IOT Based Pulse Rate Monitoring System with Database Integration and Web Visualization

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ABSTRACT In today's world as healthcare demand continues to rise, this project introduces a novel solution aimed at addressing the need for continuous health monitoring. Our project centers around the development of an IOT based health monitoring system, designed to deliver real-time heart rate monitoring to users while seamlessly connecting to a website. Our system incorporates heartbeat sensors to track patient health status. These sensors interface with a microcontroller, enabling real-time data collection and analysis. The microcontroller connects to an LCD display for local data viewing and to a Wi-Fi module for internet connectivity. The heart of our system lies in its ability to measure the pulse rate of the patient and provide a user-friendly interface to access their records from a file. The file receives and stores the transmitted data, allowing users to view their pulse rate, access previous records, and analyze health trends. The data stored in the file provides a structured repository for patient records, hence playing a vital role in data management. Additionally, the real-time pulse rates monitored are visualized in the form of graphs. In summary, this project presents an innovative approach to health monitoring, integrating hardware and software components into a single system. It offers real-time heart rate monitoring, WiFi connectivity with a website, secure data storage within a dedicated file, and intuitive data visualization. This project revolutionizes personal health monitoring, empowering users to conveniently track their health stats, make informed health decisions, and embark on a journey toward a healthier lifestyle.

INDEX TERMS IoT, wearable sensor, healthcare, real time monitor, heart rate, Wi-Fi module, health-data security

I. INTRODUCTION

The first priority of every human being is to maintain and improve their health by increasing their health reserves. Generally, the quality of medical services has an important role in maintaining and improving the health condition. The pulse rate or heart rate is the most informative key to determine the overall health condition of a person as the cardiovascular system plays a vital role in keeping a human alive. Monitoring heart rate frequently can give us valuable understanding about the physical condition and several important implications. Irregularities in heart rate can prove different types of diseases such as hypertension or heart disease and can sometimes show a sign of a slow heart rhythm condition. Regularly monitoring the health can help in early detection of diseases and can lead to prompt medical intervention.

In the times of technological advancements and growing prominence on health and well – being, Internet of Things (IoT) technology has become evident as a life-changing force in the field of health. IoT is a network of interconnected devices and sensors that can receive and send data on the internet and its advantages are very beneficial in healthcare. IoT devices such as smartwatches which allow continuous monitoring of health like heart rate, the fats burnt while you do different kinds of activities and all. The real-time data obtained from the device can be transferred to healthcare providers which enables remote patient monitoring. It is especially useful for the patients with chronic disease conditions or those recovering from surgeries. Machine learning and artificial intelligence (AI) algorithms can be used to analyze the data generated by IoT devices which can provide valuable information and guide for the patient's health by aiding in informed decisions on treatment plans and resource allocation.

This proposed work is to develop an innovative healthcare system that logically integrates IoT technology to revolutionize health monitoring. The primary objective is to implement a hardware system which can collect the pulse rate data through sensors and transmit the data over the internet and display the data in graphical representations and interpret the health condition of the user based on the data collected from the sensor and store the health information in a file. The data can be accessed by the users through a user-friendly interface website which shows the health status.

This healthcare innovation is mainly the cosmopolitan fusion of hardware and software, where the heartbeat sensors interface with a microcontroller for real-time data collection. A Wi-Fi module connects the microcontroller to the internet to transmit the data and display in the website which acts as a structured repository for patient records.

The major contributions of this paper are:

- Integration of pulse sensors with a microcontroller for real-time data collection and a LCD display for local visualization of the data.
- Connectivity to a website through a Wi-Fi module for remote data access.
- A file for storing and accessing the real-time and historical data securely.

II. LITERATURE SURVEY

In recent years, the healthcare sector has witnessed various technological advancements, especially those involving the incorporation of Artificial Intelligence and the Internet of Things to enhance the quality of healthcare practices. In the field of wearable technology, there has been a remarkable development in the domain of heart rate monitoring. The abundance of health data collected by wearables facilitate healthcare providers to make data-driven decisions. However, this system lacks data security measures, real-world testing and noise cancellation algorithms.

