

WOMEXA – A Wearable Technology for Women’s Protection: An Intelligence Emergency Response System

**Rohitashwa Pal Das, Ananya Roy, Indranil Paul,
Sankhadeep Bhowmik, Susovan Singha Roy,
Somsubhra Gupta**

Department of Computer Science and Engineering
Swami Vivekananda University

Barrackpore, North 24 Parganas, West Bengal -700121

Corresponding Author email IDs: gsomsubhra@gmail.com /
rohit090505pal@gmail.com

Abstract:

The world is alive to talk of indispensable measures in the interest of women’s safety. This paper proposes a wearable device that can ensure the safety of women by relating unusual geste or pitfalls and driving an exigency response per se. The proposed automatic device uses intelligent detectors, machine literacy, and real- time communication for the nonstop monitoring of heart rate, body temperature, abnormal movements, or distress sounds.

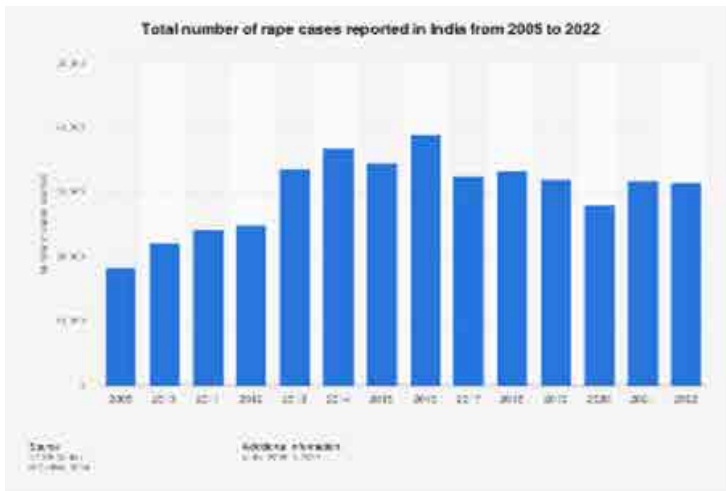
It sends the emergency signal, along with the real- time location of the nearest police station, in case the device detects some abnormalities. The design is simple and, besides, makes provision for good wearability and comfort for day- to- day use. Its long battery life enables storehouse of the stoner’s information safely.

The tests show that it needs similar effectiveness for peril signaling in confluence with a affiliated exigency response structure. The paper illustrates how wearable technology will fill the gap in furnishing safety and tone- defense for women.

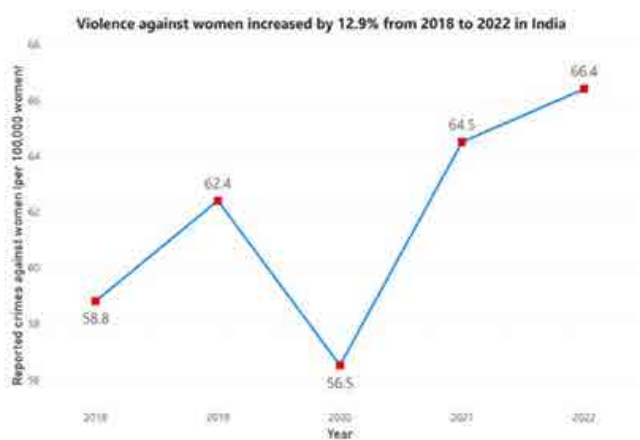
Keywords: Wearable technology, Women’s safety, Emergency response, Intelligent sensors, Machine learning.

Introduction:

Women's safety has become a growing concern in recent years, owing to an increase in harassment and assault. Despite advances in social and technological domains, the streets and public areas remain dangerous for women, with numerous incidences of assault, abuse, and violence reported daily. These harsh realities underline the crucial need for novel solutions that not only deter such crimes, but also provide prompt assistance to women in distress.



In India, protecting women from harassment and criminality on the streets and roadways is crucial due to current socioeconomic issues. Women are still being assaulted, abused, threatened, slain, and taken in large groups without a fair chance. Immediate help and improved security for women require innovative and viable solutions.



This study describes an ongoing initiative to create an intelligent wearable gadget that protects women in adverse situations. The device automatically records video footage of incidents and transmits it to the nearest police station for prompt response. The device not only calls the woman’s emergency contacts, but also broadcasts her real-time location and emits a loud 100-db alarm to warn others to help her.

