Implementation of a Wearable IoT System for Real-Time Heart Rate Monitoring Using Sensor

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***Abstract*—Now a days, most of the electronic devices will be implemented using Internet of things. Specially, the wearable devices are implementing with internet of things.SecureSparkle, a small wearable device that uses a PPG sensor to monitor heart rate. It is powered by an ESP32 microcontroller and has a voltage regulator to ensure operational stability. Securesparkle eliminates the need for handheld devices, making it appropriate for patients who require continuous monitoring. Wearable health-monitoring devices are becoming transformative tools for patient care, enabling real-time tracking of vital signs and quick response during emergencies. IoT integration allows data transmission to a mobile application via Bluetooth and Wi-Fi, allowing caregivers to remotely access patient vitals and receive abnormal heart rate alerts in real-time.**

***Index Terms*—IoT, Wearable Devices, Heart Rate Monitoring, PPG Sensor, Blynk Integration, Microcontroller ESP32**

I. Introduction

A wearable health monitoring device named SecureSparkle was created especially for patients to monitor their heart rates and notify caregivers of any changes. This device incorporates a microprocessor (ESP32) with a voltage regulator for constant operation and a Photoplethysmography (PPG) sensor for accurate heart rate measurement. The ESP-WROOM-32 Bluetooth module allows data transmission and uses Internet of Things technologies to link the device to a mobile application. Wi-Fi is used to share heart rate data for real-time monitoring. The completed work shows the feasibility of combining IoT with wearable health technology for effective patient monitoring and safety, even if development was finished before the device was integrated into a pendant. Utilizing robust networking modules and low-power microcontrollers, our project lays the groundwork for upcoming developments in wearable health monitoring technology. By providing real-time patient monitoring and administration through connected devices, the Internet of Things (IoT) has completely transformed the healthcare industry. Concerns like data privacy, trust, and risk perception are addressed by IoT-based systems, which offer safe, effective, and customized healthcare solutions. These issues have a big impact on consumer acceptance. According to Alraja et al. [1], customers' trust in IoT-based healthcare solutions is influenced by a variety of factors, including security, privacy, and device familiarity.With features like heart rate and blood oxygen level monitoring via technologies like photoplethysmography (PPG), wearable health gadgets are essential for improving accessibility to healthcare. For instance, the MAX30100 sensor from Maxim Integrated is perfect for wearable applications since it gives accurate heart rate and SpO2 values [4]. These gadgets provide smooth data transfer and intelligent healthcare management when paired with microcontrollers like ESP32, which enables IoT integration [3].Beyond conventional healthcare, IoT has also been used to enhance safety protocols. Tehseen et al.'s systematic study emphasizes the importance of IoT in protecting women's safety and the necessity of dependable wearable technology that can communicate vital information in an emergency [2]. Furthermore, improvements in Bluetooth Low Energy (BLE) technology allow for effective wireless connection, which guarantees wearable IoT devices a longer battery life and greater user convenience [6]. By utilizing the advantages of IoT technology and abiding by wearable health device standards, the suggested system seeks to solve the problems of scalability, real-time monitoring, and energy efficiency [8]. Wearable technology can improve its functioning and provide users with more insightful information about their health by using machine learning algorithms and predictive analytics [9].

II. Literature Survey

1) **Security and Privacy's Effect on IoT Healthcare:** The relationship between security, privacy, trust, and familiarity with IoT devices in the healthcare industry was examined by Alraja et al. [1]. The study highlights that customers' adoption of IoT-based healthcare systems is significantly influenced by their perception of risk. These results highlight how crucial private and secure data transfer is for wearable medical devices.
2) **IoT in Applications for Women's Safety:** In their comprehensive literature analysis on the Internet of Things' role in women's safety, Tehseen et al. [2] provided evidence of the critical function wearable technology can play in emergency scenarios. This study demonstrates how sensors and IoT frameworks can be combined to provide responsive safety solutions, opening the door for cutting-edge wearable technology.
3) **ESP32's Capabilities in Internet of Things-Based Systems:** Widely known for its Internet of Things characteristics, the ESP32 microcontroller [3] enables wireless connection and effective data processing in wearable devices. It is a good option for real-time health monitoring applications because of its versatility in handling several communication protocols, such as Bluetooth Low Energy (BLE) and Wi-Fi.
4) **PPG Sensor Technology for Monitoring SpO2 and Heart Rate:** The MAX30100 sensor [4] is a vital part of wearable medical equipment since it combines heart rate monitoring and pulse oximetry capabilities. Its acceptance in contemporary healthcare solutions has been largely attributed to its precise physiological data detection and interoperability with IoT frameworks.
5) **Bluetooth Low Energy (BLE) Advancements:** The energy-efficient communication characteristics of Bluetooth Low Energy technology [6] have led to its widespread use in wearable IoT devices. It guarantees smooth communication between mobile apps and wearable sensors, prolonging device battery life while consuming minimal power.
6) **Wearable Health Device Standards:** In order to guarantee precision, dependability, and security in wearable technology, the IEEE Standard for Wearable Health Devices [8] offers recommendations and requirements. By following these guidelines, wearable technology that satisfies medical-grade criteria for real-time patient monitoring can be developed.
7) **Analytics for Wearable Health Using Machine Learning:** The use of machine learning algorithms for predictive health analytics in wearable medical devices was emphasized by Patel and Wang [9]. By incorporating these algorithms into wearable technology, anomalies can be detected early and users' health status can be meaningfully understood.

