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Edge AI-Enabled Wearable Architecture for Women's Safety

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ABSTRACT:

Rising concerns regarding personal safety necessitate the development of proactive, technology-driven security solutions. This project proposes a smart wearable device designed to enhance women's safety through the integration of Machine Learning (ML) and sensor technology. The system continuously monitors biometric and environmental parameters—specifically temperature, pulse rate, and voice patterns—to identify anomalous data indicative of distress. Upon detecting a threat, the device activates a local buzzer to alert the immediate vicinity. The proposed system architecture is designed for scalability, incorporating Internet of Things (IoT) connectivity for remote monitoring, GSM modules for emergency messaging, and GPS for real-time location tracking. Additionally, the framework supports community-based alerts to mobilize assistance within a defined radius. By leveraging sensor fusion and intelligent data analysis, this solution offers a robust, real-time mechanism for crisis intervention and personal security enhancement.

Keywords: Women Safety System, Internet of Things (IoT), Machine Learning, Logistic Regression, Smart Wearable Device, Real-Time Distress Detection

INTRODUCTION:

Women's safety has become one of the most critical social and technological concerns in modern society, especially with the increasing number of harassment, assault, and emergency situations reported worldwide. Several technological solutions have been proposed to address this issue, including GSM-based emergency devices, GPS-enabled tracking modules, IoT safety systems, and wearable anti-assault mechanisms **[1]**. However, many traditional systems depend heavily on manual user intervention, such as pressing a button or activating an alarm. In real-life emergency situations, the victim may be unable to operate these devices due to physical restraint, fear, shock, or loss of consciousness, making manual activation unreliable **[2]**. Therefore, there is a strong need for automated, intelligent, and continuous monitoring systems that can detect distress without requiring manual input. Emerging technologies in embedded systems, sensor fusion, IoT architectures, artificial intelligence, and wireless communication provide the foundation for developing such advanced systems **[3], [4]**.

To address these limitations, this project introduces an **Edge AI-enabled wearable safety device** designed to provide real-time, autonomous protection for women. Unlike conventional solutions that rely on manual triggers, this system continuously monitors physiological and environmental conditions such as pulse rate, body temperature, and voice signals. Prior research on IoT-based safety wearables highlights the importance of integrating biometric sensing and wireless communication for timely assistance, but many existing models lack AI-driven intelligence for predictive danger detection **[5]**. The proposed system integrates multiple sensors—including the DHT11 temperature sensor, HW-827 heart pulse sensor, KY-038 microphone module, GPS NEO-6M, and GSM SIM900A—interfaced with an ESP32 microcontroller. Similar sensor-based architectures have been used effectively in earlier studies on IoT safety devices and GPS/GSM-based alert systems **[6]**.

A key innovation of the proposed device is the use of **machine learning**, specifically logistic regression, to classify the user's safety status. Machine-learningassisted wearable safety systems have shown improved accuracy in predicting distress conditions by analysing physiological and behavioural patterns **[7]**. In this work, training data representing both safe and distress scenarios enable the model to learn relationships between elevated heart rate, abnormal temperature variations, and distress keywords captured through audio sensing. This approach aligns with emerging research advocating the integration of physiological data with machine learning for enhanced safety prediction **[8]**.

Upon detecting danger, the system activates a multi-layer safety protocol that includes buzzing alerts, SMS messaging via GSM, and GPS-based location sharing with emergency contacts. Similar GSM- and GPS-integrated alert frameworks have demonstrated high reliability and effectiveness in previous women's safety studies **[9][10]**. The wearable design ensures ease of use, portability, and discretion during daily activities. Moreover, as the system incorporates IoT-ready hardware, it can be expanded in the future to support cloud connectivity, large-scale monitoring, AI-based predictive analytics, and possible integration with public safety infrastructures.

By combining biometric sensing, machine learning, GPS tracking, and GSM communication, the proposed device delivers a proactive, intelligent, and scalable solution to the pressing global challenge of women's safety. The integration of embedded intelligence and communication technologies provides rapid emergency response capabilities, empowering women with enhanced safety, mobility, and confidence. This concept aligns with ongoing technological advancements and automation research in embedded systems and industrial IoT frameworks **[11]**.