In the realm of heart rate monitoring research, particularly involving uncertainty analysis during the monitoring of human activities, a central focus revolves around the application of Internet of Things (IoT) technology. To address this uncertainty, Z. Zhou et al. introduced the Improved Bayesian Convolution Network (IBCN), focusing on the integration of wearable sensors and deep learning techniques for inferring diverse human behaviors and identifying suspicious activity [1].

Continuously monitoring heart rate and resonance frequency in real time substantially lowers the possibility of heart-related emergencies. This research conducted by C. Patil and A. Chaware, accentuates the cost-efficiency and convenience offered by healthcare systems based on the Internet of Things (IoT), thereby presenting a valuable contribution to the domains of healthcare technology and remote patient care [2].

Another significant realm of research, conducted by Gupta et al. pertains to a framework that prioritizes facilitating convenient access to healthcare data, contributing valuable insights to the ever-evolving landscape of healthcare technology. However, interpreting the collected data accurately remains a challenge [3].

X. Zhu et al. employ real-time monitoring of respiration rhythm and pulse rate during sleep, by positioning pressure sensors under the pillow, facilitating the early detection of sleep-related disorders and cardiovascular conditions. However, other factors including external noise, pillow positioning, and movements during sleep could affect the reliability of the measurements [4].

The IoT-based pulse rate monitoring device developed by Massot et al., utilizes microelectronics, cutting-edge sensors and wireless communication technologies to facilitate real-time data collection and transmission. This device helps in the continuous assessment of various physiological parameters, including skin resistance, skin temperature and heart activity, with a particular focus on evaluating autonomic nervous system (ANS) activity. Although this wearable device operates for four days on a single battery charge, its long-term reliability remains questionable [5].

A multi-mode finger clip device developed by P. Mehrgardt, M. Khushi, S. Poon and A. Withana, combines photoplethysmography (PPG) and pressure sensors with deep learning to achieve precise heart rate measurements, especially during physical activities. The inclusion of pressure sensors improves heart rate accuracy, offering potential for applications like heart rate variability analysis [6].

A novel method proposed by A. Fujii, K. Murao and N. Matsuhisa,enables PPG-based pulse data measurement through displays, allowing remote biometric monitoring in scenarios such as artificial limbs. This not only maintains smartwatch functionality but also enhances usability in unconventional settings, potentially benefiting remote healthcare [7].

Additionally,Y. Fu, S. Zhao and R. Zhua discuss a wearable pulse monitoring system that can simultaneously measure pulse waves, pulse wave velocity (PWV), and skin temperature using flexible thermosensation sensors. This system integrates various sensors, a conditioning circuit, Bluetooth-low-energy (BLE) communication and a graphical user interface (GUI) for real-time monitoring and data analysis [8].

B. Jiao's primary focus lies in creating a wearable technology for daily health monitoring. This technology is designed to monitor multiple physiological parameters without intrusion or invasiveness, while also tackling issues like motion interference, low power consumption, and real-time blood oxygen saturation monitoring using Innovative algorithms, such as an improved sliding window confidence propagation and noise estimation, enhance the precision and efficiency of monitoring systems. These advancements mark substantial strides in wearable health monitoring technology, with potential uses in remote healthcare, telemedicine, and daily health monitoring. [9].

Qin, J. et al. emphasis on the use of KNN (k-nearest neighbors algorithm) imputation to handle missing data in the CKD dataset is a robust approach that can provide valuable insights for our project's data preprocessing and management. It would be helpful if the article discussed the scalability of the proposed methodology and its potential challenges when applied to larger and more complex clinical datasets, as this could provide insights into the adaptability of such approaches in our project's context [10].

Faisal, A.I. et al. has the high classification accuracies achieved by supervised machine learning algorithms, particularly PLS-DA, suggest the effectiveness of machine learning in health assessment and early diagnosis. They do not provide information on ethical considerations, data privacy, or potential biases in the dataset, which are important aspects of health-related research [11].

