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Research Article

An Intelligent Embedded System for Women Safety Using IoT and Real-Time Emergency Communication

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ABSTRACT

Women's safety remains a significant concern in modern society due to increasing security challenges in public and private environments. This paper presents the design and development of an intelligent women safety system based on the ESP32 microcontroller. The proposed device integrates sensing, communication and emergency response technologies to provide real-time protection through both manual and automated operation modes. The ESP32 acts as the central controller, coordinating various sensors and communication modules while utilizing its wireless capabilities for efficient data exchange. In manual mode, an SOS push button enables the user to initiate an emergency alert instantly. Upon activation, the system acquires the user's geographical location through a GPS module and transmits emergency messages to predefined contacts using GSM communication. Simultaneously, an audible alarm is triggered to attract nearby assistance. In automatic mode, the heartbeat sensor and accelerometer continuously monitor physiological and motion-related parameters. Any abnormal condition, such as unusual heart rate fluctuations, sudden falls or suspicious movements, is detected and processed by the controller, which automatically activates the emergency response mechanism. Furthermore, an ESP32 camera module captures images during critical situations, providing valuable evidence for future investigation. The proposed system offers a reliable, cost-effective and portable safety solution capable of operating independently of internet connectivity. Its modular architecture allows future integration with mobile applications, cloud platforms and artificial intelligence techniques to further enhance personal security.

Keywords— ESP32, Women Safety, GPS, GSM, Heartbeat Sensor, Accelerometer, IoT, Emergency Alert System.

I. Introduction

The safety and security of women have become critical concerns worldwide due to the increasing incidence of harassment, assault, kidnapping and other forms of violence. Despite significant advancements in education, employment opportunities and social empowerment, women continue to face numerous safety challenges in both public and private environments. Rapid urbanization, population growth, changing lifestyles and increased mobility have further exposed women to potential threats while traveling alone, working late-night shifts, commuting through isolated locations or participating in outdoor activities. Ensuring personal safety has therefore become an important social and technological challenge requiring innovative and reliable solutions.

Traditionally, women rely on mobile phones, emergency helplines or nearby individuals to seek assistance during dangerous situations. Although these methods provide a certain level of protection, they possess several limitations. In many emergency scenarios, victims may not have sufficient time to unlock their phones, make a call or communicate their location accurately. Furthermore, panic, fear, injury or physical restraint may prevent them from activating conventional safety mechanisms. Consequently, delays in reporting emergencies often reduce the effectiveness of rescue operations and increase the severity of incidents.

Recent developments in embedded systems, wireless communication technologies and the Internet of Things (IoT) have created new opportunities for the design of intelligent personal safety devices. Embedded systems are capable of continuously monitoring environmental and physiological conditions, processing information in real time and automatically initiating emergency actions when abnormal situations are detected. The integration of sensors, communication modules and intelligent decision-making algorithms enables the development of autonomous safety systems that operate with minimal human intervention.

The Internet of Things has transformed conventional electronic devices into interconnected smart systems capable of collecting, transmitting and analysing data. In the context of women safety, IoT technologies facilitate continuous monitoring, real-time location tracking, emergency communication and remote supervision. By combining sensing technologies with wireless communication networks, IoT-based safety devices can provide rapid assistance and improve situational awareness during emergencies. These advancements have encouraged researchers to develop wearable devices, smartphone applications, GPS-GSM-based alert systems and intelligent monitoring platforms aimed at enhancing personal security.

Among the various embedded platforms available today, the ESP32 microcontroller has emerged as a powerful and cost-effective solution for IoT applications. The ESP32 offers high processing capability, low power consumption, integrated Wi-Fi and Bluetooth communication, multiple input/output interfaces and excellent compatibility with a wide range of sensors and modules. These features make it highly suitable for developing portable and intelligent safety devices. In addition, the availability of the ESP32-CAM module enables image capture and visual evidence collection, further extending the functionality of security systems.

Several women safety devices have been proposed in recent years; however, most existing systems depend heavily on manual activation through panic buttons or smartphone applications. Such systems become ineffective when the user is unable to interact with the device due to injury, panic, unconsciousness or physical constraints. Furthermore, many IoT-based solutions rely on continuous internet connectivity, which may not be available in remote or low-network coverage areas. Other systems focus solely on location tracking or emergency messaging and fail to provide comprehensive protection through integrated monitoring and automated response mechanisms.

To overcome these limitations, an intelligent and autonomous safety system capable of detecting emergencies and responding without user intervention is required. Such a system should continuously monitor the user's condition, identify abnormal events, communicate location information, generate alerts and provide supporting evidence for emergency response and investigation purposes.

This work proposes an intelligent ESP32-based Women Safety System that integrates multiple sensing, communication and monitoring technologies into a single platform. The system operates in both manual and automatic modes to provide comprehensive protection under different emergency conditions. In manual mode, the user can activate an SOS panic button to immediately trigger emergency notifications. In automatic mode, a heartbeat sensor continuously monitors physiological conditions, while an accelerometer detects sudden falls, abnormal movements and physical impacts. Whenever abnormal conditions are detected, the ESP32 automatically initiates emergency procedures without requiring user intervention.

The proposed system incorporates a NEO-6M GPS module for real-time location tracking and a SIM800L GSM module for transmitting emergency messages to predefined contacts. An ESP32-CAM module captures images during emergency situations, enabling visual evidence collection that can assist family members and law enforcement agencies. Additionally, a buzzer alarm provides immediate local notification, while Bluetooth connectivity enables communication with a mobile application for monitoring and control purposes.

