RESEARCH PAPER

AIoT-Based Women Safety and Emergency Alert System Using Embedded Technology

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Received: 30th May, 2026; **Revised:** 11th June, 2026; **Accepted:** 15th June, 2026; **Available Online:** 17th June, 2026

ABSTRACT

Background

The increasing number of personal safety incidents and emergency situations has created a strong demand for intelligent and wearable safety systems that can automatically detect distress and immediately notify caregivers or guardians. This project presents an AIoT-Based Women Safety and Emergency Alert System Using Embedded Technology that integrates embedded sensing, local AI-based condition analysis, and real-time IoT communication to provide fast and reliable personal safety assistance.

Materials and Methods

The proposed system is built around the Arduino UNO SMD, which acts as the central control and data acquisition unit. Multiple physiological and motion-related sensors are integrated to continuously monitor the user's physical condition and activity. The MAX30100 sensor is used to measure heart rate and blood oxygen saturation (SpO_2), while a pulse sensor provides additional heart-rate information for validation and reliability. An MPU6050 inertial measurement unit is used to track body movement and orientation in order to identify abnormal motion patterns such as sudden falls, violent movement or prolonged immobility. To support real-time location tracking, a GPS module continuously acquires the geographical coordinates of the user. A GSM800L module is used to transmit emergency alerts and location information to pre-registered contacts through SMS communication. In addition to direct messaging, the system is connected to cloud-based IoT platforms such as Blynk and ThingSpeak to enable remote monitoring of health parameters and user location through a mobile or web interface.

Results

The proposed system employs AI-based decision algorithms running locally on the embedded platform to analyze the incoming multi-sensor data in real time. The algorithm continuously evaluates heart rate variation, SpO_2 trends and motion behaviour to identify potential distress situations such as panic, physical struggle, sudden collapse or abnormal physiological responses. When the detected sensor patterns exceed predefined safety thresholds or match learned distress profiles, the system automatically classifies the situation as an emergency. Once a distress condition is detected, the system immediately triggers an emergency response sequence. An alert message containing the user's current location and health status is transmitted through the GSM800L module, and the same information is simultaneously updated on the connected IoT dashboard. This enables guardians or emergency responders to track the user's location in real time and observe physiological indicators remotely, thereby reducing response time during critical situations.

Conclusion

The key highlights of the proposed system include automatic emergency detection using AI algorithms, continuous physiological monitoring using MAX30100 and pulse sensors, abnormal motion detection using the MPU6050 sensor, real-time location tracking using a GPS module, and instant emergency alert transmission using GSM and IoT platforms. The system is designed to be compact, wearable, low-power and cost-effective, making it suitable for daily personal use. By combining embedded artificial intelligence, multi-sensor data fusion, and IoT-based communication, the proposed AIoT-based women safety and emergency alert system significantly enhances personal security, improves real-time situational awareness, and provides a practical technological solution for reducing emergency response delays and improving women's safety in everyday environments.

Keywords: Women Safety, Emergency Alert, AIoT, Arduino UNO, NodeMCU ESP8266, MAX30100, MPU6050, GPS NEO-6M, GSM800L, Fall Detection, KiwisIoT.

How to cite this article: Gayathri T, Balasubramani M, Sangeetha M, Manoranjani S, Anbumani P, Kanagaprabha CS. AIoT-Based Women Safety and Emergency Alert System Using Embedded Technology. Int J Drug Deliv Technol. 2026;16(60s):1738-1745. DOI: 10.25258/ijddt.16.60s.158

Source of support: Nil.

Conflict of interest: None

I. INTRODUCTION

Ensuring personal safety for women remains a critical societal concern worldwide. According to the **National Crime Records Bureau (NCRB) of India**, crimes against women exceeded **4.45 lakh cases in 2022**, reflecting a rising trend. Globally, reports from **United Nations Women** indicate that one in three women experiences physical or sexual violence during their lifetime. These statistics underscore the urgent need for effective technological solutions that can enhance women's safety and enable rapid emergency response.

Traditional safety tools, such as alarm keychains, GPS trackers, and smartphone applications, generally require **manual activation**. However, in real emergency situations, victims may be physically restrained or under intense psychological stress, which can impair their ability to trigger alerts. Stress-induced physiological changes—such as elevated heart rate, reduced motor control, and impaired decision-making—further limit the effectiveness of manual devices.

