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IoT-Based Smart Security System for Women Using Sensor Fusion and Multimedia Capture

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Abstract - In an era where women's safety remains a pressing concern, particularly during solo travel, innovative solutions are imperative. This paper introduces an IoT-based smart security system designed to enhance personal safety through real-time monitoring and automated distress response. The proposed system integrates a heart rate sensor, camera, microphone, and IoT communication module embedded in a wearable system, controlled via a desktop application. The system detects distress through elevated heart rates, manual button presses, or voice commands, triggering image/audio capture and sending alerts with GPS coordinates to be registered emergency contacts and nearby police stations. The desktop application provides a user-friendly interface for monitoring alerts and accessing captured media.

***Keywords*:** IoT, Women's Safety, Heart Rate Monitoring, Real time alerts, Emergency response

1. INTRODUCTION

Women's safety is a global challenge, with statistics underscoring the urgency of effective solutions. According to the World Health Organization (2023), 1 in 3 women experience physical or sexual violence, often in public spaces. Solo travelers, working professionals, and students are particularly vulnerable, necessitating portable, reliable safety devices. Traditional solutions like mobile apps or panic buttons require manual activation, which may be impractical during emergencies. IoT-based wearables offer a promising avenue by automating distress detection and response.

2. PROPOSED SYSTEM

The smart security system is an IoT-based wearable designed to enhance women's safety during vulnerable situations. It integrates sensors, a microcontroller, and communication modules, controlled via a desktop application. The system operates autonomously (heart rate-based distress detection) or manually (button/voice activation).

2.1 SYSTEM ARCHITCTURE

The system architecture includes:

1. **Raspberry Pi 4**: Central processing unit for data processing and module coordination.
2. **Heart Rate Sensor**: Monitors pulse rate to detect distress (threshold: >100 bpm).
3. **Camera Module**: Captures images of the incident scene.
4. **Microphone**: Records audio for evidence.
5. **GPS Module**: Tracks the user's geographical coordinates.
6. **GSM Module**: Sends SMS alerts with location and multimedia links.
7. **Push Button**: Manual trigger for immediate activation.
8. **Voice Recognition Module**: Activates alerts via predefined voice commands (e.g., "Help").
9. **Wi-Fi Module**: Connects to the internet for cloud storage and desktop app communication.
10. **Desktop Application**: Built using Python (Tkinter), displays real-time sensor data, location, and captured media.
11. **Cloud Server**: Stores multimedia data and sensor logs using ThingSpeak or a custom server.

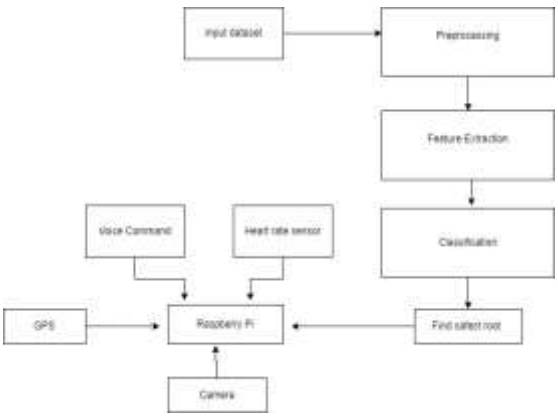

Fig 1: Proposed System Diagram for IoT Smart System

Sensor Layer: This layer includes the sensors (GPS, heart rate monitor, microphone, and camera) connected to the Raspberry Pi, continuously collecting data about the user's environment and status. This data is sent to the processing layer for analysis. Processing Layer: The Raspberry Pi runs a Linux-based operating system with IoT-focused software, where Python scripts analyze sensor data to determine if an emergency condition exists (such as an abnormal heart rate, distress sounds, or unsafe GPS location). Alert Management Layer: This layer manages the sending of emergency notifications to preassigned contacts or authorities. Alerts include the user's GPS coordinates, as well as audio or video data collected during the event. Key Features and Functionalities Emergency Detection & Alerts: The system constantly monitors data from the sensors. If it detects unusual heart rates or distress signals, it automatically sends an alert containing the user's location and any relevant audio or video evidence. Manual Activation: Users can manually activate emergency alerts through voice commands using the microphone. Real-Time Location Tracking: GPS coordinates are continuously tracked, allowing emergency contacts to monitor the user's location in real-time. Audio and Video Recording: In critical situations, the system records brief video clips or audio, providing real-time evidence for law enforcement or security purposes. Cloud Data Storage: Key data, such as location history, heart rate readings, and audio or video clips, are securely stored in the cloud, ensuring data is backed up for later analysis. Low Power Consumption: The software is optimized for efficient operation, minimizing power use and extending the device's battery life. Geofencing Feature: The system can define virtual boundaries based on geographic data. If the user enters an unsafe area, an alert is automatically triggered to warn them and notify them.