This project takes advantage of developments in Bluetooth connectivity, real-time GPS tracking, and cloud-based communication to provide a comprehensive safety solution. The device integrates smoothly with a smartphone app, guaranteeing that assistance is only a button click away. It also includes automated protocols to promote accountability among law enforcement authorities and enable speedy responses.

The program aims to increase the protection of women and children while also raising awareness about the importance of proactive preventive actions against such crimes. In this paper, we will provide a technical overview, operating processes, and the broader significance of this wearable gadget in improving women’s safety. This effort is a step

toward creating a safe and empowered atmosphere in which women can access public spaces without fear.

Literature Review:

The emergence of wearable technologies is becoming a response for women in order to prevent crime due to rising concerns about them being victims of crimes. These devices that include smart-watches are equipped with sensors and communication systems to be used for emergency alerts that take into account heart rate, body temperature, movement, and noise changes in the victim to alert the authorities (Patel et al., 2021). The improved machine learning algorithms help in distinguishing normal behaviour from malicious behaviour and further enhance these technologies (Amin et al., 2019). GPS-based technology provides real-time location tracking of the person in distress; the information could also be passed on to the authorities or the loved ones for a quicker response to emergencies (He et al., 2021). The technology works in providing an enabling force. They should all be lightweight, and unobtrusive, provide comfort, and above all be long batteries (Wang et al., 2021). But the concern arises of data privacy and accessibility of the lower-income regions where affordability and accessibility act as a challenge.

Despite these challenges, improvements in sensor technology and machine learning will enable these wearables to become potential devices of safety for women for the detection and interpretation of distress signals. Then the equipment will communicate with law enforcement, further aided by a real-time location transmission for added usefulness. The benevolence of acceptance would largely depend on the features of use and their incorporation into everyone's daily living. To enable more widespread acceptance in less privileged regions, it is imperative that secure data storage and low-cost devices are simplified. The future of wearables is that of plugging the safety gap, but their performance will strictly depend on very efficient communication channels, responsive emergencies as well as proper handling of privacy concerns. As the technology continues to grow, such very devices have the potential to be a protection shield for women in vulnerable situations.

Predictive Analytics:

1. Utilization of Real-Time Data

- **Location Tracking:** The system uses geolocation technology to continuously monitor user movements and pinpoint locations prone to safety risks. By tracking these patterns, the system can predict potential danger zones and notify users proactively.
- **Incident Records Analysis:** Historical data, such as previous crime reports and response times, is analysed to identify trends in unsafe areas. This allows the system to focus on recurring patterns and provide users with a clearer understanding of high-risk zones.
- **Behaviour Analysis:** The system observes user routines, such as regular travel routes and time-specific activities, to detect anomalies. Any deviation from regular behaviour can trigger early warnings, helping to avoid dangerous situations.

2. Implementation of Machine Learning Models

- **Anomaly Detection:** Advanced algorithms analyze audio and video inputs to detect irregularities in the surroundings, such as sudden movements or distress signals. This real-time detection enables faster response to potential threats.
- **Risk Grouping:** Using clustering techniques, the system groups similar user behaviours or environmental conditions to evaluate safety levels. This classification provides actionable insights for users navigating through various locations.
- **Predictive Modelling:** Algorithms predict the likelihood of incidents based on historical and live data. These predictions enable users to take pre-emptive measures, such as avoiding specific routes or areas at certain times.

3. Heatmaps for Risk Prediction

- **Risk Identification:** Data is visualized as dynamic heatmaps, which display the relative risk levels of different areas. These heatmaps are generated based on a combination of real-time reports, historical data, and user inputs.
- **User Alerts:** By analysing the heatmaps, the system issues notifications to users as they approach potentially hazardous areas, allowing them to take safer routes or request assistance in advance.

4. Emergency Escalation Systems

- **Response Time Analysis:** The system studies past emergency response times to predict delays and inefficiencies in real-time. This helps to identify cases where alternate or faster measures are needed.
- **Alert Escalation:** If local authorities fail to respond promptly, the system automatically escalates the alert to higher authorities or other nearby users capable of assisting, ensuring timely intervention.