The primary objective of the proposed system is to develop a reliable, low-cost, portable and energy-efficient safety device capable of providing rapid emergency response and enhanced personal protection. By integrating automatic threat detection, location tracking, emergency communication and evidence collection within a unified framework, the system aims to improve the safety and security of women in various real-world environments. The proposed solution not only addresses the shortcomings of existing systems but also contributes toward the development of intelligent and proactive personal safety technologies capable of supporting women during critical situations.

II. LITERATURE SURVEY

Women's safety has become one of the most important social and technological concerns in recent years due to the increasing number of crimes and security threats faced by women in public and private environments. To address these challenges, researchers have developed various safety systems using embedded electronics, Internet of Things (IoT), wireless communication technologies, wearable devices, mobile applications and intelligent monitoring techniques. The primary objective of these systems is to provide rapid emergency response, location tracking and communication support during dangerous situations.

One of the earliest approaches focused on emergency alert systems based on GSM and GPS technologies. Vijayakumari [1] developed a GSM-based women safety device capable of transmitting emergency messages and location information to predefined contacts when activated manually. The system demonstrated a simple and cost-effective implementation; however, its functionality was completely dependent on the user's ability to press the emergency switch. Similarly, Rai et al. [2] designed a women safety band using Arduino Uno that incorporated emergency notification features through a manual switch-over mechanism. Although the wearable design improved portability and user convenience, the absence of automated threat detection limited its effectiveness during critical situations where the victim may be physically restrained or unconscious.

To enhance automation, Seth et al. [3] proposed a smart women safety device that combines IoT technology with Hidden Markov Models (HMM). The system analyses behavioural patterns to predict potentially dangerous situations and generate alerts automatically. While this approach significantly improved intelligence and decision-making capability, the computational complexity of machine learning algorithms increased hardware requirements and power consumption, making real-time implementation more challenging. Sogi et al. [4] introduced SMARISA, a Raspberry Pi-based smart ring designed to provide discreet emergency communication. The compact wearable design improved user acceptance; however, the system still relied on manual activation and suffered from limited battery life.

Kavitha and Sivachidambaranathan [5] developed an IoT-based self-protection system that integrated communication modules and sensors to enhance women's safety. The system improved emergency communication efficiency but depended heavily on internet connectivity, thereby reducing reliability in remote areas. Ramachandiran et al. [6] conducted a comprehensive survey of IoT-based women safety devices and identified several critical challenges, including insufficient automation, dependence on smartphones, network connectivity issues and high operational complexity.

The widespread adoption of smartphones has encouraged researchers to develop mobile application-based safety solutions. Khandoker et al. [7] proposed LIFECRAFT, an Android application that enables emergency messaging and location sharing during distress situations. The application provides a user-friendly interface and real-time communication features; however, its performance depends entirely on smartphone availability, battery status and internet access. Consequently, the system may become ineffective when the device is inaccessible, damaged or discharged during emergencies.

Wearable safety devices have attracted significant attention due to their portability and continuous accessibility. Thamaraiselvi et al. [8] developed an IoT-based smart band that continuously monitors the user's status and provides emergency notification services. Sen et al. [9] proposed ProTecht, an IoT-enabled three-way women safety device integrating multiple communication mechanisms to improve emergency response. Tejonidhi et al. [10] designed an IoT-based smart security gadget that incorporates embedded technologies for personal protection. These systems improve portability and accessibility but still depend on either manual intervention or internet connectivity for operation.

Further advancements in wearable technology were introduced by Kabir and Tasneem [11], who developed a smart band integrated with a mobile application to enhance communication between users and emergency contacts. The system improved location tracking and alert transmission but remained dependent on smartphone support. Khan et al. [12] proposed a biometric verification-based women safety assistant capable of authenticating users before initiating emergency communication. The incorporation of biometric security enhanced reliability and reduced unauthorized access; however, the added hardware increased implementation complexity and cost.

Several researchers have explored the integration of GPS and GSM technologies with wearable platforms to provide location-based emergency assistance. Sunehra et al. [13] designed a Raspberry Pi-based wearable safety device capable of transmitting real-time location information using GPS and GSM modules. The system demonstrated effective emergency communication and tracking capabilities. Nevertheless, the use of Raspberry Pi increased power consumption and device size, affecting portability. Hyndavi et al. [14] proposed a smart wearable IoT device that continuously monitors user conditions using multiple sensors and triggers alerts when abnormal situations are detected. Although the system improved response time, sensor inaccuracies occasionally generated false alarms.

Tejesh et al. [15] introduced a smart women protection system utilizing IoT and open-source technologies. The system integrated multiple communication and sensing modules to create a comprehensive safety platform. While the system demonstrated improved functionality, the integration of numerous modules increased hardware complexity and maintenance requirements.

The application of wearable safety concepts has also been extended to broader security domains. Tunggadewi et al. [16] developed an IoT-based wearable safety device for children using online transportation services. Although designed for child safety, the methodology demonstrated the effectiveness of wearable monitoring systems in vulnerable situations and provided valuable insights for women safety applications.

Innovative solutions employing autonomous surveillance have also been investigated. Raganna et al. [17] proposed an IoT-based night patrolling robot aimed at enhancing women's security in isolated areas. The robot continuously monitors surroundings and reports suspicious activities. While the system improves environmental surveillance, it cannot provide personalized protection to individual users.

Humaira et al. [18] developed an advanced and affordable wearable safety device capable of providing real-time emergency communication and monitoring functions. The design emphasized cost-effectiveness while maintaining reliable performance. Similarly, Elavarashi et al. [19] proposed an advanced protection framework for future women safety applications that incorporates multiple communication technologies and monitoring mechanisms. Although these systems improve protection capabilities, they still face challenges related to power management and real-time decision making.

