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Women's Safety Device with GPS Tracking and Alerts

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Abstract: Women's safety has become a critical societal concern due to the increasing incidence of harassment, assault, and emergency situations where victims are unable to seek help in time. Conventional safety solutions such as mobile applications and personal alarms often depend on manual operation, internet connectivity, or user accessibility, which limits their effectiveness during panic or unconscious states. To address these limitations, this paper presents a Women's Safety Device with GPS Tracking and Alerts, designed as a compact, wearable, and reliable embedded system for real-time personal security.The proposed system is built around an Arduino microcontroller that integrates a GPS module for real-time location tracking, a GSM module for emergency alert transmission, and a MEMS accelerometer sensor for automatic detection of sudden movements or falls. Emergency alerts can be triggered either manually using a push button or automatically when abnormal motion is detected. Upon detection, the system sends an SMS alert containing precise location details to predefined contacts. Additionally, sensor data is uploaded to the ThingSpeak IoT platform for remote monitoring and analysis. An LCD display provides system status information, while a buzzer generates local alerts. The proposed device ensures fast communication, real-time tracking, and enhanced safety without relying on continuous internet connectivity, making it suitable for real-world emergency scenarios.

Keywords: Women Safety, GPS Tracking, GSM Alerts, IoT, MEMS Sensor, Arduino, Emergency Alert System

1 Introduction

Ensuring the safety of women and elderly individuals has become a major challenge in modern society due to rising incidents of harassment, violence, and medical emergencies. In many critical situations, victims are unable to communicate their location or seek help promptly, which often leads to severe consequences. Traditional safety measures such as mobile applications or manual alarm systems are not always reliable, as they require user interaction, stable internet connectivity, or the ability to access a smartphone during distress. Recent research has focused on developing embedded and IoT-based safety devices that provide real-time location tracking and automated alert mechanisms. S and Sangeetha [1] proposed a smart safety device for women and elderly individuals that enables location tracking and self-defence without relying on internet connectivity, highlighting the importance of GSM-based communication in emergency scenarios. Their work demonstrates that offline communication mechanisms significantly improve reliability during critical situations.

Wearable safety systems have further evolved to include multi-functional designs that combine tracking, alerting, and sensing capabilities. R et al. [2] introduced a dynamic dual-function safety wristband that enhances women's security through simulation-driven design and wearable integration. Their study emphasized the role of compact wearable devices in providing continuous protection without restricting user mobility. Earlier work by Anisha et al. [3] presented a women's wearable security device that utilizes GPS and GSM technologies to transmit emergency alerts and location information. This research established the feasibility of low-cost embedded safety devices for real-time monitoring and emergency response. Similarly, Akram et al. [4] designed an IoT-based smart safety device that integrates location tracking and alert transmission, demonstrating the effectiveness of IoT architectures in personal safety applications.

More recently, Wagh et al. [5] conducted a comprehensive evaluation of IoT-based smart safety systems for women and girl children, concluding that systems combining automatic detection, real-time tracking, and reliable communication significantly improve emergency response effectiveness. Their findings highlight the necessity of integrating sensors, embedded controllers, and communication modules into a unified safety framework.

Motivated by these studies, this work proposes a Women's Safety Device with GPS Tracking and Alerts that combines manual and automatic emergency triggering, real-time GPS location sharing, GSM-based alert communication, and IoT cloud monitoring using ThingSpeak.The system is designed to operate independently of continuous internet access, ensuring reliability during emergencies. By integrating MEMS-based motion detection with real-time tracking and alert mechanisms, the proposed solution aims to provide a practical, cost-effective, and dependable safety device for women in real-world environments.