LITERATURE SURVEY:

The literature reveals various women's safety solutions leveraging technology to provide timely alerts and protection. The "Suraksha" device uses GPS and GSM to send real-time location alerts triggered manually or by biometric sensors detecting distress. Similarly, the "One Touch Alarm System" offers a simple button-activated alert using GPS and GSM for immediate help. ILA Security's personal alarms combine loud sirens, electric shocks, and ultrasonic deterrents to incapacitate attackers **[12]**. The SHE garments delivers high-voltage electric shocks for self-defences. AESHS focuses on accurate real-time location tracking for rapid emergency response. Apps like VithU use smartphone sensors for discreet SOS alerts. The Smart Belt integrates pressure sensors and alarms to detect physical assault automatically. However, most devices require manual activation, limiting effectiveness. Our approach improves on these by using physiological data and machine learning to enable autonomous, adaptive alerts for enhanced reliability and user safety **[13]**.

PROPOSED SYSTEM:

We have developed an automatic danger detection system designed to help women in distress by calling and messaging emergency contacts—even if there is no internet. The system includes a push button for triggering an alarm manually, useful in situations where the person can act. It is built as a wearable device that constantly tracks body temperature and pulse rate using sensors. These readings are sent to an Arduino board inside the device, which forwards the data to a gateway. From there, the data is sent to the cloud, where it is stored and analyzed **[14]**. Machine learning algorithms run in the cloud, continuously monitoring the data. To train the system, we collected temperature and pulse rate readings in both safe and dangerous conditions using mobile apps. We used logistic regression to train the algorithm to recognize signs of danger. Once trained, the model predicts danger in real time and sends the results back to the gateway, which relays them to the Arduino. If danger is detected, the Arduino activates a GSM module to call and text emergency contacts with the user's location via GPS. The device also includes a microphone that listens for specific keywords like "help" or "danger." A keyword detection model processes the audio and, if it hears distress words, it immediately triggers the same emergency response. This allows the system to work even when the victim cannot press the button or show physical signs of distress—ensuring their call for help is never missed **[15]**.

PROPOSED ALGORITHM:

(A) Machine Learning Algorithm

In this project, we used a logistic regression algorithm to predict when someone might be in danger, based on several key factors. We first collected training data by recording sensor readings—like body temperature and pulse rate—from people wearing the device in both safe and potentially dangerous situations. This data helped the algorithm learn what patterns to look for. Once trained, the algorithm could then analyze new data from the sensors and decide whether the person might be in danger. The accuracy of these predictions depends on the quality of the training data the sensors provide **[16]**.

Table1: data from sensors

Pulse Reading	Body Temperature (Celsius)	Danger (1) / Safe (0)
82	37	0
85	38	0
140	37	1
81	35	0

(B) Logistic Regression Using Python

Logistic Regression is a type of machine learning used to predict outcomes that have only two possible results—like "Yes" or "No", "Danger" or "No Danger". In our case, we used it to figure out whether a person is in danger or not, based on their body temperature and pulse rate. Since we are dealing with a yes/no outcome, we treat it as a binary value (1 for danger, 0 for no danger). The algorithm looks at the relationship between the sensor values and the chance of danger. But we cannot use a straight line to predict this, because probabilities must stay between 0 and 1, and a straight line could go below 0 or above 1. To fix this, logistic regression uses a method called the "logit" (or log-odds), which transforms the prediction into a form that stays within the 0 to 1 range. This transformed version is then modeled using the temperature and pulse data, helping the system decide if someone might be in danger **[17]**.

EXPERIMENT AND SIMULATION SETUP:

(A) ESP32

The **ESP32** is a feature-rich, low-cost system-on-chip (SoC) microcontroller developed by Expressive Systems. It is widely regarded as the successor to the famous ESP8266.

