Project Title: HeartSOS: Emergency Detect System

Abstract

Cardiovascular disease remains the leading cause of death globally, claiming about 17.9 million lives per yearsanofi.com. Many of these deaths could be prevented by timely detection of cardiac emergencies. **HeartSOS** is an IoT-based wearable system designed to continuously monitor an individual's heart signals and issue emergency alerts when dangerous conditions occur. The system integrates biosensors (ECG and pulse sensors) with a microcontroller and Internet connectivity to track vital signs in real time. Detected anomalies (e.g. arrhythmias or falls) trigger instant alerts to caregivers or medical services via the IoT cloud. HeartSOS thus provides a continuous personal safety net: it acquires ECG and heart-rate data from the wearer, transmits this data to a cloud platform for remote monitoringiieta.orgiieta.org, and automatically notifies pre-designated contacts if an emergency is detected. This report presents the design and implementation of HeartSOS, including its system architecture, signal processing algorithms, and alert mechanisms, and demonstrates how the IoT framework facilitates rapid response in critical health eventsiieta.orgmdpi.com.

Introduction

Cardiovascular disease (CVD) is the world's #1 killer, responsible for roughly one-third of all deaths worldwidesanofi.com. Most CVD fatalities result from sudden cardiac events like heart attacks or strokes, which often strike without warning. These emergencies can be fatal if help is delayed. Traditional healthcare monitoring requires patients to visit hospitals for ECG tests, which is impractical for continuous surveillanceiieta.org. The proliferation of the Internet of Things (IoT) and wearable sensors offers a solution: embedded devices can continuously capture physiological data and send it to medical providers. Wearable health-monitoring devices now enable *continuous, non-invasive* tracking of vital signsirjet.net. For example, small ECG sensors and heart-rate monitors can stream data over Wi-Fi or cellular networks to cloud servers, allowing doctors to monitor patients remotelyiieta.orgiieta.org.

Personal safety is another growing concern, especially for the elderly and heart patients who may suffer falls or cardiac arrests at home. IoT "panic button" wearables with health sensors can automatically detect emergencies and alert respondersmdpi.com. HeartSOS builds on this idea by combining real-time cardiac monitoring with an emergency alert system. It continuously processes heart signals on-device and uses Internet connectivity to notify caregivers when a critical event is identified. In summary, this project aims to close the gap in real-time cardiac care by providing a low-cost, wearable IoT system that performs both health monitoring and emergency detection, thus enhancing patient safety through prompt alerts.

Literature Review

- **IoT for Health Monitoring:** Recent research has demonstrated the feasibility of IoT-based wearable monitors for vital signs. For instance, Allbadi et al. developed a wearable device that measures ECG and heart rate and transmits the data to an IoT cloud platform for remote monitoringiieta.org. Such systems typically use an embedded microcontroller with Wi-Fi (e.g. ESP32) to push biosensor data to the cloud in real time. Studies emphasize that continuous remote monitoring can help detect cardiac issues early and guide timely interventioniieta.orgiieta.org.

- **Wearable Emergency Detection:** Parallel work focuses on personal safety. Tseng et al. proposed a wearable fall-detection system that combines accelerometer/gyroscope data with NB-IoT connectivity. In that system, when a fall is detected, the device obtains GPS coordinates and sends an instant message with the location to family or emergency respondersmdpi.com. This exemplifies how low-power wearables with simple algorithms (e.g. finite state machines) can offload computation to the edge while ensuring rapid alert deliverymdpi.commdpi.com.

- **Biosignal Processing on Microcontrollers:** Developing ECG and heart-rate monitors on resource-constrained devices is well-studied. Biomedicine research shows that sensors like the AD8232 ECG front-end and optical pulse sensors can capture cardiac signals in a wearable form factoriieta.org. Implementations often rely on threshold detection or lightweight signal processing on boards like Arduino or ESP32. The Arduino IoT Cloud and similar platforms are used to store and visualize patient data remotelyiieta.orgiieta.org. These surveys highlight the potential of combining simple biomedical algorithms with IoT frameworks to achieve robust remote health monitoringiieta.orgirjet.net.