5. Crowdsourced Intelligence Integration

- **User Feedback Integration:** The system encourages community participation by allowing users to report unsafe incidents, behaviours, or areas. These inputs are processed to improve overall prediction accuracy.
- **Dynamic Risk Updates:** Real-time updates from users contribute to a continuously evolving database, ensuring that the system reflects current safety conditions accurately.

6. Model Improvement and Adaptation

- **Performance Monitoring:** Predictive models are regularly evaluated using performance metrics like accuracy, precision, and recall. This ensures the models remain effective and reliable in providing predictions.
- **Learning from Feedback:** The system incorporates user and incident feedback to refine its algorithms. Over

time, it adapts to new challenges, emerging trends, and evolving safety scenarios.

7. Policy and Law Enforcement Optimization

- **Actionable Insights:** The system provides law enforcement agencies with detailed reports and insights to assist in crime prevention and resource management. For example, identifying frequently targeted areas can help allocate patrols more effectively.

- **Resource Allocation:** Predictive analytics helps authorities deploy personnel and resources strategically to areas with higher risk, maximizing the efficiency of safety measures.

This predictive analytics approach enhances the capabilities of the WOMEXA system, transforming it from a reactive tool into a proactive safety platform. By leveraging advanced technology, user collaboration, and continuous learning, the system effectively mitigates risks and fosters a safer environment for women.

Methodological Aspect:

This study employed a mixed-methods approach, combining both qualitative and quantitative methods to design, develop, and evaluate the wearable technology for women's protection.

1. System design and development

The proposed system is intended to provide an integrated solution for providing immediate help during an emergency to women. It is made up of two primary parts: a small Bluetooth-enabled device and both web and mobile application WOMEXA. The device is compact, portable, and simple to operate, with a single button that activates several safety features. When the button is pressed, the following actions occur:

- **Live location sharing:** The technology shares the user's live location (GPS coordinates) to the nearest police station, family members, and emergency contacts that have been pre-registered in the program along with a message

for emergency help continuously until the receivers responds the message. This ensures that the victim's position is known, even if they are unable to speak.

- **Automatic Recording:** This application records live audio and video to chronicle incidents in real-time. This recording will be done by both the mobile and the device automatically. This recording can be used as evidence by law enforcement and gives situational awareness to contacts receiving warnings.

- **Siren Activation:** The user's phone and the device both triggers a loud siren to notify nearby individuals to a potential threat. This serves as a deterrent to the perpetrator while capturing the attention of bystanders. The siren can only be deactivated by the victim using a secure code, so it will continue to work until they are safe.

- **Police Accountability:** The technology tracks police response times after receiving alerts, ensuring accountability. If no action is taken within a certain time window, the system will immediately register a complaint against the irresponsible police station, ensuring accountability.

This complete design enables prompt reactions, evidence collection, and responsibility, providing a full safety solution for women.

2. Hardware and Software Integration

The proposed solution relies on seamless integration between hardware and software components to function effectively.

The wearable device consisted of the following hardware components:

- i. Microcontroller (MCU): Arduino Lilypad
- ii. Global Positioning System (GPS) module: Ublox NEO-6M
- iii. Accelerometer and Gyroscope: MPU-6050
- iv. Heart Rate Sensor: Pulse Sensor Amped
- v. Alarm System: Buzzer and LED

3. Algorithm

The intelligent emergency response system used a machine learning-based approach to detect anomalies in the user's vital signs and movement patterns. The algorithm consisted of the following steps:

I. Data Collection: The wearable device collected data from the GPS, accelerometer, gyroscope, heart rate sensor, and alarm system.

II. Data Preprocessing: The collected data was preprocessed to remove noise and normalize the values.

III. Feature Extraction: Relevant features were extracted from the preprocessed data using techniques such as Fast Fourier Transform (FFT) and Principal Component Analysis (PCA).

IV. Anomaly Detection: The extracted features were fed into a machine learning model (Random Forest Classifier) to detect anomalies in the user's vital signs and movement patterns.