Soangra, R. et al. focuses on the utilization of wearable body sensors combined with machine learning algorithms offers a non-invasive and efficient way to identify and monitor toe walking patterns, allowing for targeted interventions and personalized treatment plans for children with ITW. It would be beneficial to explore the scalability and long-term feasibility of implementing wearable sensors and machine learning algorithms in a clinical setting, as the sample size of 36 children is relatively small [12].

Lavric, A. et al explains the use of machine learning algorithms to detect keratoconus at early stages is innovative and has the potential to significantly improve diagnosis and treatment outcomes. It would be helpful to have information on the size and diversity of the dataset used for training and testing the machine learning models to assess the robustness of the results [13].

R. Benlamri and L. Docksteader discuss the Mobile zOntology-based Reasoning and Feedback (MORF) health-monitoring system, which is a mobile platform designed to monitor a patient's health status using data from various sensors. MORF aims to provide means for effective and independent health monitoring, potentially reducing the need for continuous human intervention in the healthcare monitoring process [14].

Addressing the crucial need for real-time heart rate monitoring in telemedicine while ensuring patient privacy, J. Zhang and H. Yang introduce a remote heart rate abnormality monitoring system that is also privacy-preserving. They propose a dual cloud server model with a privacy comparison protocol that ensures the privacy of heart rate data, the patient's healthy heart rate range, and monitoring results. The experimental results demonstrate the scheme's effectiveness and efficiency, while the security analysis shows it successfully achieves its privacy and security goals [15].

C. E. Poenaru et al. explore the challenges associated with storing and managing medical data within Health Information Systems (HIS). The authors also explore the role of RDBMS, Cloud Computing data modeling, classification structures, etc. in enhancing the efficiency, scalability, and real-time analytical capabilities of Data Warehouses within the healthcare domain [16].

Another significant study by H. Liu et al. introduces a novel algorithm designed for processing real-time Photoplethysmogram (PPG) data. Their focus lies in extracting informative features that can classify knee joint and gait characteristics based on factors like age, body mass index (BMI), and sex. The research highlights the significance of understanding the physiological origins of PPG waveforms and suggests that this approach could lead to valuable insights for cardiovascular health monitoring and risk prevention [17].

A. N. A. Yusuf et al. put forth the concept of Mooble (Monitoring for Better Life Experience), which is a mobile health monitoring system. The Mooble system allows patients to monitor their health conditions, report pain levels, view health progress in graphical form, schedule doctor appointments, access medical treatments and advice, read health articles, and even make emergency calls through a user-friendly Android mobile application, hence empowering both patients and healthcare institutions [18].

III. PROPOSED DESIGN

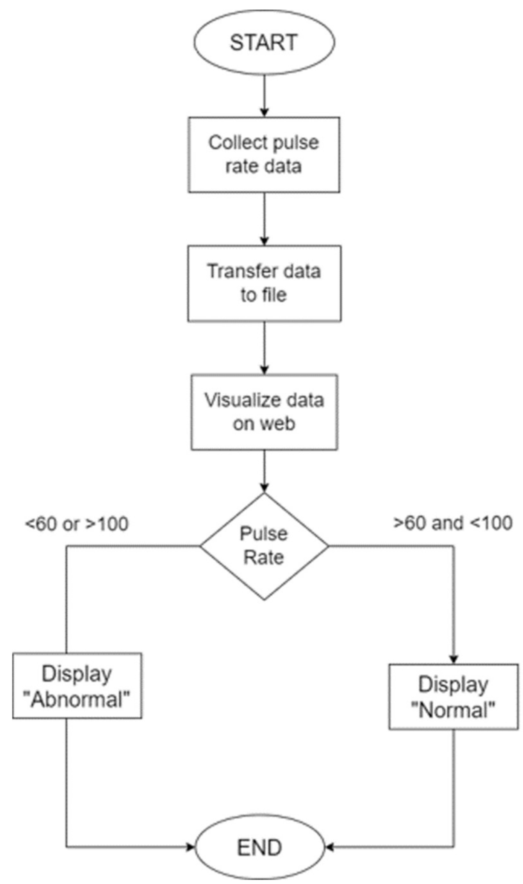

FIGURE 1. Design of the proposed pulse rate monitoring system

IV. HARDWARE

A. COMPONENTS USED

1. Arduino Uno Board
2. ESP8266 Wifi Module
3. Heartbeat Sensor
4. 16*2 LCD Display
5. 1K and 2K ohm resistors
6. Breadboard
7. LED
8. Jumper wires

B. *ARDUINO UNO BOARD*

Arduino uno board is an open-source microcontroller board, based on the ATmega328p processor, that is commonly used to implement projects.