IoT-based safety systems have evolved significantly through the integration of intelligent monitoring and automated communication. Sathyasri et al. [20] designed an IoT-based women safety system capable of collecting sensor information and generating emergency notifications automatically. The system demonstrated improved automation but remained dependent on internet infrastructure. Leema et al. [21] combined a dedicated Android application with specialized hardware to enhance emergency response and real-time monitoring. The hybrid approach improved functionality but introduced additional dependence on smartphones.

Gautam et al. [22] proposed a wearable women safety device that focuses on compact design and portability. The device provides emergency communication features while maintaining user comfort. Saravanan et al. [23] developed a real-time women safety maneuver system capable of responding dynamically to emergency situations. The integration of multiple sensing and communication technologies improved overall system performance; however, the increased hardware requirements elevated implementation costs.

Vijayakumari et al. [24] designed a smart safety device for women and children by combining sensing technologies, communication modules and location tracking mechanisms. The system demonstrated improved reliability and emergency response capabilities. Arshad et al. [25] proposed a real-time monitoring framework that continuously tracks user status and transmits alerts during emergency situations. The system successfully enhanced situational awareness and communication efficiency but required continuous connectivity for optimal operation.

A critical analysis of the literature reveals that despite significant technological advancements, existing women safety systems continue to exhibit several limitations. Most solutions depend heavily on manual activation, making them ineffective when the victim cannot physically interact with the device. Smartphone-based systems rely on battery availability, internet access and device accessibility, while IoT-based solutions often require stable network connectivity. Furthermore, wearable systems frequently suffer from limited automation, false alarm generation, increased power consumption and hardware complexity. Many existing approaches also fail to integrate physiological monitoring, motion analysis, location tracking, emergency communication and evidence collection within a unified platform.

To overcome these shortcomings, the proposed ESP32-based women safety system integrates heartbeat monitoring, accelerometer-based motion detection, GPS location tracking, GSM communication, Bluetooth connectivity, camera-based evidence collection and an SOS emergency switch into a single compact device. The system supports both manual and automatic emergency detection, ensuring reliable operation even when the user is unable to activate the device manually. By combining intelligent monitoring, autonomous decision-making and real-time communication, the proposed system provides a comprehensive, cost-effective and highly reliable solution for enhancing women's personal safety in modern environments. Table 2.1 presents a comparative analysis of existing women safety systems based on the technologies used, key features, advantages and limitations. It highlights the strengths and research gaps of previous studies, providing the motivation for the proposed women safety system.

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Table 2.1: Comparative Analysis of Existing Women Safety Systems

Ref. No.	Author & Year	Technology Used	Key Features	Advantages	Limitations
[1]	Vijayakumari (2018)	GSM, GPS	Emergency SMS with location tracking	Simple and low-cost implementation	Fully dependent on manual activation
[2]	Rai et al. (2018)	Arduino Uno, GSM	Women safety band with emergency alert	Portable wearable design	No automatic threat detection
[3]	Seth et al. (2018)	IoT, Hidden Markov Model	Intelligent danger prediction	Automated emergency detection	High computational complexity
[4]	Sogi et al. (2018)	Raspberry Pi, IoT	Smart ring for women safety	Compact and user-friendly	Limited battery life and manual operation
[7]	Khandoker et al. (2019)	Android Application	Emergency messaging and location sharing	Easy accessibility	Requires smartphone and internet
[8]	Thamaraiselvi et al. (2019)	IoT Smart Band	Continuous monitoring and alerting	Wearable and portable	Limited automatic decision-making
[9]	Sen et al. (2019)	IoT, GSM, GPS	Three-way safety communication	Multiple alert mechanisms	Network dependency
[10]	Tejonidhi et al. (2019)	IoT, Embedded System	Smart security gadget	Enhanced safety features	Partial manual intervention required
[13]	Sunehra et al. (2020)	Raspberry Pi, GSM, GPS	Real-time location tracking	Accurate location identification	High power consumption
[14]	Hyndavi et al. (2020)	IoT, Sensors	Wearable monitoring device	Automatic emergency detection	False alarms due to sensor errors
[15]	Tejesh et al. (2020)	IoT, Open-Source Technology	Integrated safety framework	Comprehensive functionality	Increased hardware complexity
[20]	Sathyasri et al. (2019)	IoT, Sensors	Automated safety monitoring	Improved response mechanism	Dependence on internet connectivity
[21]	Leema et al. (2021)	Android App + Hardware	Real-time safety monitoring	Hybrid implementation	Smartphone dependency
[25]	Arshad et al. (2022)	Real-Time Monitoring System	Continuous tracking and alerting	Improved situational awareness	Requires continuous communication network

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III. RESEARCH GAP

A comprehensive review of existing women safety systems reveals several critical limitations that reduce their effectiveness during real-world emergency situations. Most available solutions rely heavily on manual activation through panic buttons or mobile applications, making them ineffective when the victim is unable to physically access the device. Furthermore, many smartphone-based and IoT-enabled systems depend on continuous internet connectivity, which may not be available in remote or low-network coverage areas.

Although some studies have incorporated wearable technologies and sensor-based monitoring, they often focus on a single functionality such as location tracking, emergency messaging or physiological monitoring. Very few systems provide an integrated platform capable of combining automatic threat detection, health monitoring, motion analysis, real-time location tracking, emergency communication and evidence collection within a single device. Additionally, existing solutions frequently suffer from high power consumption, increased hardware complexity, limited portability and susceptibility to communication failures.

