.

The system is programmed to flag any BPM reading below 60 as potential bradycardia and any reading above 100 as potential tachycardia. These threshold values can be customized based on individual patient profiles or specific monitoring requirements. The real-time BPM value is displayed on the local LCD screen, providing immediate feedback to the user. Simultaneously, the BPM data, along with timestamps, is transmitted via the ESP8266 Wi-Fi module to the Thing Speak cloud platform. On ThingSpeak, the data is stored in channels, and users can create visualizations (e.g., line graphs) to observe trends and historical heart rate patterns.When the Arduino detects a BPM value that falls outside the predefined normal range, it triggers an alert. This alert, along with the current BPM reading, is formatted as a message and sent via the Telegram Bot API to the designated Telegram user(s) or group chat. This ensures that both the individual being monitored and their caregivers or healthcare providers are promptly notified of any potential heart rate anomalies.

5. RESULTS



The prototype system underwent initial testing using both simulated pulse signals and real-time data from human subjects under controlled conditions. The system demonstrated the ability to accurately track pulse rate values within a range of 55 to 120 BPM. The anomaly detection mechanism effectively triggered alerts when the simulated or measured BPM fell outside the predefined thresholds (below 60 or above 100 BPM).The real-time BPM readings were consistently and clearly displayed on the local LCD screen, providing immediate visual feedback. The integration with the Telegram bot proved successful in delivering timely notifications. The bot responded within a few seconds of anomaly detection or at the regular reporting intervals, providing the current heart rate and an alert message when necessary. The data transmitted to the Thing Speak cloud platform was successfully visualized through graphs, allowing for the observation of heart rate trends over time. This historical data can be invaluable for healthcare professionals in assessing a patient's cardiac health. The initial results indicate the feasibility of the proposed IoT-based heart defect monitoring system. However, further rigorous testing with a larger and more diverse subject group, under various physiological conditions, is necessary to validate the system's accuracy, reliability, and robustness.

Potential Future Enhancements:

- Integration of Multi-Parameter Sensors
- AI-Based Anomaly Classification
- Improved BPM Calculation Algorithms
- Enhanced Security Measures
- User Interface Improvements

6. APPLICATIONS

The developed IoT-based heart defect monitoring system has a broad range of potential applications:

- Personal Fitness and Health Tracking
- Elderly Care
- Post-Surgery Supervision
- Emergency Detection
- Telemedicine

7. CONCLUSION

This research has presented the design and implementation of an IoT-based heart defect monitoring system that effectively utilizes a non-invasive pulse sensor, a local LCD display, and a remote alert mechanism via a Telegram bot. The prototype system demonstrates the feasibility of providing real-time, cost-effective, and continuous heart rate monitoring, with the capability to detect and alert on abnormal pulse patterns. The integration of cloud technology for data storage and visualization further enhances the system's utility for both

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