III. Ease of Use

1) **User-Friendly Design**: Patients no longer need to carry along handheld equipment thanks to the wearable pendant design. Its small size and lightweight provide comfort even with extended use.
2) **Automatic Heart Rate Monitoring**: Without requiring human input, the PPG sensor tracks the patient's heart rate continually.
3) **Easy Data Access via Mobile App**: A user-friendly mobile app interface makes it simple for patients and caregivers to access real-time heart rate data. The user doesn't have to constantly watch because alerts and messages are automatically created for aberrant readings.
4) **Smooth Connectivity**: The gadget easily connects to the mobile app without requiring complicated setup steps thanks to IoT integration via Bluetooth or Wi-Fi.
5) **Minimal Maintenance**: The voltage regulator and microcontroller guarantee steady and dependable functioning with little to no assistance from the user.
6) **Emergency Features**: In times of crisis, the SOS alarm system offers caregivers peace of mind by facilitating prompt and simple contact.

IV. Technical Nomenclature

A. *Abbreviations and Acronyms*

1) **PPG:** Photoplethysmography (Used for detecting heart rate by measuring blood volume changes in the skin.)
2) **ESP:** Espressif Systems Platform (ESP32 microcontroller used in your project for data processing and transmission.)
3) **IoT:** Internet of Things (Refers to the technology used to connect the wearable device to the mobile application.)
4) **BLE:** Bluetooth Low Energy (Used for wireless communication between the microcontroller and mobile devices.)
5) **Wi-Fi:** Wireless Fidelity (Used to transmit data for real-time heart rate monitoring.)
6) **SOS:** Save Our Souls (Represents the emergency alert system integrated into the device.)
7) **VR:** Voltage Regulator (Ensures stable power supply to the ESP32 microcontroller.)
8) **HRM:** Heart Rate Monitoring (Main feature of your wearable device to track the patient's heart rate.)

B. *Units*

1. Monitoring Heart Rate: The heart rate is measured in beats per minute (bpm). Voltage and Power Source 2. Voltage: Volts (V), as in the case of the ESP32 microcontroller and voltage regulator Current in amperes (A) Power in watts (W) 3. Data Transmission Bits per second (bps) is the data rate for Bluetooth and WiFi. 4. Consistency: Bluetooth frequency: Hertz (Hz); for BLE,

this is usually 2.4 GHz. 2.4 GHz or 5 GHz is the typical Wi-Fi frequency in Hertz (Hz). 5. PPG Sensor: If light-based heart rate measurement is used, the light intensity is Lux (lx). 6. Dimensions of the body: Size of pendant: centimeters (cm) or millimeters (mm) Weight of pendant: grams (g) 7. Measurements of Time: Interval of sampling: milliseconds (ms) or seconds (s) 8. Battery Life: Ampere-hours (Ah) or milliampere-hours (mAh) are the two possible capacities.

METHODOLOGY

1. Component Setup

- **Microcontroller**: The ESP32 microcontroller is used as the central processing unit to handle sensor data and communication protocols efficiently.

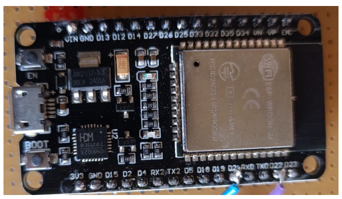

Fig. 1. ESP32 Microcontroller

- **PPG Sensor (MAX30100)**: Integrate the PPG sensor for heart rate monitoring. Connect its `Vin` to `INT` using a 1.6 kΩ resistor to prevent excess voltage and avoid interrupt occurrences.