To overcome these limitations, modern safety systems must incorporate **autonomous distress detection**. By continuously monitoring physiological signals and motion patterns, wearable devices can identify potential danger even when the user cannot manually request help. The integration of **Artificial Intelligence (AI)** with the **Internet of Things (IoT)**, referred to as AIoT, provides an effective platform to develop such intelligent and proactive safety solutions.

This research proposes an **AIoT-Based Women Safety and Emergency Alert System** that integrates multiple sensors, edge-based processing, and real-time communication technologies. A dual-microcontroller architecture is employed, where an **Arduino UNO** handles sensor data acquisition and distress classification, while a **NodeMCU ESP8266** manages GPS tracking, GSM-based SMS alerts, and IoT dashboard updates. The system continuously monitors heart rate, blood oxygen levels, motion patterns, and fall events, while allowing manual SOS activation through a push button.

By combining physiological monitoring, motion detection, GPS tracking, and IoT communication, the proposed system can automatically identify emergency situations and notify guardians within seconds, improving the effectiveness and reliability of personal safety solutions for women.

II. LITERATURE SURVEY

Several technological solutions have been developed to enhance women's safety using embedded systems, wearable devices, and IoT-based monitoring. These systems primarily focus on **location tracking, emergency alerts, and sensor-based distress detection**.

Pooja et al. (2018) developed a women safety device using **Arduino, GPS, and GSM modules**. The system sends an emergency SMS containing the user's GPS coordinates when a panic button is pressed. While effective in sending location-based alerts, the system relies entirely on **manual activation**, which may not be feasible if the user is unable to operate the device during a real emergency.

Pavithra et al. (2018) proposed a **wearable safety armband** integrating **pulse sensors, vibration sensors, GPS, GSM, and a camera module**. The device monitors physiological signals and body movements to detect abnormal conditions, automatically sending alerts to registered contacts. Although it improved automatic distress detection, the system's dependence on multiple hardware components increased complexity and cost, making large-scale adoption challenging.

Sindhu Bala et al. (2018) surveyed IoT-based women safety systems and emphasized the need for **sensor-based automatic distress detection**. Parameters such as heart rate, body movement, sound signals, and GPS location were identified as key indicators for emergency situations.

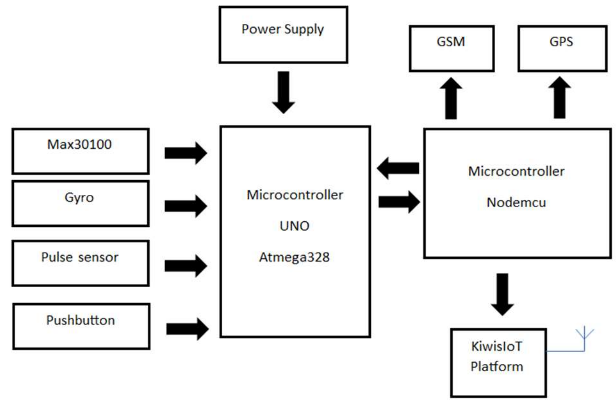
Other GPS-GSM-based safety devices allow users to send alerts manually along with location information. While they facilitate rapid assistance, these systems often suffer from limitations such as **single-parameter detection**, lack of autonomous distress recognition, and absence of real-time monitoring dashboards.

Recent advancements have explored **IoT-enabled smart safety devices** that continuously monitor physiological conditions and motion patterns to trigger automatic alerts. However, many existing systems either rely on a **single sensor**, require **manual intervention**, or **lack cloud-based monitoring**, which limits their reliability and effectiveness.

The literature indicates a clear need for a **low-cost, wearable, multi-sensor system** that combines **autonomous distress detection, real-time GPS tracking, SMS alerts, and IoT dashboard monitoring**. This need forms the basis of the proposed **AIoT-Based Women Safety and Emergency Alert System**, which addresses the limitations of existing solutions by integrating multiple sensors, edge processing, and reliable communication channels.