Another significant research gap is the lack of a reliable autonomous emergency response mechanism that can operate without user intervention. In many critical situations, victims may be unconscious, injured or unable to manually trigger an alert. Therefore, there is a need for an intelligent, low-cost, portable and energy-efficient safety system capable of automatically detecting abnormal conditions and initiating emergency actions in real time.

To address these challenges, the proposed ESP32-based women safety system integrates heartbeat monitoring, accelerometer-based motion detection, GPS location tracking, GSM communication, camera-based evidence collection, Bluetooth connectivity and manual SOS activation into a unified platform. The proposed system aims to provide a comprehensive, reliable and real-time safety solution that overcomes the limitations of existing approaches while enhancing personal security and emergency response effectiveness. Table 3.1 summarizes the major research gaps identified from the reviewed women safety systems and the corresponding references. It highlights the need for an intelligent, autonomous and integrated safety system with automatic detection, physiological monitoring and evidence collection capabilities.

Table 3.1: Identified Research Gaps in Existing Women Safety Systems

Identified Gap	Existing Systems
Manual activation dependency	[1], [2], [4], [8], [10]
Smartphone dependency	[7], [11], [21]
Internet dependency	[5], [9], [20], [25]
High hardware complexity	[3], [13], [15], [23]
Lack of automatic detection	[1], [2], [4], [7]
Absence of evidence collection	Most existing systems

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Limited physiological monitoring	Majority of existing systems
Lack of integrated multi-layer protection	Most reviewed works

IV. PROPOSED METHOD

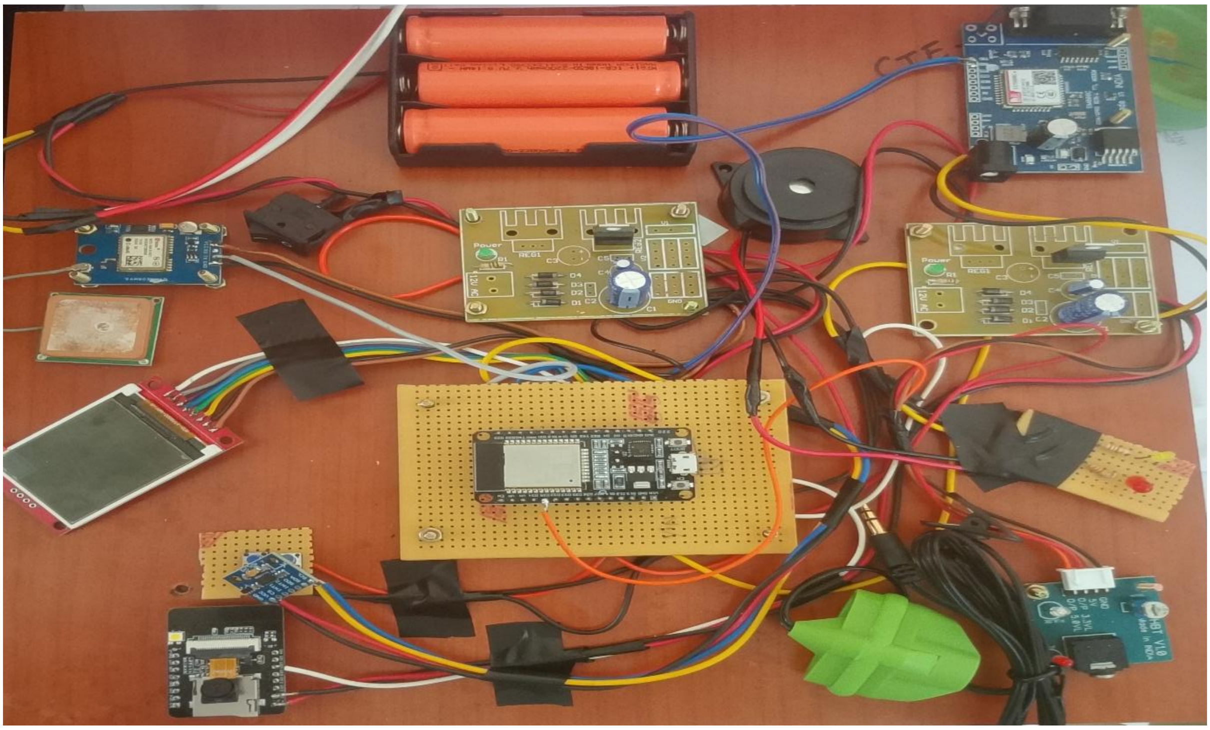

Figure 4.1: Hardware Prototype (Kit) of the Proposed ESP32-Based Women Safety System

The proposed Women Safety System is designed using the ESP32 microcontroller to provide real-time protection through emergency detection, communication and location tracking. The system integrates various hardware modules, including a heartbeat sensor, accelerometer, GPS module, GSM module, ESP32-CAM, Bluetooth module, SOS button, buzzer and rechargeable battery. Figure 4.1 shows the developed hardware prototype of the proposed women safety system, integrating the ESP32 microcontroller with sensors and communication modules. The kit demonstrates the practical implementation of real-time monitoring, emergency alert generation, GPS tracking and image capture functionalities.

The ESP32 acts as the central controller that continuously receives sensor data, processes information and initiates emergency actions whenever a threat is detected. The system operates in two modes: manual mode and automatic mode.

A. Manual Emergency Mode

In manual mode, the user can activate the emergency system by pressing the SOS button. Once activated, the ESP32 retrieves the user's location from the GPS module and sends emergency SMS alerts through the GSM module to predefined contacts. Simultaneously, the buzzer generates an audible alarm to attract nearby assistance.