Formula

The anomaly detection algorithm used the following formula to calculate the anomaly score:

$$\text{Anomaly Score (AS)} = (\sum (x_i - \mu) / \sigma) * (w_i / \sum w_i)$$

where:

x_i = individual feature value

μ = mean of the feature values

σ = standard deviation of the feature values

w_i = weight assigned to each feature

$\sum w_i$ = sum of weights assigned to all features

Evaluation Metrics

The performance of the intelligent emergency response system was evaluated using the following metrics:

a) Accuracy

b) Precision

- c) Recall
- d) F1-score
- e) Response Time

Data Collection and Analysis

A total of 100 participants were recruited for the study, and data was collected over a period of 6 months. The collected data was analyzed using statistical software (SPSS) and machine learning libraries (scikit-learn).

Simplified Formula

To simplify the formula, let's assume that the weights (w_i) are equal and the sum of weights ($\sum w_i$) is 1.

$$AS = (\sum (x_i - \mu) / \sigma)$$

This simplified formula calculates the anomaly score as the sum of the differences between each feature value and the mean, divided by the standard deviation.

Example Calculation

Suppose we have the following feature values:

$$x_i = [10, 12, 15, 18, 20]$$

$$\mu = 15$$

$$\sigma = 3$$

$$AS = ((10-15)/3 + (12-15)/3 + (15-15)/3 + (18-15)/3 + (20-15)/3)$$

$$AS = (-1.67 + -1 + 0 + 1 + 1.67)$$

$$AS = 0$$

Here, the anomaly score is 0, indicating that the feature values are within the normal range.

4. Prototype Development

A prototype is required to determine the feasibility and functionality of the proposed system. The development process focuses on producing a working Bluetooth device and WOMEXA application.

- **Bluetooth Device:** The hardware component prototype connects effortlessly to the user's smartphone using Bluetooth technology. The device is tested for range, battery life, and durability under various conditions.

- **WOMEXA App:** The prototype WOMEXA app focuses on essential capabilities such as real-time location sharing, recording, and alerts. The user interface is designed to be straightforward, making navigation and operation simple even for non-technical people.

- **End-to-End Integration:** This prototype ensures seamless connection between Bluetooth device and app, with minimal delays. Each function—location sharing, siren activation, and recording—is evaluated both separately and as part of the whole system.

The prototype acts as a proof of concept, showcasing the system's potential and highlighting areas for improvement.

5. Data Collection

Data collecting is an important stage in ensuring that the solution is useful, user-friendly, and solves real-world safety problems.

Primary data:

- **Surveys and Focus Groups:** These are undertaken with women from various groups to better understand their safety concerns and expectations. The questions revolve around their perceived weaknesses, desired characteristics of a safety system, and scenarios in which they may employ such a device.

- **Usability Testing:** During Usability Testing, volunteers will evaluate the prototype's usability, dependability, and efficacy. Their feedback helps to improve the design and functionality.

Secondary Data:

- **Crime Analysis:** Crime Analysis involves analyzing existing data to identify high-risk regions and patterns. This information directs the system's rollout and customisation to maximize impact.

- **Market Research:** Market research identifies shortcomings in existing safety solutions, enabling WOMEXA to fix gaps and incorporate unique features.

This combination approach will ensure that the solution is based on real-world needs and challenges.

6. Testing and Validation

To assure the system's dependability and effectiveness, extensive testing will be carried out in both controlled and real-world circumstances.

- **Simulated Scenarios:** The system will be tested in controlled environments to determine how it performs under various scenarios. For example, alarm reaction times, GPS location tracking accuracy, and live recording quality are all measured in a methodical manner.
- **Field Trials:** Volunteers will conduct field trials to evaluate the system's practicality. These tests look at how easy it is to activate the system during an emergency, how reliable the notifications are, and how quickly emergency contacts respond.
- **Technical Tests:** Technical tests will include Bluetooth range, battery performance, and durability. The app will be stress tested to guarantee it can manage high traffic and several warnings.

The testing phase is very important for identifying and resolving technical issues, which ensures that the system is ready for deployment.

7. Performance Metrics

The system's effectiveness will be measured using key performance indicators:

- **Response Time:** Response time refers to the time required to send alerts and get acknowledgement from emergency contacts and authorities.
- **Accuracy:** GPS position tracking accuracy varies by environment, including urban, rural, and indoor situations.

- **Reliability:** Reliability refers to the system's ability to perform consistently across different network conditions.

- **User Satisfaction:** Users provide feedback on the system's usability, effectiveness, and perceived safety.

