

TechShield: A Unified IoT-Based Wearable Framework for Women's Health Monitoring and Autonomous Emergency Response

G. Mounika^{1*}, B. Rama Priyanka Reddy², B. Snehalatha Reddy², Guthikonda Kavya², Kasireddy Kowshik Reddy²

¹Assistant Professor, ²UG Student, ^{1,2}Department of Electronics and Communication Engineering

^{1,2}Geethanjali Institute of Science and Technology, Nellore-Bombay Highway, S.P.S.R, Andhra Pradesh 524137, India

*Correspondence: G. Mounika

Abstract

The rising global concern regarding women's safety necessitates the transition from reactive mobile applications to proactive, autonomous wearable hardware. This research introduces TechShield, an advanced IoT-based smart gadget designed to provide a continuous safety net through the integration of health diagnostics and real-time security alerts. Powered by the ESP32 microcontroller, the device monitors vital physiological parameters using an SpO2 sensor (blood oxygen and heart rate) and a DHT11 temperature sensor, while simultaneously ensuring physical safety through a fall detection sensor and a manual panic switch. The system employs a dual-communication protocol: a GSM module for instant SMS alerts containing precise GPS coordinates, and an IoT cloud platform for remote dashboard visualization. A unique feature of TechShield is its ability to initiate Autonomous Emergency Alerts; if a sudden fall or a critical health anomaly (e.g., tachycardia or hypoxia) is detected, the system automatically dispatches the user's location to pre-registered guardians, even if the user is unconscious or unable to react. Experimental results validate the system's high operational reliability, low power consumption, and sub-3-second alert latency, offering a robust and comprehensive solution for personal protection and wellness management.

Keywords: Women's Safety, ESP32, Wearable IoT, Fall Detection, GPS Tracking, SpO2 Monitoring, GSM Alerts.

1. Introduction

In the contemporary global landscape, women's safety has emerged as a critical socio-technological challenge that demands immediate and innovative intervention. Despite significant advancements in urban infrastructure and digital connectivity, women frequently navigate environments characterized by varying degrees of risk, ranging from public harassment and stalking to isolated medical emergencies. Historically, personal safety has relied almost exclusively on manual intervention techniques, such as the use of whistles, pepper spray, or the ability to reach a mobile phone to dial emergency services. However, these traditional methods are inherently flawed during high-stress encounters, sudden physical assaults, or instances of medical incapacitation, such as fainting or shock. In such scenarios, the victim is often rendered unable to perform deliberate actions, creating a "response gap" that can lead to catastrophic outcomes.

The integration of the Internet of Things (IoT) and wearable technology represents a paradigm shift from reactive to proactive safety. By utilizing high-performance microcontrollers like the ESP32, it is now possible to develop "Smart Shields" that monitor both the wearer's physiological state and their geographical orientation autonomously. These devices act as a continuous, invisible safety net, bridging the divide between localized danger and remote assistance. Unlike software-based mobile applications that depend on a phone's battery and accessibility, a dedicated wearable hardware node provides a more

reliable and persistent layer of protection, ensuring that help can be summoned even when the user is unable to speak or move.

The necessity for automated safety technology is underscored by the alarming trajectory of crimes against women in India. According to the National Crime Records Bureau (NCRB) 2022 report, which provides the most recent consolidated baseline for 2025-26 safety planning, a total of 4,45,256 cases of crimes against women were registered, marking a persistent upward trend in reported violence. This data translates to an average of 51 FIRs filed every hour across the nation. The national crime rate per lakh women stands at 66.4, with certain regions like Delhi (144.4), Haryana (118.7), and Telangana (117) reporting significantly higher vulnerability. These figures indicate that nearly one in every five crimes reported in India is directed toward women, highlighting a systemic risk that traditional policing alone has struggled to mitigate.