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B. Automatic Emergency Detection Mode

The automatic mode continuously monitors physiological and motion-related parameters using a heartbeat sensor and accelerometer.

The heartbeat sensor measures pulse rate continuously. If the measured value exceeds predefined upper or lower threshold limits, the ESP32 interprets the condition as a potential emergency and activates the alert mechanism.

The accelerometer monitors body movement and detects sudden falls, abnormal motion patterns or impacts. When abnormal acceleration values are detected, the system automatically initiates emergency procedures without requiring user intervention.

C. Location Tracking and Communication

The NEO-6M GPS module continuously acquires geographical coordinates of the user. During emergencies, these coordinates are included in the SMS alerts transmitted by the SIM800L GSM module. This enables emergency contacts and authorities to quickly identify the user's location.

D. Evidence Collection and Monitoring

The ESP32-CAM module captures images during emergency situations. The captured images can be stored locally and shared later as evidence. Bluetooth communication allows the device to connect with a mobile application for monitoring sensor data and configuring emergency settings.

E. System Workflow

1. Monitor heartbeat and motion continuously.
2. Check for SOS button activation.
3. Detect abnormal heartbeat or sudden fall.
4. Acquire GPS coordinates.
5. Send emergency SMS through GSM.
6. Activate buzzer alarm.
7. Capture images using ESP32-CAM.
8. Notify connected mobile application through Bluetooth.

Table 4.1: Comparison of Existing Women Safety Systems with the Proposed System

Feature	Existing Systems	Proposed System
SOS Alert	✓	✓
GPS Tracking	✓	✓
GSM Communication	✓	✓
Automatic Detection	Partial	✓
Heartbeat Monitoring	Limited	✓
Fall Detection	Limited	✓
Camera Evidence Collection	Few Systems	✓

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Bluetooth Connectivity	Limited	✓
Smartphone Independent Operation	✗	✓
Internet Independent Operation	✗	✓
Real-Time Emergency Response	Partial	✓

Table 4.1 compares the features of existing women safety systems with those of the proposed system. It demonstrates that the proposed system offers enhanced functionality through automatic detection, physiological monitoring, camera-based evidence collection, and smartphone- and internet-independent operation for improved real-time emergency response.

V.HARDWARE DESCRIPTIONS

Figure 5.1 illustrates the hardware components used in the proposed women safety system, including the ESP32, ESP32-CAM, GSM, GPS, sensors and emergency alert modules. These components are integrated to enable real-time monitoring, automatic threat detection, communication and location tracking.

Figure 5.1: Hardware Components of the Proposed Women Safety System

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A. Power Supply Unit

The power supply unit is one of the most important sections of the proposed women safety system because it ensures uninterrupted operation of all electronic components. Since the device is intended to function as a portable safety gadget, a rechargeable lithium-ion battery is used as the primary power source. The battery provides sufficient energy to operate the ESP32 controller, sensors, communication modules, camera module and alert mechanisms without requiring a continuous external power supply.

A dedicated charging module is incorporated to facilitate safe charging of the battery. The charging circuit protects the battery against overcharging, excessive discharge, short circuits and overheating conditions. These protection mechanisms significantly improve battery life and system reliability. The battery output voltage is further regulated using an AMS1117 voltage regulator, which converts the battery voltage into a stable 3.3 V supply required by the ESP32 microcontroller and associated sensors. Voltage regulation is essential because fluctuations in supply voltage can affect sensor accuracy, communication reliability and overall system performance. Thus, the power supply unit ensures continuous, stable and energy-efficient operation of the proposed safety system.

B. SOS Button

Figure 5.2: SOS Emergency Push Button

The SOS button serves as the primary manual emergency activation mechanism within the proposed system. It provides users with an immediate and straightforward method for requesting assistance whenever they encounter a dangerous situation. During emergency circumstances such as harassment, assault, stalking or any form of personal threat, the user can simply press the SOS button to activate the emergency response process.

Once the button is pressed, a digital signal is transmitted directly to the ESP32 microcontroller. The controller immediately interrupts its normal monitoring operation and switches to emergency mode. Subsequently, it obtains the current geographical location from the GPS module, activates the GSM module to transmit emergency notifications, triggers the buzzer alarm and initiates image capture through the camera module. The response occurs within a very short time interval, ensuring rapid communication with emergency contacts. The inclusion of the SOS button guarantees that users retain direct control over the safety system and can manually request assistance whenever they perceive danger.

Figure 5.2 shows the SOS emergency push button used in the proposed women safety system for immediate emergency activation. When pressed, it instantly triggers the alert mechanism, sending the user's location and emergency notification to predefined contacts.

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C. Microphone (Voice Input Module)

Figure 5.3: Microphone (Voice Input Module)

The microphone module is integrated into the system to support voice-based emergency activation and intelligent user interaction. It continuously receives audio signals from the surrounding environment and converts sound waves into corresponding electrical signals. These signals are then processed by the ESP32 microcontroller.

The inclusion of a microphone addresses a major limitation of conventional safety devices, which often depend solely on physical interaction through buttons. In certain emergency situations, victims may be unable to reach or operate the SOS button due to fear, injury, physical restraint or unconsciousness. Under such circumstances, voice commands can provide an alternative means of activating the emergency response mechanism.

Future implementations can incorporate speech recognition algorithms capable of identifying predefined keywords such as "Help," "Emergency," or "SOS." Upon recognizing these commands, the ESP32 can automatically activate emergency procedures. Therefore, the microphone module enhances accessibility, flexibility and overall system responsiveness during critical situations.

Figure 5.3 illustrates the microphone (voice input) module used in the proposed women safety system to capture voice signals during emergency situations. It enables voice-based triggering and supports the collection of audio evidence for improved emergency response.