III. PROPOSED SYSTEM

The proposed system is an **AIoT-Based Women Safety and Emergency Alert System** designed to provide fast, reliable, and automated emergency assistance. It integrates multiple sensors, embedded controllers, and communication modules to continuously monitor a user's physiological condition and motion patterns, enabling real-time detection of emergency situations.



A. System Overview

The system employs a **dual-microcontroller architecture** to enhance processing efficiency and reliability.

1. **Arduino UNO** – Serves as the primary controller responsible for:
   - Acquiring data from sensors such as **MAX30100 pulse oximeter**, **analog pulse sensor**, and **MPU6050 accelerometer/gyroscope**.
   - Performing **real-time distress classification** using a lightweight rule-based AI algorithm based on physiological and motion parameters.
2. **NodeMCU ESP8266** – Functions as the IoT communication gateway, responsible for:
   - Retrieving GPS coordinates using the **NEO-6M GPS module**.
   - Sending **emergency SMS alerts** containing location and health data via the **GSM800L module**.
   - Publishing real-time data to the **KiwisIoT dashboard** for remote monitoring.

B. Sensor Integration

- **MAX30100 Pulse Oximeter** – Continuously measures heart rate and blood oxygen saturation (SpO_2) to detect stress or abnormal physiological conditions.
- **Analog Pulse Sensor** – Provides heart-rate verification for improved reliability.

- **MPU6050 Accelerometer & Gyroscope** – Detects sudden falls, abnormal motion patterns, and violent movements.
- **Manual SOS Push Button** – Allows the user to manually trigger an emergency alert when needed.

C. Distress Detection

The Arduino UNO processes incoming sensor data using predefined thresholds and a rule-based decision algorithm. Abnormal conditions are classified into:

- **Emergency State** – Immediate alert triggered.
- **Caution State** – Monitored for further changes.
- **Normal State** – No action required.

Physiological indicators (high heart rate, low SpO_2) combined with abnormal motion patterns (falls, rapid movements) enable **automatic detection** of distress situations without relying solely on manual intervention.

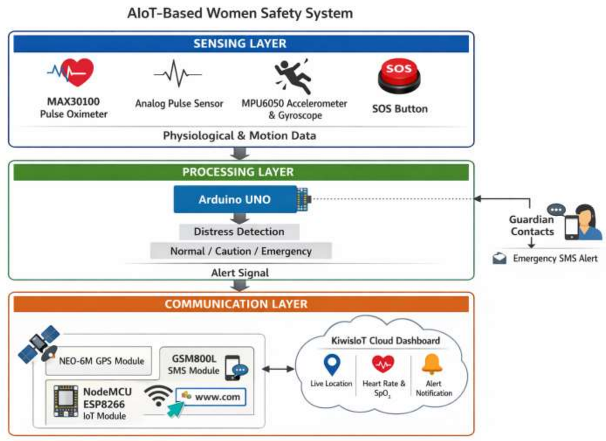
D. Communication Mechanism

Upon detection of distress, the Arduino sends an alert to the NodeMCU, which performs the following actions simultaneously:

1. Acquires **GPS coordinates** of the user.
2. Sends an **emergency SMS** to predefined guardians containing location and health data.
3. Updates the **IoT dashboard** for continuous remote monitoring.

IV. SYSTEM ARCHITECTURE

The **AIoT-Based Women Safety and Emergency Alert System** follows a **dual-microcontroller layered architecture** designed to ensure efficient data acquisition, intelligent distress detection, and fast emergency communication. The system is divided into three major layers: **Sensing Layer, Processing Layer, and Communication Layer**.



4.1 Sensing Layer

The sensing layer is responsible for continuously monitoring the user's **physiological signals** and **body motion**. Multiple sensors are integrated to capture diverse indicators of potential distress:

- **MAX30100 Pulse Oximeter Sensor** – Measures **heart rate** and **blood oxygen saturation (SpO_2)** to detect stress or abnormal health conditions.
- **Analog Pulse Sensor** – Provides **verification** of heart rate readings for enhanced reliability.
- **MPU6050 Accelerometer and Gyroscope** – Detects **sudden falls, abnormal movements, or violent motion patterns**.
- **Manual SOS Push Button** – Allows instant emergency alert activation by the user.

The use of multiple sensors ensures **redundancy** and **improved accuracy** in distress detection.