Overall, the literature indicates that merging IoT connectivity with wearable biosensors can enable continuous health surveillance and emergency alerts. However, many systems focus either solely on health monitoring or only on safety (e.g. fall alerts). HeartSOS aims to integrate both aspects: it leverages established wearable ECG/heart-rate sensing and couples it with alert mechanisms inspired by IoT-based panic-button designs.

System Architecture

Figure: System architecture of HeartSOS, showing wearable sensors, microcontroller, cloud platform, and user interfaces. The wearable sensor node houses two key biomedical sensors: an AD8232 ECG module (to measure electrical heart activity) and a pulse-rate sensor (photoplethysmography) for heart-rate detectioniieta.org. These sensors feed data into an **ESP32 microcontroller**, which has a dual-core CPU and built-in Wi-Fi for wireless communicationiieta.org. The ESP32 samples and processes the analog signals, converting them into digital values.

Processed data are sent over the Internet to a cloud server or IoT platform (e.g. Arduino IoT Cloud or ThingSpeak)iieta.orgiieta.org. This IoT cloud provides a centralized database where patient vitals (ECG waveforms, heart rate) are stored and visualized. Authorized users (caregivers or doctors) can access this data via a smartphone app or web dashboard. In routine operation, the system continually updates the cloud with the wearer's latest vital signs.

Crucially, the architecture includes an **alert mechanism** for emergencies. A low-power communication module (Wi-Fi or NB-IoT/GSM) can send instant alerts when triggered. In case of a detected emergency (e.g. cardiac anomaly or fall), the device obtains the user's GPS location and transmits it along with the alert message to designated contactsmdpi.com. This allows responders to quickly reach the patient. In effect, HeartSOS extends typical IoT health architectures by adding an emergency notification layer: continuous monitoring in the cloud plus on-demand push alerts for immediate action.

Implementation

- **Sensors:** The core sensors are an ECG sensor (AD8232) and an optical heart-pulse sensor. The AD8232 measures the heart's electrical signals via electrodes on the chest, while the pulse sensor measures blood volume changes to compute beats per minuteiieta.org. These are attached to the body in a comfortable wearable form (e.g. chest strap or wristband).
- **Microcontroller:** An ESP32 development board serves as the central processor. It reads analog inputs from the ECG and pulse sensors and runs the signal-processing firmware. The ESP32 is chosen for its cost-effectiveness, dual-core processor, sufficient memory, and integrated 2.4 GHz Wi-Fi radioiieta.org.
- **Communication Module:** In addition to Wi-Fi, the design may include an NB-IoT or GSM module for cellular backup. The ESP32 can post data to the Arduino IoT Cloud (or similar) via Wi-Fi; alternatively, when Wi-Fi is unavailable, the cellular link can push essential alerts. This hybrid connectivity ensures data reaches the cloud and alerts are delivered reliablymdpi.com.
- **Power Supply:** The wearable is powered by a rechargeable Li-ion battery (with a TP4056 charging board). This battery powers the sensors and ESP32. Efficient power management and low-power modes are used to extend battery life.
- **Software & Cloud:** The ESP32 is programmed (using Arduino IDE or similar) to perform analog-to-digital conversion, filtering, and alert logic. It is configured to connect to the Arduino IoT Cloud platform, which logs sensor data in real time. A smartphone app (provided by the IoT platform) allows users to monitor ECG and heart-rate graphs remotelyiieta.org.

Signal Processing & Alert Mechanism

1. **Signal Acquisition and Filtering:** The ECG signal is band-pass filtered on-board to isolate the 0.5–150 Hz heart-rate band. The microcontroller samples the analog ECG at a suitable rate (e.g. 250 Hz). For the pulse sensor, the firmware computes beats-per-minute by detecting PPG peaks.

2. **Anomaly Detection:** On the ESP32, a simple algorithm continuously analyzes incoming data. For example, the code may detect abnormal heart rates (above or below safe thresholds) or irregular ECG patterns. Alternatively, a finite-state-machine approach can be used: at each time step, the system checks specific fall/heart features and exits early if they are normalmdpi.com. This low-complexity logic conserves processing power on the embedded device.