Fig. 2. PPG Sensor (MAX30100)

- **Voltage Regulator (L78D5CV)**: Ensure stable voltage output at `3.3V`, connecting `3V3` to `Vin` to power the system and regulate current flow.
- **Bluetooth Module (ESP-WROOM-32)**: Utilize the built-in Bluetooth Low Energy (BLE) capabilities of ESP-WROOM-32 for heart rate data transmission to a smartphone.
- **Battery**: Use a `9V` battery for powering the device, ensuring proper connection to `GND` and voltage regulator.

- **Power Control**: The switch controls power to the ESP32 and PPG sensor, allowing the system to be turned on or off.

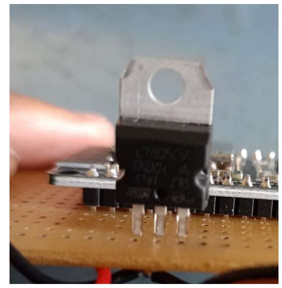

Fig. 3. Voltage Regulator(L78D5CV)

Fig. 4. Battery

2. Circuit Connections

- **Data Sync and Transfer**:
  - Connect `D22` to `SCL` for data synchronization.
  - Connect `D21` to `SDA` for data transmission and transfer.
  - Ensure `GND to GND` connection for stable current flow.
- **PPG Sensor Filtering**: Link the PPG sensor to the ESP32 microcontroller and implement filtering to remove noise using the FFT (Fast Fourier Transform) algorithm.

3. Signal Processing

- **Noise Removal**: Apply the FFT algorithm within the ESP32 microcontroller to process raw PPG sensor data and filter out noise.
- **Data Filtering**: Extract clean heart rate signals and eliminate artifacts to ensure accurate monitoring.

4. Communication via Bluetooth

- **Bluetooth Low Energy (BLE)**: ESP-WROOM-32 transmits processed heart rate data wirelessly to a connected smartphone.

Fig. 5. Switch

- **Two-Way Communication**: Enable two-way communication to allow real-time data transfer and reception.

5. Power Management

- Use the `9V` battery as the primary power source.
- Ensure `GND connection` to regulate current flow and prevent inconsistencies.
- Maintain stability across components using the `L78D5CV` voltage regulator.

6. Validation and Testing

- **Hardware Testing**: Verify proper connections for `D22 (SCL)`, `D21 (SDA)`, `GND`, and `Vin` to ensure reliable data transmission and synchronization.
- **Software Testing**: Test the FFT algorithm for effective noise removal and ensure accurate heart rate signal processing.
- **Bluetooth Testing**: Validate BLE functionality to confirm seamless data transfer between ESP32 and smartphone.

C. Figures and Tables

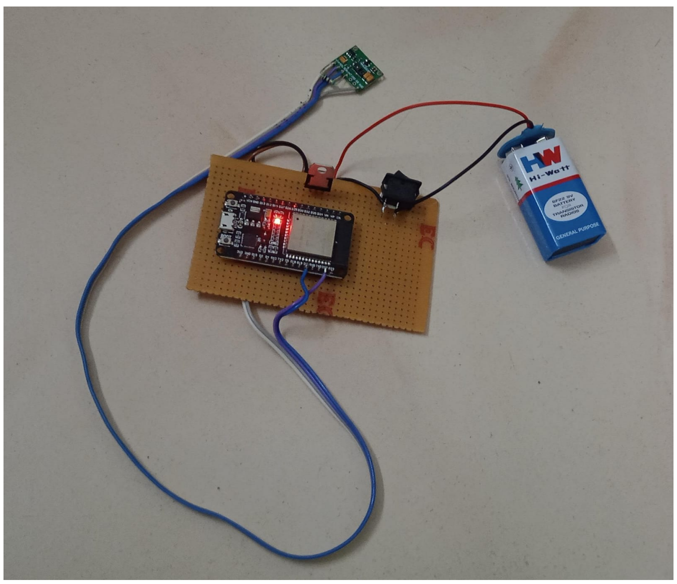

Fig. 6. Hardware Design of Securesparkle

Component Type	Component Name
Microcontroller	ESP32
PPG Sensor	MAX30100
Bluetooth Module	ESP-WROOM-32
Voltage Regulator	L78D5CV

TABLE I
LIST OF COMPONENTS AND THEIR NAMES

Component	Specifications
PPG Sensor	High sensitivity, based on optical
ESP32 Microcontroller	Dual-core, low-power processor
Voltage Regulator	3.3V stable
Battery Capacity	9V