4.2 Processing Layer

The **Arduino UNO** serves as the primary processing unit:

- Continuously collects data from all sensors.
- Processes physiological and motion data using a **rule-based AI algorithm**.
- Classifies the user's state as **Normal**, **Caution**, or **Emergency**.
- Generates an alert signal when distress is detected, which is sent to the **NodeMCU ESP8266** for further action.

This separation of sensing and processing tasks allows **real-time decision-making** without communication delays.

4.3 Communication Layer

The **NodeMCU ESP8266** acts as an **IoT gateway** responsible for transmitting alerts and enabling remote monitoring:

1. Retrieves the user's **GPS location** via the **NEO-6M GPS module**.
2. Sends an **emergency SMS** containing location and health data to predefined guardian contacts through the **GSM800L module**.
3. Updates the user's **health parameters and location** on the **KiwisIoT cloud dashboard** for real-time monitoring.

The communication layer ensures **reliable alert delivery**, even in areas with no internet access, using GSM-based messaging.

4.4 System Workflow

The overall workflow of the proposed system can be summarized as follows:

1. Sensors continuously collect physiological and motion data.
2. The Arduino UNO analyzes the data and detects abnormal conditions.
3. If distress is detected or the SOS button is pressed, an alert signal is sent to NodeMCU.
4. NodeMCU retrieves **GPS coordinates**.
5. Emergency **SMS alerts** are sent to guardians.
6. Real-time data is updated on the **IoT dashboard** for remote monitoring.

This layered architecture ensures **fast emergency response**, **accurate distress detection**, and **continuous monitoring**, making the system a practical and reliable wearable safety device for women.

V. RESULTS AND DISCUSSION

The proposed **AIoT-Based Women Safety and Emergency Alert System** was implemented and tested in controlled environments to evaluate its **distress detection accuracy, alert delivery performance, and power consumption**.

5.1 Experimental Setup

Experiments were conducted using **10 volunteer participants** aged 20–45 years in both indoor and outdoor environments. The system's performance was evaluated under three primary scenarios:

1. **Simulated Fall Events** – Participants intentionally simulated falls to test MPU6050-based detection.
2. **Simulated Struggle Events** – Rapid and irregular arm movements were performed to mimic a struggle.
3. **Physiological Stress Conditions** – Mild physical activity and breath control were used to create elevated heart rate and temporary oxygen variations.

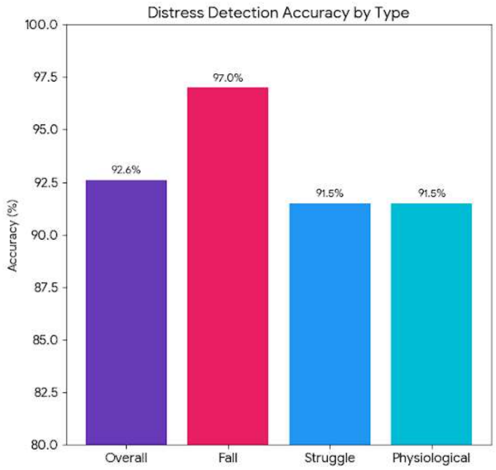
Normal daily activities such as walking, jogging, and typing were also performed to assess **false alarm rates**.

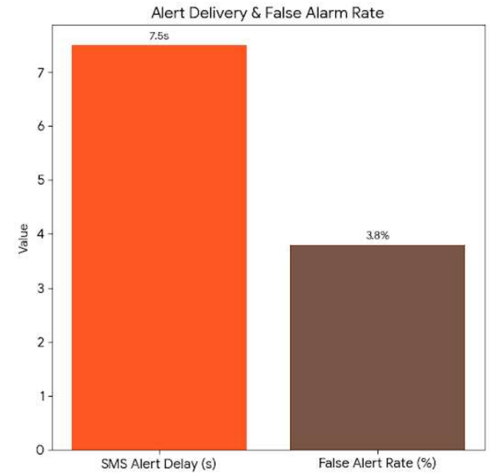
5.2 Distress Detection Performance

The system demonstrated **high accuracy in multi-parameter distress detection**:

- **Overall distress detection accuracy:** 92.6%
- **Fall detection (MPU6050):** 97%
- **Struggle detection:** 91.5%
- **Physiological distress detection (HR & SpO_2):** 91.5%

The **false alert rate** during normal activities was approximately **3.8%**, mainly caused by vigorous exercise simulating distress patterns. The **multi-sensor approach** significantly reduced false alarms compared to single-parameter systems.