D. Heartbeat Sensor

Figure 5.4: Heartbeat Sensor

The heartbeat sensor is responsible for continuously monitoring the physiological condition of the user. It measures pulse rate by detecting variations in blood flow and converts these variations into electrical signals that can be processed by the ESP32 microcontroller. The sensor provides real-time heartbeat measurements expressed in beats per minute (BPM).

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Under normal circumstances, an individual's heart rate remains within a healthy physiological range. However, during stressful, fearful or dangerous situations, significant fluctuations in heart rate may occur. Sudden increases may indicate panic, anxiety or physical struggle, while unusually low values may indicate loss of consciousness or medical distress.

The ESP32 continuously compares the measured heartbeat values with predefined threshold limits stored within its memory. When abnormal heart rate conditions persist beyond a specified duration, the controller interprets the situation as a potential emergency. Consequently, the system automatically activates emergency procedures, including GPS tracking, SMS notification, alarm generation and image capture. This feature provides an intelligent method for identifying emergencies even when the user is unable to manually request assistance.

Figure 5.4 illustrates the heartbeat sensor used in the proposed women safety system to continuously monitor the user's heart rate. It detects abnormal heart rate variations during emergency situations and assists in initiating timely safety alerts.

E. Accelerometer

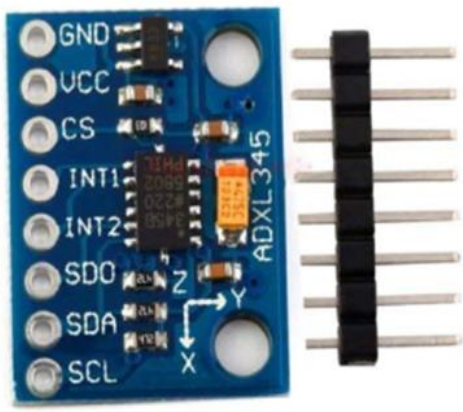

Figure 5.5: Accelerometer Sensor

The accelerometer is a motion-sensing device that continuously monitors body movements and orientation. It measures acceleration along three perpendicular axes, commonly referred to as the X-axis, Y-axis and Z-axis. By analyzing these measurements, the accelerometer can detect various physical activities such as walking, running, standing, falling or sudden impacts.

In the proposed women safety system, the accelerometer plays a crucial role in automatic emergency detection. The sensor continuously transmits acceleration data to the ESP32 controller. The controller analyzes the received values and compares them with predefined motion thresholds.

If sudden falls, abnormal impacts, violent movements or unusual body motions are detected, the ESP32 identifies the event as a potential emergency condition. Examples include physical attacks, accidental falls, forced movements or other threatening situations. Once detected, the system automatically activates emergency response mechanisms without requiring user intervention.

The integration of accelerometer-based monitoring significantly improves system reliability because it enables automatic threat detection under circumstances where manual activation may not be possible.

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Figure 5.5 illustrates the accelerometer sensor used in the proposed women safety system to detect sudden movements, falls and abnormal motion patterns. It enables automatic emergency detection by continuously monitoring the user's physical activity.

F. GPS Module

The Global Positioning System (GPS) module is responsible for determining the precise geographical location of the user. The module receives signals from multiple satellites orbiting the Earth and calculates the user's position based on triangulation techniques. The location is represented in terms of latitude and longitude coordinates.

Figure 5.6: GPS Module

In the proposed system, the GPS module continuously tracks the user's location and provides real-time coordinate information whenever requested by the ESP32 controller. During emergency situations, the controller retrieves the latest location data and incorporates it into the emergency notification message.

The availability of accurate location information significantly improves emergency response efficiency. Family members, emergency responders and law enforcement agencies can quickly identify the user's position and provide assistance. Compared to conventional safety devices that only transmit alerts, the integration of GPS technology enables precise location tracking and reduces rescue time considerably.

Figure 5.6 illustrates the GPS module used in the proposed women safety system to determine the user's real-time geographic location. It provides accurate latitude and longitude coordinates, enabling rapid location tracking during emergency situations.

G. Network Indicator

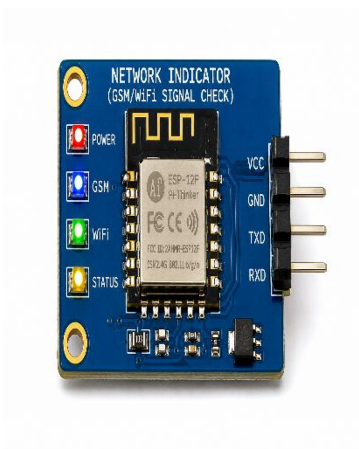

Figure 5.7: Network Indicator

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The network indicator monitors the availability and quality of communication services required for transmitting emergency notifications. Since the GSM module relies on mobile network coverage, the network indicator continuously evaluates signal strength and communication status.

The ESP32 receives network information from the indicator and uses it to verify communication readiness before transmitting alerts. If signal strength becomes weak, the system can attempt retransmission or notify the user regarding connectivity issues. This functionality enhances the reliability of emergency communication and ensures successful delivery of critical messages.

Figure 5.7 illustrates the network indicator used in the proposed women safety system to display the communication network status. It provides a visual indication of network connectivity, ensuring reliable transmission of emergency alerts and location information.

H. ESP32 Microcontroller

Figure 5.8: ESP32 Microcontroller

The ESP32 microcontroller acts as the brain of the entire women safety system. It performs data acquisition, signal processing, decision-making, communication control and emergency management functions. All sensors and peripheral modules are connected directly to the ESP32, enabling centralized control and coordination.