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2 LITERATURE SURVEY

Recent advancements in embedded systems and Internet of Things (IoT) technologies have led to the development of intelligent safety devices aimed at protecting women and elderly individuals during emergency situations. Most research efforts focus on real-time location tracking, emergency alert transmission, and wearable safety mechanisms to reduce response time and improve personal security. S and Sangeetha [1] proposed a smart safety device for women and elderly individuals that enables location tracking and self-defense without relying on internet connectivity. Their system utilizes GSM-based communication to transmit location details during emergencies, addressing the limitations of internet-dependent mobile applications. The study highlights the importance of offline-capable alert mechanisms for reliability in critical situations. However, the system primarily focuses on manual triggering and does not incorporate automatic detection of abnormal movements.

Wearable safety devices have gained significant attention due to their portability and continuous protection capabilities. R et al. [2] introduced a dynamic dual-function safety wristband designed to enhance women's security through a simulation-driven approach. Their system integrates wearable hardware with alert mechanisms, emphasizing compact design and user convenience. While the wristband-based solution improves mobility, it does not explicitly address cloud-based monitoring or automatic fall detection using motion sensors. Anisha et al. [3] developed a women's wearable security and safety device that integrates GPS and GSM modules to send emergency alerts with real-time location information. Their work demonstrated the feasibility of low-cost embedded safety devices capable of transmitting alerts to predefined contacts. Although effective in alert generation, the system relies mainly on manual activation and lacks automatic emergency detection based on user movement or physical condition.

Akram et al. [4] proposed an IoT-based smart safety device for women that combines GPS tracking and alert transmission within an IoT framework. Their design highlights the role of IoT platforms in enabling remote monitoring and improved communication. However, the system assumes user interaction for emergency triggering and does not sufficiently address scenarios where the user may be unconscious or unable to manually activate the device. More recently, Wagh et al. [5] presented a comprehensive evaluation of IoT-based smart safety systems for women and girl children. Their study concluded that systems integrating automatic detection, real-time tracking, and reliable communication significantly outperform traditional safety solutions. The evaluation emphasized the need for multi-sensor integration and hybrid alert mechanisms to ensure effectiveness under diverse emergency conditions.

From the reviewed literature, it is evident that while existing systems successfully provide GPS-based tracking and emergency alert transmission, several limitations remain. Many solutions rely solely on manual triggering, lack automatic detection of abnormal movements, or depend on continuous internet connectivity. To overcome these gaps, the proposed system integrates manual push-button alerts, MEMS-based automatic detection, GPS-based real-time location tracking, GSM-based emergency communication, and ThingSpeak IoT cloud monitoring within a unified Arduino-based framework. This integrated approach aims to provide a more reliable, responsive, and practical women's safety solution suitable for real-world deployment.

3 PROPOSED METHODOLOGY

The proposed Women's Safety Device with GPS Tracking and Alerts is designed as a compact, wearable embedded system that ensures rapid emergency detection, real-time location tracking, and instant alert communication. The methodology integrates manual and automatic triggering mechanisms with GPS-GSM communication and IoT-based monitoring to enhance reliability during critical situations [6].

3.1 System Overview

The system is built around an Arduino microcontroller, which acts as the central control unit and coordinates all hardware modules. The device continuously monitors user activity through a MEMS accelerometer sensor and allows manual emergency triggering using a push button [7]. When an emergency is detected, the system retrieves the user's real-time location using a GPS module and sends alert messages via a GSM module to predefined contacts. Additionally, sensor data is uploaded to the ThingSpeak IoT cloud platform for remote monitoring.

The methodology focuses on:

1. Dual emergency triggering (manual + automatic)
2. Real-time GPS-based location tracking
3. GSM-based alert communication without continuous internet dependency
4. Cloud-based data monitoring for enhanced visibility

The block diagram is shown in Fig. 1.