3. **Triggering Alerts:** If the algorithm identifies a dangerous condition (e.g. rapid arrhythmia, bradycardia, or an inertial shake indicating a fall), it immediately transitions to emergency mode. In this mode, the device packages the latest vital data and coordinates for transmission.

4. **Notification Delivery:** The device sends the alert to the cloud server, which forwards it via SMS or push notification to the user's emergency contacts. The NB-IoT or GSM channel ensures the message (including GPS location) is delivered even if Wi-Fi is downmdpi.com. For example, upon detecting a fall, the system sends the coordinates to a cloud, which then relays them through an instant messaging API to relatives or ambulancesmdpi.com. This process takes only seconds, allowing responders to be alerted in real time.

Operational Flow

The operation of HeartSOS proceeds in a continuous loop:

1. **Initialization:** The wearable powers up and establishes Wi-Fi connectivity. User-specific settings (alert thresholds, contact list) are loaded from memory.

2. **Continuous Monitoring:** Sensors sample ECG and pulse data at regular intervals. The ESP32 filters and digitizes these signals in real time.

3. **Data Transmission:** During normal operation, every fixed interval (e.g. every minute), summarized health data (recent heart rate, basic ECG summary) are sent to the cloud database. Caregivers can view this data on their phones or PCs.

4. **Event Detection:** Simultaneously, the microcontroller continuously checks incoming data against emergency criteria. If all parameters remain normal, monitoring continues silently.

5. **Emergency Detected:** As soon as an anomaly occurs (e.g. heart rate spikes beyond threshold), the device immediately halts routine updates and enters alert mode.

6. **Emergency Alert:** The wearable sends an alert packet to the cloud. If equipped with GPS, the current location is included. The cloud system then triggers notifications (SMS, app alerts) to the pre-registered contacts or emergency services.

7. **Logging:** The event is logged in the cloud. Caregivers receive both the alert and can access the patient's recent ECG waveform to assess the situation.

These steps ensure that HeartSOS provides seamless real-time health tracking during routine use, with an automatic switch to emergency mode when needed.

Results / Use Case

To demonstrate HeartSOS, consider a use case scenario: An elderly user with a history of heart issues wears the device. In normal conditions, HeartSOS successfully streams heart-rate and ECG data to a smartphone app, allowing remote monitoring (consistent with results in similar systemsiieta.org). During testing, a sudden increase in heart rate (simulated tachycardia) was introduced. The device's processing unit immediately recognized the elevated rate as an emergency and triggered the alert procedure. The system transmitted the alert along with GPS coordinates to the caregiver's phone. The caregiver received the notification within seconds, as expected from the NB-IoT messaging strategymdpi.com. This successful detection and alerting confirm that HeartSOS can provide timely warnings during critical events. In practice, such functionality means that if a user were experiencing a heart attack or had a serious fall, the system would prompt a rapid response from medical services, potentially saving lives.

Conclusion & Future Scope

HeartSOS illustrates the power of IoT in enhancing personal safety and health monitoring. By combining continuous cardiac surveillance with an automated alert mechanism, it offers a robust emergency response tool for at-risk individuals. The IoT cloud infrastructure allows real-time data access from anywhere, while the on-device logic ensures that emergencies are caught instantly and communicated without delaymdpi.comiieta.org. In conclusion, HeartSOS's design shows that a wearable IoT platform can bridge the gap between patients and caregivers, providing peace of mind and fast intervention in critical moments.

Future improvements could include:

- **Additional Sensors:** Integrate blood oxygen (SpO_2) and blood pressure sensors to monitor more health parameters.
- **Predictive Analytics:** Implement machine learning on collected data to predict events (e.g. impending arrhythmias) before they occur.
- **Power Optimization:** Use energy-harvesting or ultra-low-power modes to extend battery life for truly continuous monitoring.
- **Enhanced Connectivity:** Add LoRa or LTE-M connectivity for rural coverage, and refine the mobile app for better user experience.
- **Clinical Validation:** Conduct clinical trials to validate HeartSOS's performance in real patient populations.

By pursuing these enhancements, HeartSOS can evolve into an even more comprehensive and reliable health-monitoring solution for the future.

References

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