M It consists of 14 input and output pins, and 6 Analog pins used to connect the board to different electronic components. It also contains a USB connection that allows communication with other devices, a reset button, LED indicators, and a power jack.

Arduino Uno boards are widely used due to its beginner-friendly structure that is easily programmable, and its compatibility with other components.

FIGURE 2. **Arduino Uno Board**

C. ESP8266 WIFI MODULE

ESP8266 is a Wi-Fi microchip used to transmit data over the internet. It can collect data and upload it onto the internet making IOT easily implementable.

It consists of various pins, including ground, 3.3V, TX, RX, and three GPIO pins - GPIO 0, GPIO 1, GPIO 2.

The ESP8266 can also be programmed using Arduino IDE and is hence compatible with Arduino Uno board.

It utilizes a photodiode positioned at the top to detect the expansion and contraction of blood vessels, enabling accurate pulse rate measurement.

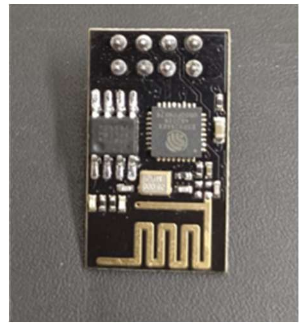

FIGURE 3. **ESP8266 WiFi Module**

D. HEARTBEAT SENSOR

The part of the sensor that makes contact with the skin is the front, while the backside emits light.The sensor features three pins for connection: a ground pin, a power supply pin (analog), and an analog pin that links to the Arduino.

Additionally, it incorporates an LED at its center to aid in heartbeat detection. Just below the LED, there is a built-in noise reduction circuitry designed to filter out unwanted interference and ensure precise readings.

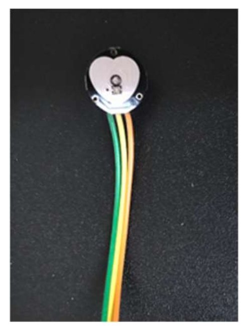

FIGURE 4. **Pulse rate sensor – front side**

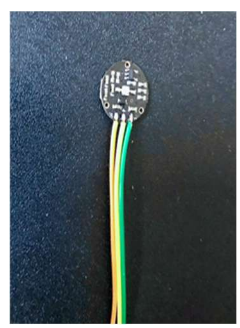

FIGURE 5. **Pulse rate sensor – back side**

E. 16*2 LCD DISPLAY

In embedded system applications, Liquid Crystal Displays (LCDs) are employed to showcase a range of system parameters and status indicators. A "16x2" LCD has two lines, each displaying 16 characters, totaling 32 characters at once. Scrolling allows showing more than 32 characters. It's compatible with both 4-bit and 8-bit modes. Custom characters can be designed on the display. With 8 data lines and 3 control lines, these are available for control functions and custom character creation.

FIGURE 6. **16*2 LCD Display**

V. METHODOLOGY

This project uses an Arduino Uno Board that is connected to a pulse rate sensor used to measure the pulse rate (heartbeats per minute). 1K and 2K ohm resistors are used to create a voltage divider that converts the 5V signal to 3.3V to ensure compatibility with the ESP8266 WiFi Module. The pulse rate sensor is connected to a 16*2 LCD that displays the pulse data and a 5mm LED that works as an indicator. This arrangement enables the Arduino Uno board to receive the pulse data, display it on the LCD and transfer this data using the ESP8266 WiFi Module.