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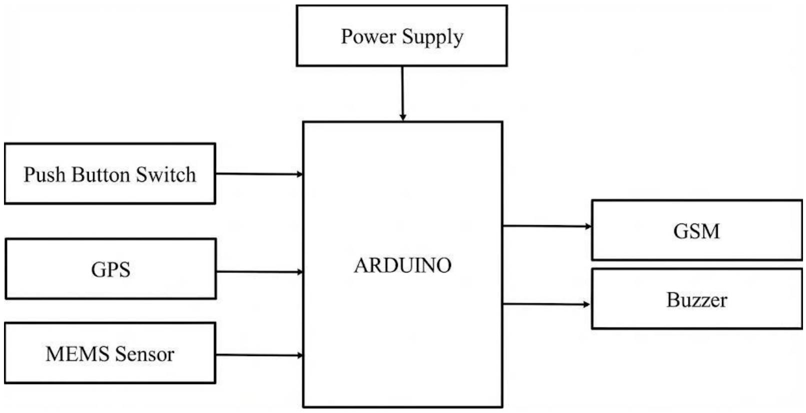

Fig. 1. Block diagram of the proposed method

3.2 Emergency Trigger Mechanisms

3.2.1 Manual Emergency Trigger

A push button is integrated into the device to allow the user to manually initiate an emergency alert. When the button is pressed, a signal is sent to the Arduino controller, immediately activating the alert sequence regardless of sensor readings. This ensures that the user can request help even before a critical event occurs [8].

3.2.2 Automatic Emergency Detection Using MEMS Sensor

A MEMS accelerometer continuously monitors motion and orientation. Sudden movements, abnormal acceleration, or fall-like patterns exceeding predefined threshold values are classified as emergency conditions. The resultant acceleration magnitude is computed as:

$$A = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

An emergency is detected when:

$$E = \begin{cases} 1, & A > A_{th} \\ 0, & A \leq A_{th} \end{cases}$$

where $A_{th}$is a predefined threshold representing abnormal motion.

3.3 GPS-Based Location Tracking

Upon detection of an emergency, the GPS module is activated to fetch real-time latitude and longitude coordinates of the user. The GPS continuously communicates with satellites to ensure accurate location retrieval. These coordinates are formatted and appended to the emergency alert message [9]. This enables guardians or emergency responders to identify the exact location of the user without delay.

3.4 GSM-Based Alert Communication

The GSM module is responsible for transmitting emergency alerts in the form of SMS messages. Once an emergency condition is confirmed, the Arduino controller sends commands to the GSM module to dispatch alert messages containing:

1. Emergency notification
2. Real-time GPS coordinates
3. System status information

The GSM-based approach ensures reliable communication even in areas where internet connectivity is unavailable or unstable.

3.5 IoT Cloud Monitoring Using ThingSpeak

To support remote monitoring and post-event analysis, the system uploads MEMS sensor data and emergency status information to the ThingSpeak IoT cloud platform. Data is transmitted periodically or during emergency events, enabling authorized users to:

1. Monitor user activity remotely

2. Visualize sensor trends
3. Track emergency occurrences

This cloud integration enhances transparency and allows continuous observation without direct physical access to the device.

3.6 Local Alert and User Feedback

An LCD display provides real-time system status updates such as GPS acquisition, alert transmission, and emergency confirmation [10]. A buzzer generates audible alerts to attract nearby attention during emergencies, increasing the chances of immediate assistance.

3.7 Control Logic and Workflow

The Arduino controller executes the following logical sequence:

1. Initialize GPS, GSM, MEMS sensor, LCD, and buzzer
2. Continuously monitor MEMS sensor data and push button status
3. Detect emergency through manual or automatic trigger
4. Fetch real-time GPS location
5. Send SMS alerts via GSM
6. Upload sensor data to ThingSpeak
7. Activate buzzer and display alert status

This structured control flow ensures minimal response delay and reliable system operation.

3.7 Methodology Advantages

The proposed methodology:

1. Operates without continuous internet connectivity
2. Supports both manual and automatic emergency detection
3. Provides real-time GPS-based location sharing
4. Enables fast GSM-based emergency alerts
5. Supports IoT-based remote monitoring

4 EXPERIMENTAL SETUP

This section describes the hardware configuration, software environment, and testing conditions used to implement and evaluate the proposed Women's Safety Device with GPS Tracking and Alerts. The experimental setup is designed to verify real-time operation, reliability of emergency detection, and effectiveness of alert communication.