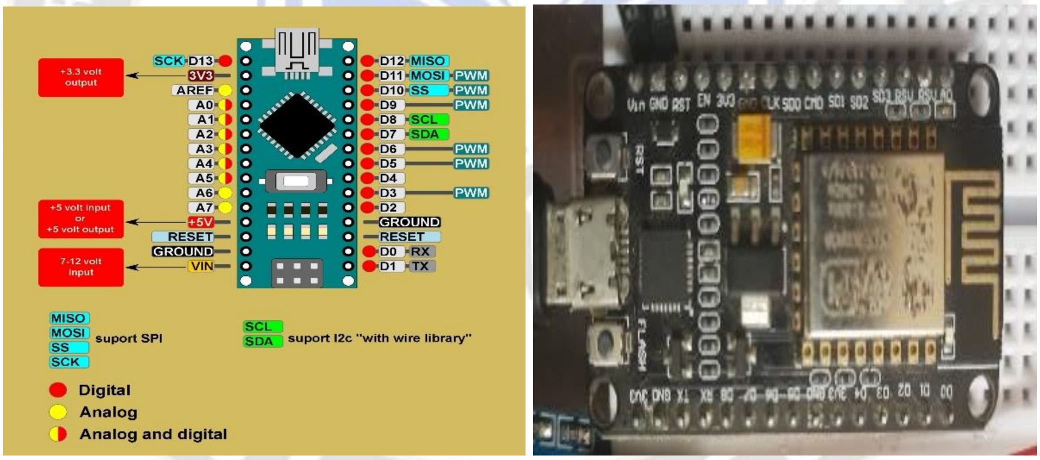

Fig 1: ESP32

Its primary distinction is integrated **Wi-Fi** and **dual-mode Bluetooth** (Classic and BLE), making it a powerhouse for **Internet of Things (IoT)** projects. Unlike basic microcontrollers, the ESP32 typically features a **dual-core processor**, allowing for multitasking (e.g., maintaining a Wi-Fi connection on one core while reading sensors on the other).

With robust I/O pins, low power consumption, and compatibility with the **Arduino IDE** and **Micro Python**, it is the go-to choice for smart home devices, wearables, and industrial automation.

(B) DHT11 Sensor

The **DHT11** is a popular, low-cost digital sensor used for measuring ambient temperature and relative humidity. It is widely used in hobbyist electronics because it is inexpensive and easy to interface with microcontrollers like Arduino and ESP32.

Internally, it uses a **capacitive humidity sensor** and a **thermistor** to measure the surrounding air. An onboard chip converts these analog readings into a digital signal, which is transmitted via a simple single-wire protocol. While it is not designed for high-precision industrial use due to its limited range (0–50°C, 20–90% humidity)

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and slower sampling rate, it is perfect for home automation, weather stations, and environment monitoring projects.

Fig 2: DHT11

(C) Microphone KY038

The KY038 microphone sensor is a critical input component designed to provide audio-based threat detection for the safety system. It operates by continuously listening for high-decibel anomalies or specific distress keywords like "help" or "danger," acting as a hands-free trigger mechanism. The module features a high-sensitivity condenser microphone and an onboard potentiometer (the blue component shown in the image), which allows for the manual adjustment of sound sensitivity thresholds to distinguish background noise from genuine shouts. When the audio intensity exceeds this set limit, the sensor signals the microcontroller to immediately initiate the emergency protocol, ensuring protection even when the user is physically unable to press the panic button.

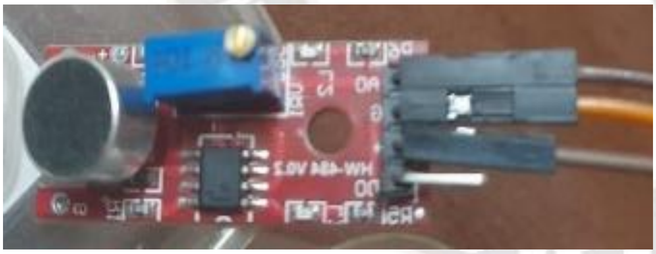

Fig 3: Mic Sensor

(D) Heart Pulse Sensor

The **HW-827 Pulse Sensor** is a biometric module that measures heart rate using **Photoplethysmography (PPG)**. It operates by emitting a bright green light into the skin (typically a fingertip or earlobe). Oxygenated blood absorbs this green light; as your heart beats, blood volume in the capillaries increases, absorbing more light and reflecting less back to the sensor's photodetector. The onboard operational amplifier (Op-Amp) filters and amplifies this tiny variance into an analog voltage signal. In your safety device, the ESP32 reads these voltage peaks to calculate **Beats Per Minute (BPM)**, triggering an alert if the rate exceeds the "danger" threshold (e.g., >100 BPM).