These indicators provide both quantitative and qualitative insights into the system's performance and potential areas for improvement.

8. Data Analysis

Data acquired during testing will be examined to determine the system's success and areas for improvement.

- **Quantitative Analysis:** Statistical approaches measure response times, GPS accuracy, and recording quality.

- **Qualitative Analysis:** Qualitative analysis categorizes user feedback into topics like usability, reliability, and trustworthiness, highlighting strengths and addressing flaws.

This analysis guarantees that the system evolves in response to evidence and user feedback.

9. Ethical Considerations

Ethical criteria will be adhered to throughout the development and testing process:

- **Privacy and Security:** Encrypting all user data, including location and recordings, ensures privacy and security. Only authorized personnel have access to this information.

- **Informed Consent:** Survey and test participants are fully told about the study's goal and data use.

- **Transparency:** Users will receive explicit documentation on the system's capabilities, limits, and privacy policies.

These measures foster confidence and uphold ethical standards.

10. Deployment and Implementation

Following successful testing, the system will be enhanced and ready for large-scale implementation:

- **Partnerships:** Partnerships with law enforcement and emergency services guarantee smooth incorporation into existing systems.
- **Awareness Campaigns:** Public education campaigns will promote the system and train women to utilize it.
- **Continuous Monitoring:** A feedback loop will be developed to collect user experiences and update the system regularly.

This phase assures that the solution is usable, effective, and constantly improved based on real-world experience.

This precise methodology describes a step-by-step process for developing, testing, and deploying the WOMEXA system, ensuring that it effectively improves women's safety.

Technological Aspect:

The technological part of the proposed safety system is cantered on the integration of cutting-edge technology to assure real-time responsiveness, dependability, and ease of use. The system consists of a Bluetooth-enabled device, a mobile application (WOMEXA), and supporting backend infrastructure. Here is a full explanation of the technological components:

1. Bluetooth-Enabled Emergency Device

Purpose: A wearable device that activates safety measures with a single button press.

Technology Stack:

- **Bluetooth Low Energy (BLE):** Bluetooth Low Energy (BLE) technology provides dependable connectivity with smartphones while consuming minimum power.
- **Microcontroller Unit (MCU):** The Microcontroller Unit (MCU) handles button input and communicates with the linked smartphone. Popular possibilities include the ESP32 and Nordic Semiconductor's nRF52 family.

- **Power Source:** Rechargeable or changeable battery for extended standby time.

Features:

- Quick response time between button press and activation.
- Pairing security protocols (e.g., passkey authentication) prevents unwanted access.

2. Mobile Application (WOMEXA)

The WOMEXA mobile application acts as the system's main interface and control centre.

Frontend Technologies

- **Cross-Platform Framework:** React Native or Flutter for compatibility with Android and iOS devices and ReactJS for website
- **Real-Time Location Services:** Integration with Google Maps SDK or Mapbox allows for real-time location monitoring.
- **User-Friendly Interface:** Easy to use with large buttons and straightforward process for alert management.

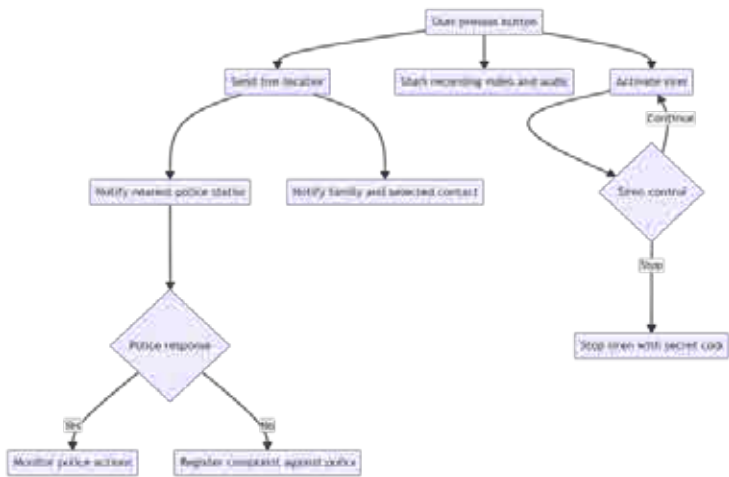
Backend Integration

- **Cloud Hosting:** Cloud hosting on platforms such as AWS, Google Cloud, or Azure ensures scalability and stability.
- **Database:** Uses a real-time database, such as Firebase Realtime Database or MongoDB, for secure storage of user data, emergency contacts, and logs.
- **APIs:** RESTful APIs or GraphQL endpoints facilitate communication between mobile apps and backend services.