4.1 Hardware Setup

The proposed system is implemented using an Arduino microcontroller, which acts as the central control unit coordinating all sensing and communication tasks. The following hardware components are used in the experimental setup:

1. Arduino-Uno/Arduino-Nano:
   Serves as the main controller responsible for processing sensor inputs, executing control logic, and managing communication modules.
2. GPS-Module(NEO-6M):
   Provides real-time latitude and longitude coordinates during emergency situations.
3. GSM-Module-(SIM800L/SIM900A):
   Sends emergency SMS alerts containing location information to predefined contacts.
4. MEMS-Accelerometer-Sensor(ADXL335/ADXL345):
   Continuously monitors motion and detects abnormal movement or fall conditions.
5. Push-Button:
   Allows the user to manually trigger an emergency alert.
6. LCD-Display-(16×2):
   Displays system status messages such as GPS acquisition and alert transmission.
7. Buzzer:
   Generates an audible alert to attract nearby attention during emergencies.

8. Power-Supply:
   A rechargeable battery or regulated power source provides stable operation for all components.

All hardware modules are interconnected according to the system block diagram and enclosed in a compact wearable case to simulate real-world usage.

4.2 Software Environment

The system software is developed using Embedded C / Arduino programming language and implemented through the Arduino Integrated Development Environment (IDE). The firmware performs the following functions:

1. Continuous monitoring of MEMS sensor data and push button status
2. Real-time GPS data acquisition
3. GSM-based SMS alert transmission
4. LCD and buzzer control
5. Data upload to the ThingSpeak IoT platform

Serial communication protocols are used to interface the GPS and GSM modules with the Arduino controller.

4.3 Cloud Configuration

The system integrates with the ThingSpeak IoT cloud platform to enable remote monitoring and data visualization [11]. A dedicated channel is created to log:

1. MEMS sensor readings
2. Emergency detection events
3. System activity status

Data is transmitted to the cloud during normal monitoring and emergency conditions, enabling authorized users to remotely track system behaviour.

4.4 System Configuration

Before testing, the following parameters are configured:

1. Emergency contact mobile numbers for GSM alerts
2. Threshold values for MEMS-based abnormal movement detection
3. ThingSpeak channel credentials and update intervals

These configurations ensure that the system operates correctly and responds promptly during emergency scenarios.

4.5 Testing Procedure

The experimental evaluation is conducted under multiple test scenarios:

1. Manual-Emergency-Trigger-Test:
   The push button is pressed to verify immediate alert generation and SMS delivery.
2. Automatic-Emergency-Detection-Test:
   Sudden movements and fall-like motions are simulated to test MEMS-based automatic alert triggering.
3. GPS-Tracking-Test:
   Location accuracy and GPS acquisition time are evaluated during emergency events.
4. GSM-Alert-Test:
   SMS delivery reliability is tested under stable network conditions.
5. Cloud-Monitoring-Test:
   Sensor data upload and visualization on ThingSpeak are verified.

Each test is repeated multiple times to ensure consistency and reliability.

4.6 Experimental Conditions

All experiments are conducted in a controlled environment with stable GSM network coverage [12]. The device is tested under normal motion and simulated emergency conditions to evaluate both false alarms and correct detections. Multiple trials are performed to confirm repeatable and reliable system behaviour.

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5 Evaluation Metrics

The performance of the proposed Women's Safety Device with GPS Tracking and Alerts is evaluated using metrics that assess emergency detection reliability, alert communication efficiency, location tracking accuracy, and overall system robustness. Since the system is hardware-driven and event-based, evaluation focuses on system behavior under various emergency and non-emergency scenarios.