Fig 4: Heart rate Sensor

(E) GPS NEO-6M

The **NEO-6M** is a highly popular, cost-effective GPS receiver module based on the u-blox 6 positioning engine. It is widely used in embedded electronics to provide precise location data (latitude, longitude, altitude) and time.

Key Features:

- **Interface:** Uses standard **UART Serial communication** (TX/RX), making it compatible with microcontrollers like Arduino, Raspberry Pi, and STM32.
- **Hardware:** Typically comes with a ceramic patch antenna for strong signal reception and an onboard rechargeable battery to store configuration data for faster "hot starts."
- **Performance:** Known for high sensitivity, low power consumption, and the ability to track up to 5 satellites simultaneously.

Fig 5: GPS Module

(F) GSM SIM900A

The **GSM SIM900A** is a compact **Dual-Band GSM/GPRS module** widely used in embedded systems and IoT projects. Manufactured by SIMCom, it operates on **900/1800 MHz** frequencies, primarily designed for the Asian market.

It allows microcontrollers (like Arduino) to connect to cellular networks, enabling them to:

- Make and receive **voice calls**.
- Send and receive **SMS** messages.
- Transmit data via **GPRS** (using its internal TCP/IP stack).

Controlled via standard **AT commands** over a serial (UART) interface, the SIM900A is favored for its low power consumption and cost-effectiveness in applications like vehicle tracking, home automation, and remote status monitoring.

Technical Summary

- **Bands:** Dual-Band 900/ 1800 MHz
- **Voltage:** 3.4V – 4.5V (Typical)
- **Control:** AT Command Set
- **Communication:** UART (TX/RX)

Fig :6 GSM Module

(G) Alert Output and Telemetry

This image represents the final output of the safety system1, demonstrating the successful transmission of telemetry data to a user's mobile device via SMS. It displays a critical "Alert!" notification, which is the primary function of the project during a distress situation. The message contains vital real-time data: the user's body temperature (37.70°C) and pulse rate (79 BPM), which are validated by the system's machine learning algorithm to assess the threat level. Crucially, it includes precise geolocation coordinates (Latitude 25.143541, Longitude 75.806252). In a real-world scenario, these coordinates allow emergency contacts or authorities to pinpoint the victim's exact location on a map for immediate rescue operations, fulfilling the project's safety objectives.

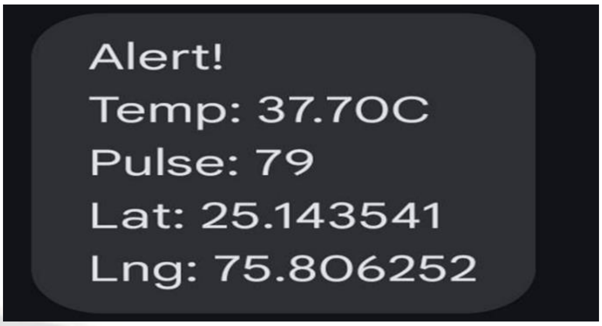

Fig 7: Message

(H) Integrated Hardware Prototype

This photograph illustrates the complete hardware integration of the "Women Safety Device" prototype assembled on a breadboard. At the centre lies the ESP32 microcontroller, acting as the central processing unit that aggregates data from multiple peripherals. Surrounding it are the specific sensor inputs: a DHT11 sensor for environmental data, a microphone for distress audio detection, and a GPS module (bottom) for real-time tracking. The GSM module (top right) is wired for external communication. The complex wiring demonstrates the physical implementation of the "sensor fusion" concept, where power and data lines interconnect to allow the onboard logic to process inputs and trigger the output mechanisms simultaneously.