VI. CIRCUIT DIAGRAM

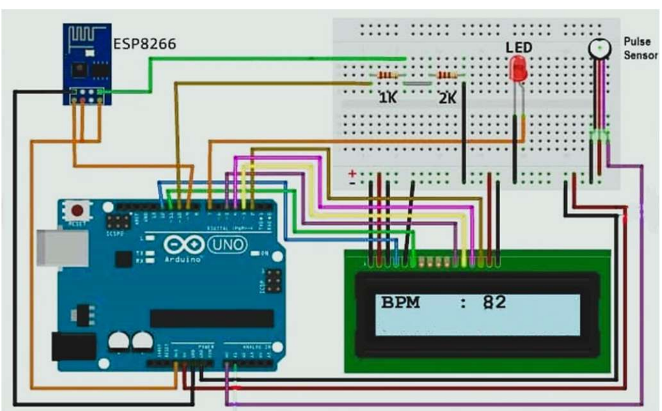

FIGURE 7. **Circuit diagram**

VII. SOFTWARE

The program implements collection of the patient's pulse rate and integration of this data. First, the pulse rate data collected is transmitted over the internet with the help of ESP8266 Wi-Fi module. The transmitted data is visually represented using different types of graphs, wherein the axis of time is plotted against the corresponding pulse rate, measured in beats per second (BPM). This data is securely stored in a file. Access to the patient records is facilitated through a user-friendly website secured by employing user authentication protocol, thereby safeguarding sensitive medical information and preserving confidentiality.

A. GRAPHIC VISUALIZATION

FIGURE 8. **Graphical representation**

B . ACCESSING PATIENT RECORDS ONLINE

A user-friendly website has been created to conveniently access patient records stored in a file. Users can measure their pulse rate, and the gathered data is securely stored in a file. If users opt to view their records, the website retrieves this data from the file and presents it. Additionally, the website assesses the recorded heart rate, categorizing it as 'Normal' if it falls within the recommended range of 60 to 100 beats per minute (BPM) and as 'Abnormal' otherwise. The website also provides insightful suggestions and comments related to the recorded heart rate for the user's convenience. This ensures a smooth and secure experience for users seeking medical information.

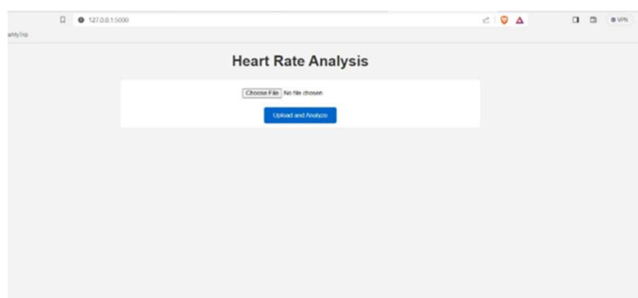

FIGURE 9. **Home page of the website**

FIGURE 10. **Abnormal heart rate**

FIGURE 11. Normal heart rate

C. DATA STORAGE

The data collected from the pulse sensor is then stored in a file using CoolTerm, a terminal emulator software, to capture and log serial data from an Arduino board. . This is done to create a repository for patient records that can be accessed anytime. This also enables patients to access their historical data if required.

Steps followed:

1. *Arduino Setup:* The Arduino sketch is uploaded to the Arduino Uno board. The Arduino IDE is opened and the sketch is uploaded, ensuring the board is connected.
2. *Serial Port Configuration:* Launch CoolTerm, ensuring that all other serial terminals are closed. Navigate to the Options menu, where you should choose the appropriate serial port (e.g., COM8) and configure the baud rate to align with the settings in the Arduino sketch (e.g., 9600).
3. *Capture to a File:* Within the Connection menu, opt for "Capture to Text or Binary File." Initiate the data capture by selecting "Start." Save the resulting file, which holds the serial data, with a distinctive name like "serial_data.txt.".
4. *Upload file in the website:* Choose the file from your desktop location and press the button to upload and analyze your data.
5. *Get the Heart rate analysis:* After uploading the file and analyzing the data, the result is being displayed.