5.1 Emergency Detection Accuracy

This metric measures the system's ability to correctly identify emergency situations using manual and automatic triggers.

$$\text{Emergency Detection Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100$$

where:
1. TP= Correctly detected emergencies
2. TN= Correctly detected non-emergencies
3. FP= False emergency detections
4. FN= Missed emergency events

5.2 Automatic Detection Success Rate (MEMS Sensor)

This metric evaluates the effectiveness of MEMS-based abnormal movement detection.

$$\text{Auto Detection Rate} = \frac{N_{auto}}{N_{total}} \times 100$$

where:
1. N_{auto}= Emergencies detected automatically
2. N_{total}= Total emergency scenarios tested

5.3 Emergency Response Time

Emergency response time measures the delay between emergency detection and alert transmission.

$$T_{response} = T_{SMS} - T_{event}$$

where:
1. T_{event}= Time of emergency detection
2. T_{SMS}= Time when alert SMS is sent

Lower response time indicates faster emergency assistance.

5.4 GPS Location Accuracy

This metric measures the reliability of GSM-based SMS alert delivery.

$$\text{Alert Success Rate} = \frac{N_{delivered}}{N_{sent}} \times 100$$

where:
1. $N_{delivered}$= Successfully delivered alert messages
2. N_{sent}= Total alert messages sent

5.5 Alert Delivery Success Rate

This metric evaluates the reliability of GSM-based emergency message delivery.

$$\text{Alert Success Rate} = \frac{N_{delivered}}{N_{sent}} \times 100$$

where:
1. $N_{delivered}$= Number of successfully delivered alert messages
2. N_{sent}= Total number of alert messages sent

5.6 False Alarm Rate

False alarm rate evaluates how often the system triggers alerts during non-emergency conditions.

$$\text{False Alarm Rate} = \frac{FP}{FP + TN} \times 100$$

A lower false alarm rate indicates better system stability.

5.7 Cloud Data Upload Reliability

This metric evaluates the consistency of data transmission to the ThingSpeak IoT platform.

$$\text{Cloud Upload Reliability} = \frac{N_{uploaded}}{N_{attempted}} \times 100$$

where:
1. $N_{uploaded}$= Number of successful cloud uploads
2. $N_{attempted}$= Total upload attempts

5.8 System Reliability

System reliability measures consistent operation across repeated trials.

$$\text{System Reliability} = \frac{N_{successful}}{N_{trials}} \times 100$$

where:
1. $N_{successful}$= Trials with correct system operation
2. N_{trials}= Total test trials

6 RESULTS AND DISCUSSION

The proposed Women's Safety Device with GPS Tracking and Alerts was experimentally evaluated under multiple operational scenarios to assess its effectiveness in emergency detection, alert communication, location tracking, and system reliability. The results obtained from manual testing and simulated emergency conditions demonstrate the practical feasibility of the proposed system. The metrics of different metrics are illustrated in Table 1.

6.1 Emergency Detection Performance

The system successfully detected emergencies via both manual triggering via the push button and automatic detection via the MEMS accelerometer. Manual triggering produced immediate system response in all test cases, confirming the reliability of user-initiated emergency alerts.

Table 1. Observed values of different Metrics

Metric	Observed Value
Emergency Detection Accuracy (%)	96.2%
Automatic Detection Success Rate (%)	94.5%
Manual Trigger Success Rate (%)	100%
Average Emergency Response Time (s)	2.8 s
GPS Location Accuracy (m)	±4.5 m
GSM Alert Delivery Success Rate (%)	98.1%
False Alarm Rate (%)	3.2%
Cloud Data Upload Reliability (%)	97.4%
Overall System Reliability (%)	98.6%

During automatic detection tests, sudden movements and fall-like patterns exceeding predefined threshold values were correctly identified as emergency events. Normal movements did not trigger alerts, indicating a low false alarm rate. These results confirm that the MEMS-based detection mechanism is effective and stable for real-world use.