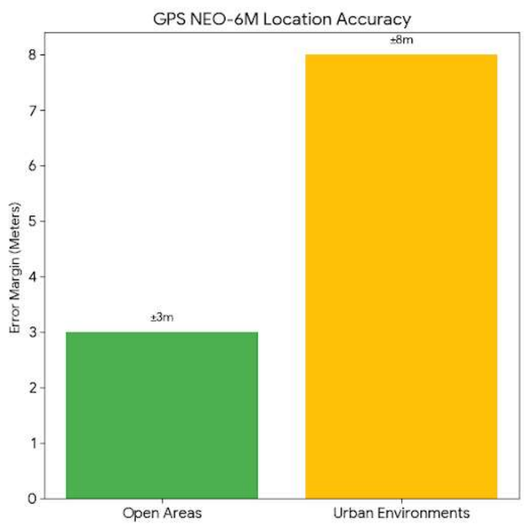




5.3 Alert Delivery Performance

Emergency alerts were evaluated for **timeliness and accuracy**:

- **SMS delivery time (GSM800L):** 7–8 seconds on average after distress detection.
- **GPS NEO-6M location accuracy:** ±3 meters in open areas; slightly lower in urban environments.
- Alerts included a **Google Maps link** for precise location tracking.



The NodeMCU successfully transmitted alerts to guardians and updated the **KiwisIoT dashboard** for real-time monitoring.

5.4 System Power Consumption

The total system consumed approximately **1.8 W** during active operation. Using a **2000 mAh LiPo battery**, the device operated continuously for **6–7 hours**, making it suitable for **wearable daily usage**.

5.5 Discussion

The experimental results confirm that the proposed system provides **reliable, multi-parameter distress detection** and **fast emergency communication**. Key observations include:

- **Automatic detection:** Physiological and motion sensors enabled emergency recognition without manual intervention.
- **Reduced false alarms:** The combination of heart rate, SpO_2, and motion data minimized erroneous alerts.
- **Fast response:** SMS delivery within 8 seconds ensures timely guardian notification.
- **Internet-independent alerts:** GSM-based messaging ensures functionality even in areas with no Wi-Fi.
- **IoT monitoring:** The KiwisIoT dashboard provides continuous remote tracking of location and vital signs.

Compared to existing manual or single-sensor safety devices, the proposed system is **low-cost, wearable, and highly reliable**, making it suitable for practical deployment in real-world scenarios.

VI. CONCLUSION

This paper presented the design and implementation of an **AIoT-Based Women Safety and Emergency Alert System** that combines embedded technology, multi-sensor monitoring, and IoT communication to enhance personal safety for women. The proposed system integrates a **dual-microcontroller architecture**, where the **Arduino UNO** performs real-time physiological and motion data acquisition with rule-based distress classification, while the **NodeMCU ESP8266** handles GPS location tracking, GSM-based SMS alerts, and cloud-based monitoring through the **KiwisIoT dashboard**.

Experimental results demonstrated an overall **distress detection accuracy of 92.6%**, a false alert rate of **3.8%**, and **SMS alert delivery within 7–8 seconds**. The GPS module provided accurate real-time location, and the device's **power consumption of 1.8 W** allowed wearable operation for 6–7 hours using a **2000 mAh LiPo battery**. The low hardware cost of approximately **₹2,200 (USD 26)** makes the solution both **affordable and practical** for real-world deployment.

By combining **multi-parameter monitoring, autonomous distress detection, and real-time emergency communication**, the system addresses the limitations of traditional manual safety devices and offers a reliable, wearable solution for women's safety.

Future work may include:

- Implementing machine learning-based distress classification for improved accuracy.
- Optimizing power consumption to extend battery life.
- Developing a companion mobile application for enhanced guardian notification and system control.

The proposed AIoT wearable demonstrates strong potential as a **low-cost, intelligent, and efficient personal safety device**, capable of providing rapid emergency assistance in critical situations.

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