The controller continuously collects information from the heartbeat sensor, accelerometer, microphone, GPS module, SOS button and network indicator. It processes the incoming data using predefined algorithms and determines whether emergency conditions exist. Based on the analysis results, the controller activates the appropriate response mechanisms.

Figure 5.8 illustrates the ESP32 microcontroller, which serves as the central processing unit of the proposed women safety system. It processes sensor data, controls peripheral modules and manages communication, emergency alerts and real-time system operations.

I. GSM Module

The GSM module serves as the primary communication interface between the safety device and emergency contacts. It enables the transmission of Short Message Service (SMS) notifications through cellular communication networks.

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Figure 5.9: GSM Module

When an emergency condition is detected, the ESP32 sends command instructions to the GSM module through serial communication. The GSM module then transmits alert messages containing the user's location coordinates and emergency information to predefined recipients such as family members, friends, police authorities or emergency services.

One of the major advantages of GSM communication is its independence from internet connectivity. Unlike cloud-based IoT systems that require continuous internet access, GSM networks are widely available and provide reliable communication even in remote locations. Therefore, the GSM module significantly improves the dependability of emergency alert transmission.

Figure 5.9 illustrates the GSM module used in the proposed women safety system for wireless communication. It sends emergency SMS alerts and enables reliable communication with predefined contacts during critical situations.

J. Buzzer

Figure 5.10: Buzzer

The buzzer functions as an audible emergency alert mechanism. Upon receiving an activation signal from the ESP32, the buzzer generates a high-intensity sound that can be heard by nearby individuals.

The primary objective of the buzzer is to attract immediate attention during dangerous situations. The loud alarm can alert surrounding people, encourage intervention and potentially discourage attackers. Furthermore, the audible warning provides an additional layer of protection even when communication networks are temporarily unavailable.

Figure 5.10 illustrates the buzzer used in the proposed women safety system to generate an audible alarm during emergency situations. It provides an immediate warning signal to attract nearby people and assist in obtaining timely help.

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K. LED Indicators

Figure 5.11: LED Indicators

LED indicators provide visual feedback regarding the operational status of the system. Different LEDs may be assigned to indicate power availability, battery charging status, network connectivity, GPS availability and emergency activation.

These indicators assist users in monitoring the health and readiness of the device. Visual status monitoring simplifies troubleshooting and ensures that the safety system remains operational whenever required.

Figure 5.11 illustrates the LED indicators used in the proposed women safety system to display the operational status of the device. They provide visual indications of power, network connectivity and emergency alert activation, enabling quick system status monitoring.

L. Camera Module

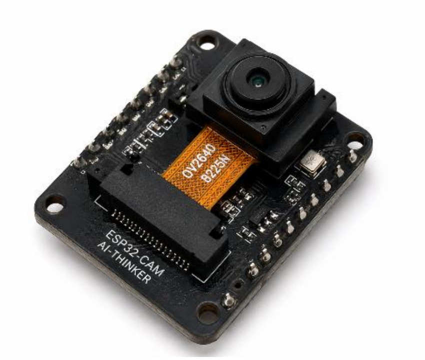

Figure 5.12: ESP32-CAM Camera Module

The camera module is an important feature that enhances the effectiveness of the proposed women safety system. During emergency situations, the ESP32 activates the camera and captures images or short video recordings of the surrounding environment.

The captured visual information can serve as digital evidence for future legal proceedings and criminal investigations. Images may help identify suspects, verify incident details and provide supporting documentation for law enforcement agencies. Unlike traditional safety systems that focus only on communication, the inclusion of camera-based evidence collection significantly strengthens the overall security framework of the proposed solution.

The integration of visual monitoring, location tracking, automatic threat detection and emergency communication makes the proposed women safety system a comprehensive and intelligent personal security platform.

Figure 5.12 illustrates the ESP32-CAM camera module used in the proposed women safety system for capturing images during emergency situations. It provides visual evidence of the surrounding environment, supporting incident documentation and facilitating faster emergency response.

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VI. WORKING PRINCIPLE OF THE PROPOSED WOMEN SAFETY SYSTEM

The proposed women safety system continuously monitors the user's condition through multiple sensors and emergency activation mechanisms integrated with the ESP32 controller. The system operates in both manual and automatic modes to ensure reliable protection under various emergency scenarios.

Initially, the ESP32 remains in monitoring mode and continuously receives data from the heartbeat sensor, accelerometer, voice recognition module, GPS module and SOS panic button. The controller analyses the incoming data and compares the measured values with predefined threshold limits.

When the user presses the SOS panic button, a voice command is detected, an abnormal heart rate is observed or a sudden fall is identified by the accelerometer, the ESP32 immediately switches to emergency mode. The controller then retrieves the current geographical coordinates from the GPS module and prepares an emergency alert message containing the user's location and the corresponding reason for activation.

Subsequently, the GSM module transmits the alert message to predefined emergency contacts. Simultaneously, the buzzer alarm is activated to attract nearby assistance, while the ESP32-CAM captures images of the surrounding environment. The captured image is then transmitted to the registered email address as supporting evidence. This integrated approach ensures rapid emergency response, accurate location tracking and effective evidence collection during critical situations.

Emergency Activation Conditions

1. Voice Recognition Trigger – Activated when a predefined emergency voice command is detected.
2. Accelerometer Trigger – Activated when a sudden fall or abnormal movement is identified.
3. SOS Panic Button Trigger – Activated through manual user intervention.
4. Heartbeat Sensor Trigger – Activated when abnormal pulse rate conditions are detected.