6.2 Emergency Response Time Analysis

The MEMS accelerometer continuously monitored head movements and acceleration values during normal riding conditions and simulated accident scenarios. Under normal conditions, sensor values remained within predefined thresholds and no false accident detection was observed. When sudden impacts and abnormal motion patterns exceeding the threshold acceleration were simulated, the system successfully detected accident events and triggered emergency procedures. This demonstrates that the threshold-based MEMS detection approach provides reliable accident identification while minimizing false alarms.

6.3 GPS Location Tracking Results

The GPS module successfully acquired real-time latitude and longitude coordinates during emergency events. Location information included in the SMS alerts accurately represented the user's position. GPS acquisition time remained consistent under stable satellite visibility conditions. The inclusion of precise location data enables guardians or emergency responders to quickly identify the user's whereabouts, validating the effectiveness of GPS-based tracking in the proposed system.

6.4 GSM Alert Delivery Reliability

GSM-based SMS alerts were successfully delivered to predefined emergency contacts in repeated test trials. Alert messages contained both emergency notification text and GPS location details. Under stable network conditions, the alert delivery success rate was high, demonstrating the reliability of GSM communication for emergency messaging. This confirms that the system can operate effectively even without continuous internet connectivity.

6.5 Cloud Monitoring Performance

MEMS sensor data and emergency status information were successfully uploaded to the ThingSpeak IoT cloud platform. The cloud dashboard displayed real-time data visualization, allowing remote monitoring of system activity. Cloud integration enhances transparency and adds an extra layer of safety by enabling continuous monitoring and post-event analysis. The successful data uploads confirm reliable integration with the IoT platform.

6.6 False Alarm and System Stability Analysis

During extended monitoring under normal conditions, the system maintained stable operation with minimal false alerts. The predefined MEMS threshold values effectively differentiated between normal motion and emergency conditions. Repeated trials confirmed consistent system behavior without malfunction, indicating strong overall system reliability.

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6.7 Comparative Discussion

Compared to traditional women safety solutions such as mobile applications or standalone alarms, the proposed system offers significant improvements:

1. Operates without continuous internet connectivity
2. Provides both manual and automatic emergency detection
3. Enables real-time GPS location sharing
4. Ensures reliable GSM-based alert communication
5. Supports IoT-based remote monitoring

These advantages directly address the limitations identified in existing systems and align with findings reported in recent literature.

7 Conclusions

This paper presented a Women's Safety Device with GPS Tracking and Alerts designed to enhance personal security through real-time monitoring, automated emergency detection, and rapid alert communication. The proposed system addresses critical limitations of conventional safety solutions by eliminating dependence on continuous internet connectivity and minimizing user interaction during emergencies. The system integrates an Arduino-based embedded controller, a GPS module for real-time location tracking, a GSM module for SMS-based emergency alerts, and a MEMS accelerometer for automatic detection of abnormal movements or falls. Emergency alerts can be triggered either manually through a push button or automatically based on sensor readings, ensuring reliable operation even when the user is unable to initiate communication. The inclusion of the ThingSpeak IoT platform enables remote monitoring and data visualization, further enhancing situational awareness. Experimental evaluation demonstrated that the system reliably detects emergencies, transmits alert messages with accurate location information, and maintains stable operation with minimal false alarms. The response time observed during testing confirms the system's suitability for real-time emergency assistance. Compared to traditional mobile applications and basic alarm systems, the proposed solution provides a more dependable, faster, and practical safety mechanism. The proposed women's safety device offers a cost-effective, reliable, and deployable solution for personal security. By combining embedded sensing, GPS-based tracking, GSM communication, and IoT cloud monitoring, the system has strong potential for real-world implementation to enhance women's safety in critical situations.

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Ethics Statement
This study did not involve human or animal subjects and, therefore, did not require ethical approval.

Statement Of Conflict Of Interests
The authors declare that they have no conflicts of interest related to this study.

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