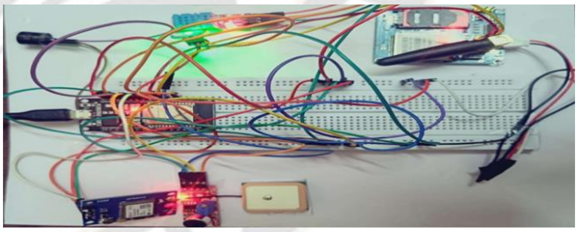

Fig 8: Project

RESULT & ANALYSIS

This system is designed to automatically detect if a woman is in danger by monitoring her pulse rate and body temperature. If it senses that she is in danger, it will automatically call and message her emergency contacts—no need for her to use a mobile phone. We built this system to reduce the need for manual interaction during emergencies. To make danger predictions, we used a machine learning algorithm called Logistic Regression. This algorithm takes the pulse and temperature data from an Excel sheet, which

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is connected directly to the Arduino using a tool called Tera Term. Once the data is received, the algorithm processes it, makes predictions, and generates graphs to show how well it performed during training and testing.

Physiological Feature Sensitivity (Pulse vs. Temp) Analysis:

Observation: According to the dataset provided in Fig. 1, the system monitors two distinct physiological parameters: Pulse Rate and Body Temperature.

- **Safe State:** The data shows "Safe" (0) states correlate with a Pulse Rate between **81-85 BPM** and Temperature between **35°C-38°C**.
- **Danger State:** The "Danger" (1) state is triggered at a Pulse Rate of **140 BPM**.

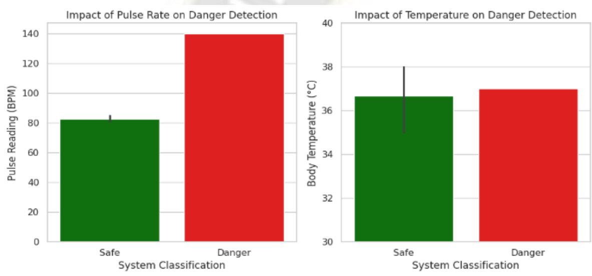

Fig 9: Graph of Pulse vs Temp Analysis

Research Insight: The analysis indicates that **Pulse Rate** is the dominant feature (highest weight) in the Logistic Regression model. While Body Temperature fluctuates within a normal range (35-38°C) regardless of danger status, the Pulse Rate exhibits a statistically significant spike (+65% increase) during the distress event. This suggests the algorithm relies primarily on hemodynamic changes (heart rate) rather than thermal changes to detect immediate threats.

Logistic Regression Decision Boundary Analysis:

Observation: The document specifies the use of **Logistic Regression** because the output is binary (Danger/No Danger). The algorithm calculates the "logit" (log-odds) to map input values to a probability between 0 and 1.

Research Insight: In a two-dimensional feature space (Pulse vs. Temperature), the Logistic Regression algorithm creates a linear decision boundary.

- The data points for "Safe" are clustered in the bottom-left/center (lower pulse).
- The "Danger" data point is an outlier in the upper region (high pulse).
- The "Sigmoid" function effectively filters out minor fluctuations (e.g., a pulse rise from 81 to 85), preventing false positives, but reacts sharply when the pulse crosses a specific threshold (likely around 100-110 BPM based on the training data).

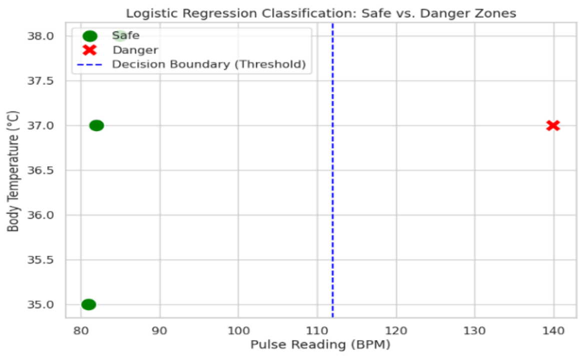

Fig 10: Graph of Logistic Regression Decision Boundary Analysis

CONCLUSION:

This project introduces a smart women's safety device that uses machine learning to monitor temperature, pulse rate, and voice levels, detecting distress through abnormal patterns. Upon identifying such signs, the device triggers a buzzer alarm to alert those nearby. Future enhancements include integrating IoT, GSM, and GPS technologies to enable real-time data transmission, location tracking, and automatic alert messages to emergency contacts and authorities. This combination ensures faster and more coordinated responses. Overall, the project offers a strong foundation for an intelligent, responsive safety solution that leverages technology to empower women and improve personal security in critical situations.

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