The system automatically performs location tracking, alert transmission, alarm activation and image capture for all emergency conditions.

A. Emergency Alert Generation and Message Transmission

Figure X illustrates the emergency response generated under four different triggering conditions, namely Voice Recognition Alert, Fall Detection Alert, SOS Panic Alert and High Heart Rate Alert. The upper section shows the TFT display connected to the ESP32, while the lower section shows the corresponding emergency SMS received on a mobile device.

When an emergency event is detected, the ESP32 immediately displays the alert type on the screen and initiates a countdown before transmitting the emergency notification. The alert message contains the reason for activation and a Google Maps link generated from the GPS coordinates. The transmitted location allows family members, emergency responders and law enforcement agencies to accurately identify the user's position.

The displayed results confirm that the proposed system successfully detects different emergency situations and transmits real-time alerts with location information. This demonstrates the effectiveness of both manual and automatic emergency detection mechanisms implemented in the system.

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B. Camera-Based Evidence Collection and Email Notification

Figure Y demonstrates the image capture and email transmission capability of the proposed women safety system. During an emergency event, the ESP32-CAM module automatically captures a photograph of the surrounding environment. The captured image is then attached to an email and transmitted to a predefined email address.

The left side of the figure shows the received email containing the captured image as an attachment, while the right side presents the actual photograph captured by the ESP32-CAM module. The image can be used as digital evidence for future investigation and legal proceedings.

The integration of camera-based monitoring significantly enhances the functionality of the proposed system compared to conventional women safety devices that provide only alert messages. The captured visual information can assist authorities in identifying suspects, understanding the emergency situation and improving response effectiveness. Therefore, the ESP32-CAM module adds an additional layer of security and reliability to the overall safety framework.

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VIII. CONCLUSION

The proposed ESP32-based Women Safety System presents an intelligent and reliable solution for enhancing personal security through the integration of embedded systems and Internet of Things (IoT) technologies. The system combines multiple sensing, monitoring, communication and evidence collection mechanisms within a single platform to provide comprehensive protection during emergency situations. Unlike conventional safety devices that depend primarily on manual intervention, the proposed system incorporates both manual and automatic emergency detection capabilities, thereby improving responsiveness and operational reliability.

The ESP32 microcontroller functions as the central processing unit, continuously monitoring inputs received from the heartbeat sensor, accelerometer, voice recognition module, GPS module and SOS panic button. By analysing physiological and motion-related parameters in real time, the system can identify abnormal conditions such as sudden falls, unusual body movements, elevated stress levels or emergency voice commands. Once a potential threat is detected, the system automatically initiates emergency procedures without requiring user intervention.

The integration of the NEO-6M GPS module enables accurate location tracking, while the SIM800L GSM module ensures reliable transmission of emergency notifications to predefined contacts. The buzzer alarm provides immediate local attention and the ESP32-CAM module enhances security by capturing images that can serve as supporting evidence during investigations. Furthermore, Bluetooth connectivity allows convenient communication with mobile devices for monitoring and control purposes.

Experimental results demonstrate that the system successfully generates emergency alerts for various triggering conditions, including voice activation, panic button activation, fall detection and abnormal heart rate conditions. The system accurately transmits location information and emergency notifications while simultaneously capturing visual evidence. Therefore, the proposed solution effectively overcomes many of the limitations associated with existing women safety systems, such as dependence on smartphones, internet connectivity and manual activation.

Overall, the developed system provides a low-cost, portable, energy-efficient and dependable safety solution capable of delivering rapid emergency response. The integration of intelligent sensing, location tracking, communication and evidence collection significantly enhances user protection and contributes toward creating a safer environment for women in both urban and remote locations.

IX. FUTURE SCOPE

Although the proposed women safety system demonstrates effective performance, several enhancements can be incorporated in future versions to further improve functionality, reliability and user convenience.

One potential enhancement is the development of a dedicated mobile application that enables real-time monitoring, emergency notification management and live location tracking. The application can provide a user-friendly interface for configuring emergency contacts, monitoring device status and reviewing historical emergency records.

Cloud-based connectivity can also be integrated to enable secure storage of sensor data, location information and emergency records. Cloud storage would facilitate remote monitoring and provide access to historical information for analysis and investigation purposes. Additionally, cloud integration can improve scalability and support large-scale deployment of safety devices.

Artificial Intelligence (AI) and Machine Learning (ML) techniques can be incorporated to enhance emergency detection accuracy. By analysing behavioural patterns, physiological signals and environmental conditions, intelligent algorithms can reduce false alarms and improve decision-making capabilities. AI-based models can also predict potential threats before they escalate into dangerous situations.

Voice recognition technology can be further improved to support multiple emergency keywords and natural language commands. This enhancement would allow users to activate emergency functions through speech, particularly in situations where physical interaction with the device is difficult or impossible.

The ESP32-CAM module can be upgraded to support live video streaming instead of static image capture. Real-time video transmission would provide emergency responders and family members with immediate visual information regarding the surrounding environment, enabling faster and more informed decision-making.

Power management techniques can be optimized to extend battery life and improve energy efficiency. Advanced sleep modes, adaptive sensor sampling and intelligent power scheduling can significantly increase operational duration without compromising system performance.

Finally, the hardware architecture can be miniaturized and transformed into wearable formats such as smart bands, pendants, bracelets or smart clothing accessories. A compact wearable design would improve user comfort, portability and continuous accessibility, making the safety system more practical for everyday use.

With these enhancements, the proposed women safety system can evolve into a fully autonomous, intelligent and highly reliable personal security platform capable of providing comprehensive protection and rapid emergency assistance in a wide range of real-world scenarios.

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