TABLE II
DEVICE SPECIFICATIONS

Age Group	Average Resting Heart Rate (bpm)
Newborns (0–1 month)	70–190
Infants (1–12 months)	80–160
Children (1–10 years)	70–120
Teens (11–17 years)	60–100
Adults (18–64 years)	60–100
Older Adults (65+ years)	60–100

TABLE III
AVERAGE RESTING HEART RATE BY AGE GROUP

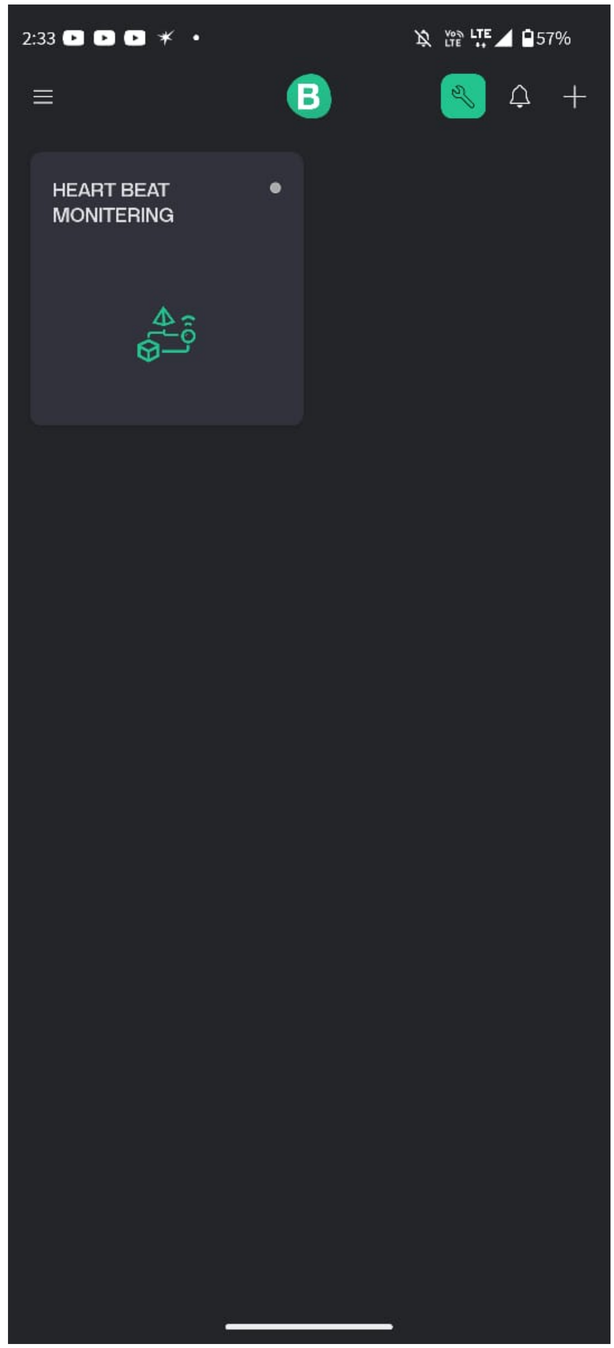

Fig. 7. Mobile Application Interface Design

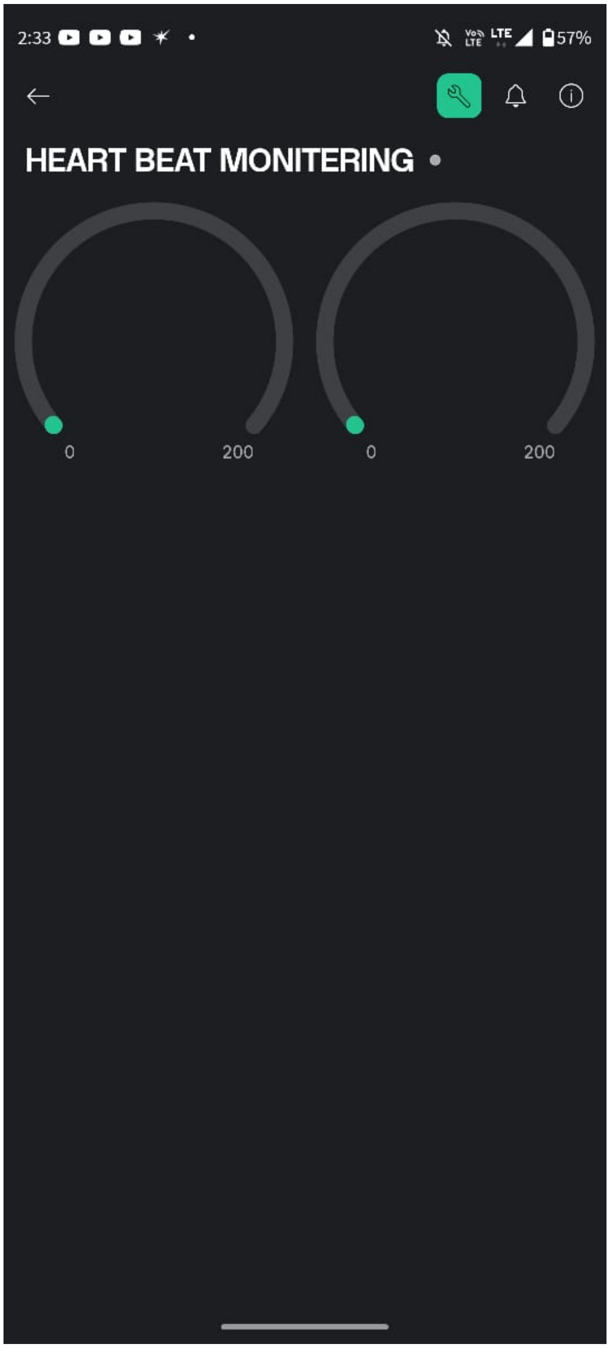

Fig. 8. Processing Logic Flowchart

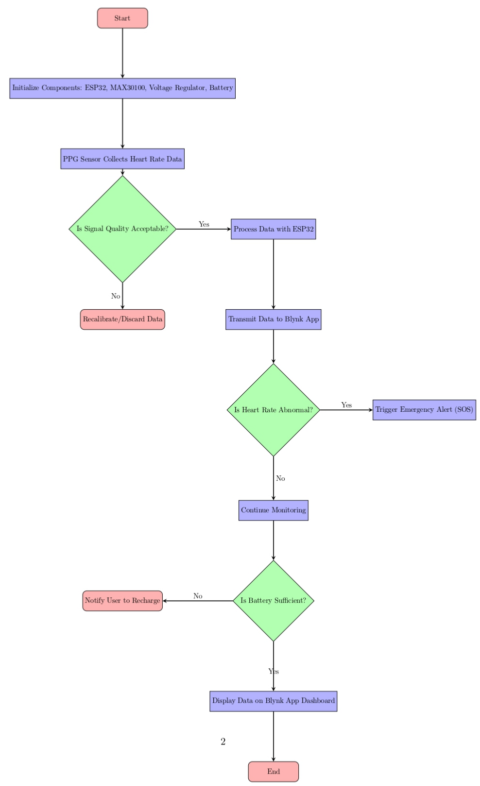

Fig. 9. SYSTEM FLOWCHART DESIGN

V. Future Works

1) **Wearable Form Integration:** In order to improve user comfort and accessibility, future versions of the project could concentrate on refining the hardware design to create a small, portable pendant or bracelet form.
2) **Improved Signal Processing:** To further increase the accuracy of PPG signal processing, particularly in dynamic situations, sophisticated noise reduction methods outside of the FFT algorithm can be investigated.
3) **Real-Time Monitoring and Notifications:** Rather than depending only on smartphone applications, the system can become more reliable and self-contained by integrating real-time anomaly detection with SOS notifications straight from the device.
4) **Battery Optimization:** The device's battery life can be increased for extended use by putting in place power management algorithms and energy-efficient hardware components.
5) **Increased Communication Capabilities:** Supporting additional wireless communication protocols, such as Zigbee or Wi-Fi, can provide connectivity choices for a range of use cases.
6) **Clinical Validation:** To make sure the gadget satisfies requirements for medical-grade wearable technology, future research can concentrate on using clinical trials to validate its accuracy and dependability.
7) **Data Analytics and Machine Learning:** By incorporating machine learning algorithms into predictive health analytics, users may be able to learn more about the health of their hearts and be warned about possible dangers.
8) **Scalability for Multi-Sensor Integration:** The system's use in comprehensive health monitoring can be expanded by adding more physiological sensors, like ECG modules.

VI. Conclusion

The goal of this research was to create a novel wearable technology. The device was made to wirelessly send heart rate data to a smartphone, process PPG signals, and eliminate noise using FFT techniques. Unexpected limitations prevented the project from moving further to the last phase of encapsulating the device into a pendant form, despite notable advancements in the integration of the hardware components and the establishment of data processing and transmission workflows.

Preliminary tests showed the promise of the suggested design and its functionality, even though the final product could not be completed. Future research might concentrate on improving the current configuration, resolving issues found, and creating a small, wearable design appropriate for wider use in medical monitoring systems.

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