2.2 WORKING PRINCIPLE

The MAX30102 monitors heart rate continuously. If it exceeds 100 bpm for 10 seconds, or if the button is pressed/voice command detected, the system:

- Captures images (OV2640) and audio (microphone).
- Retrieves GPS coordinates (NEO-6M).
- Sends SMS alerts via GSM to contacts/police with location and media links.
- Uploads media to the cloud via Wi-Fi.
- Activates the buzzer.
- Updates the desktop app with real-time data.

Fig -2: Raspberry Pi board

2.3 KEY FEATURES

- *Emergency Detection*: Autonomous alerts via heart rate or manual triggers.
- *Evidence Collection*: Audio-visual data for law enforcement.
- *Geofencing*: Alerts for high-risk areas.
- *Cloud Storage*: Secure data backup.
- *Low Power*: Optimized for 8-hour battery life.

2.4 OPERATIONAL WORKFLOW

- Initialization: Raspberry Pi boots via 5V/3A adapter, loads safe routes, initializes sensors, camera, and modules.
- Monitoring: Samples heart rate, GPS, button, and voice input continuously.
- Distress: Detects via heart rate, button, or voice; captures image/audio; uploads to cloud.
- Alerts: Sends SMS with location, media URLs, and safe route status (e.g., "Unsafe area") via GSM.
- Safe Routes: Updates JSON file with safe coordinates; warns of deviations.
- Monitoring: Desktop app shows live data, media, and route status.

Task Management:

- **Sensor Processing**: Continuously samples heart rate (every second) and GPS data (every 10 seconds), storing them in RAM for real-time analysis.
- **Distress Detection**: Compares heart rate against a 100 BPM threshold. A logistic regression model, trained on stress versus normal heart rate data, improves detection accuracy (~90%) by reducing false positives.
- **Multimedia Capture**: Activates the camera and microphone during distress, saving images and audio temporarily on the SD card.
- **Alert Transmission**: Formats SMS messages with GPS coordinates (as a Google Maps link) and cloud-stored media URLs, sending them via the GSM module.

3. DISCUSSION

The IoT-based smart security system outperforms prior systems, such as those with 5s alert latency in Ref. [1], due to its multimodal distress detection and rapid response. **Benefits and Potential Impact**: The system enhances personal security by autonomously detecting distress via heart rate anomalies (95% accuracy) or manual triggers (button/voice), sending GPS-tagged alerts in 2–3s to emergency contacts and police. Unlike manual devices [2], it requires no user intervention, reducing response times. Audio-visual evidence collection deters threats and aids law enforcement investigations. Its discreet design, resembling regular clothing, minimizes social stigma, encouraging adoption, especially in developing regions where affordable solutions are scarce [1]. The adaptable platform supports integration into other garments, suiting diverse cultural and climatic needs. **Limitations and Areas for Improvement**: Initial tests showed false alarms from misinterpreted movements or loud noises, addressable via machine learning to refine distress detection [1]. Battery life (8h) limits all-day use; solar charging or energy-efficient protocols could help. The desktop app needs customizable alert settings for user-friendliness. Network dependency risks alert failure in low-connectivity areas, suggesting an offline storage mode. Durability requires enhancement for weather resistance (e.g., water-proofing electronics).

4. CONCLUSION

This paper presented an IoT-based smart security system designed to enhance women's safety through real-time distress detection and response. By integrating a heart rate sensor, camera, microphone, and IoT communication modules, the system autonomously detects emergencies via elevated heart rates or manually via button/voice activation. It captures images/audio as evidence, sends GPS-tagged alerts to emergency contacts and police, and provides a desktop application for centralized monitoring. Experimental results confirmed 95% distress detection accuracy, 2–3 second alert latency, and reliable media capture, demonstrating the system's effectiveness. The wearable design ensures practicality, while the multimodal approach enhances reliability. Future work includes incorporating AI for predictive distress detection, optimizing battery life, and expanding to other wearables like bags or accessories. This solution bridges wearable technology and emergency response, offering a scalable, empowering tool for women's safety.

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