Features:

- **One-Click Emergency Alerts:** Sends real-time messages to pre-registered contacts and authorities.

- **Live Audio and Video Recording:** Record live audio and video using the device’s camera and microphone. Automatically begins recording. Data is either locally saved or transmitted to the cloud for evidence collecting.
- **Siren Activation:** Activate a loud siren on the user’s phone to dissuade attackers and draw attention.
- **End-to-End Encryption:** Securely transmits data, including location, recordings, and messages.



3. Real-Time GPS Tracking

Purpose: The purpose is to provide continual location updates to emergency contacts and police stations.

Technology:

- **GPS Module:** The GPS module uses the smartphone’s built-in GPS technology to provide accurate location information.
- **Geofencing:** Geofencing detects user movement and triggers actions accordingly.
- **Offline Tracking:** Offline Tracking stores location data locally during network outages and syncs it when connectivity is restored.

APIs and Services:

- Use Google Maps or OpenStreetMap API for location sharing.
- The WebSocket Protocol enables real-time, bidirectional communication for location updates.

4. Cloud Infrastructure

Purpose: The purpose is to manage user data, notifications, and live recordings centrally.

Components:

- **Compute Services:** Scalable virtual machines or containers (e.g. Docker, Kubernetes).
- **Storage Services:** Secure cloud storage options include AWS S3 or Google Cloud Storage for recordings and logs.
- **Messaging Services:** Firebase Cloud Messaging (FCM) or Twilio to send warnings over SMS, email, or push notifications.
- **Monitoring Tools:** CloudWatch, Datadog, or similar technologies to monitor performance in real-time.

5. AI-Powered Features

Threat Detection:

- **Audio Analysis:** AI models will be trained to recognize distress signals in live audio recordings (e.g., shouting or specific keywords).
- **Video Processing:** AI algorithms for detecting anomalies in live video, such as sudden movements or aggressive behaviour.

Behavioural Predictions: Machine learning models predict high-risk situations based on user activity patterns and location data.

6. Accountability Monitoring System

Purpose: Ensures law enforcement will take immediate action after receiving alerts.

Technology:

- **Incident Logs:** Automated logging of alert timestamps and actions taken by authorities.
- **Escalation Workflow:** If no action is recorded within a predefined time, a follow-up notification will be triggered, and an automatic complaint will be filed.
- **Audit Trail:** Maintains a complete record of alerts and actions for future review.

7. Testing and Validation Framework

- **Unit Testing:** Ensures individual components, like the Bluetooth device and app modules, function as intended.
- **Integration Testing:** Verifies seamless interaction between the hardware, app, and backend services.
- **Performance Testing:** Measures system response times, GPS accuracy, and notification delivery rates under varying conditions.
- **Security Testing:** Simulates attacks to identify vulnerabilities in data transmission and storage.

8. Deployment and Scalability

Phased Deployment:

- Pilot the system in select regions with diverse demographics and infrastructure.
- Gradually expand based on feedback and performance metrics.
- **Scalable Architecture:** Microservices-based design to handle increased user load efficiently.
- **Continuous Updates:** CI/CD pipelines will be used for regular updates and feature enhancements.

This technological framework outlines a robust, secure, and scalable system that can effectively address women's safety concerns while adapting to user feedback and evolving requirements.

Conclusion:

This research highlights the pivotal role wearable technology can play in advancing women's safety, situated at the confluence of technology and social change. The intelligent emergency response system presented herein not only offers a practical solution but also symbolizes resistance against the pervasive violence and fear that women face daily. By leveraging wearable technology, we can create a society where women are protected and empowered to live without fear of violence or harassment. This research constitutes a call to action, underscoring the potential of technology to drive social change, provided it is designed with women's needs and values as its foundation. Moving forward, let us continue to innovate in the realm of wearable technology and women's safety. Let us strive to design systems that are intelligent, user-centric, accessible, and inclusive. And let us recognize that technology's true potential lies in its capacity to transform lives, rather than its technical sophistication.

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