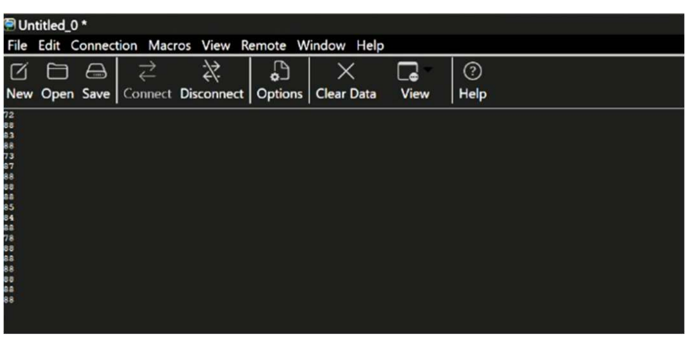

FIGURE 12. CoolTerm serial data collection

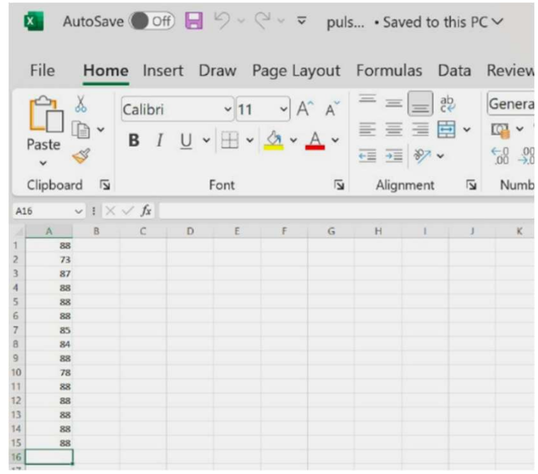

FIGURE 13. Data stored in the file

D. ALGORITHM

1) INCLUDE NECESSARY LIBRARIES:

Import required libraries such as SoftwareSerial and LiquidCrystal_I2C for communication and display.

2) DEFINE CONSTANTS:

Define constant values for the Wi-Fi credentials (SSID, PASS), and the API key (msg).

3) DECLARE VARIABLES:

Declare variables pulse sensor, LED pins, and others.Declare variables for Pulse Sensor and heartbeat calculations, including BPM (beats per minute), Signal, IBI (Interbeat Interval), Pulse flag, etc.

4) SETUP FUNCTION:

Initialize the LCD display.Begin serial communication with the ESP8266 module.Connect to Wi-Fi using the `connectWiFi` function.Setup interrupt for pulse sensor using `interruptSetup` function.

5) LOOP FUNCTION:

Continuously check and display the heart rate (BPM) on the LCD.If BPM is abnormal, print "Abnormal," otherwise, print "Normal."Update heartbeat data and store it.If there is an error in connecting to Wi-Fi, attempt to reconnect.

6) UPDATEBEAT FUNCTION:

Establish a TCP connection If successful, send a GET request with the BPM data.If an error occurs during communication, close the connection and set an error flag.

7) CONNECTWIFI FUNCTION:

Set the ESP8266 to station mode.Attempt to connect to the specified Wi-Fi network with SSID and password.Return true if connection is successful, false otherwise.

8) INTERRUPT SETUP FUNCTION:

Configure Timer2 for interrupt-driven pulse sensor readings.

9) ISR FUNCTION (TIMER2_COMPA_VECT):

Handle interrupts triggered by Timer2. Read the analog signal from the pulse sensor. Identify peaks and troughs in the pulse waveform. Calculate IBI, BPM, and update flags accordingly.

VIII. CONCLUSION

This IoT-based health monitoring system marks a significant stride in personalized healthcare, offering real-time heart rate monitoring and data accessibility through a user-friendly website. The structured data repository ensures seamless record retrieval, empowering users to actively engage in monitoring their health trends. Looking ahead, future extensions could explore the integration of additional health parameters, broadening the scope of monitored data for a more comprehensive health overview. Enhanced user interfaces, incorporation of machine learning for predictive analysis, and compatibility with wearable devices represent promising avenues for further development. As technology continues to advance, the potential applications of this system may extend beyond heart rate monitoring, contributing to a holistic and proactive approach to individual well-being. This project serves as a foundation for future innovations in the field of IoT-enabled health systems, fostering a culture of informed and preventative healthcare practices.

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