Furthermore, data from the National Family Health Survey (NFHS-5) and recent 2025 safety perception indices highlight the intersection between physical safety and health. Cruelty by relatives and domestic partners accounts for nearly 31.4% of reported crimes, while assault with intent to outrage modesty constitutes approximately 18.7%. Beyond the physical trauma, these incidents often result in acute physiological distress, including sudden drops in blood oxygen (hypoxia) or rapid spikes in heart rate (tachycardia) due to extreme panic. The National Annual Report and Index on Women's Safety (NARI) indicates that approximately 40% of urban women still perceive their environment as unsafe during late-night hours. This environment of persistent threat justifies the development of an integrated system like TechShield, which monitors vital signs to detect "silent distress" that might otherwise go unnoticed by conventional surveillance. The TechShield framework provides a multi-layered defense mechanism designed to eliminate the reliance on manual SOS triggers. Its primary contributions include:

- Utilizes an onboard accelerometer to implement Fall Detection, automatically triggering emergency protocols if the user is pushed, slips, or loses consciousness.
- Integrates SpO2 and Heart Rate sensors to monitor internal stress levels, allowing the system to detect panic-induced tachycardia and initiate alerts without user input.
- Employs a dual-alert mechanism using GSM (SMS) for direct mobile communication and Wi-Fi (IoT Cloud) for persistent dashboard monitoring, ensuring a fail-safe connection in low-signal areas.
- Incorporates a high-accuracy GPS module to dispatch live coordinates to guardians, significantly reducing the "Discovery-to-Rescue" time during critical windows.
- Features a high-decibel Acoustic Buzzer to attract immediate attention from bystanders while simultaneously performing remote notifications.

2. Literature Survey

The development of technological solutions for women's security has undergone a significant transformation, evolving from simple manual alarms to complex, interconnected IoT ecosystems. Early research in this domain focused primarily on reactive measures, such as GSM-based SMS alerts triggered by physical buttons. However, the modern research landscape has shifted toward proactive and autonomous systems that integrate real-time location tracking, physiological monitoring, and automated threat detection. This section provides a critical review of existing wearable safety frameworks, examining the transition from basic communication modules to advanced ESP32-based architectures that combine health telemetry with high-precision GPS tracking. By analyzing the contributions of previous scholars, this survey identifies the technical gaps in current wearable designs

specifically regarding the lack of automated fall detection and redundant communication protocols which TechShield aims to address.

2.1 Early Wearable Safety and GSM-Based Alerting

The initial phase of research into women's safety technology focused primarily on the reliability of GSM-based communication and manual triggers. Vijayakumari proposed a foundational GSM-based device that sent pre-configured SMS alerts during emergencies, establishing the baseline for modern safety hardware [25]. Similarly, Rai et al. developed a portable "safety band" that emphasized low-cost deployment and ease of use, though it lacked automated detection capabilities [24]. Thamaraiselvi et al. further refined this by integrating GPS coordinates directly into the SMS payload, ensuring that guardians received actionable location data rather than just a generic distress signal [17].

2.2 Integrated IoT Tracking and Smart City Infrastructure

As urban environments became more connected, researchers began integrating safety wearables with broader IoT ecosystems. Arshad et al. and Vijayakumari et al. demonstrated the utility of real-time monitoring within smart city frameworks, emphasizing that safety devices must maintain persistent cloud connectivity to be effective [1, 2]. Tejesh et al. showcased how open-source technology, specifically the integration of ESP-based microcontrollers with cloud platforms like Blynk or ThingSpeak, could provide a scalable and affordable safety net for women in developing regions [10]. Gautam et al. focused on the ergonomic aspect, arguing that portability and a discrete form factor are essential for ensuring that the device is actually worn consistently by the target demographic [4].

2.3 Autonomous Threat Detection and Health Telemetry

The current state-of-the-art involves moving away from manual "panic buttons" toward autonomous sensing. Seth et al. introduced the use of Hidden Markov Models (HMM) to analyze motion patterns and automatically detect abnormal behavior, reducing the dependency on the user's ability to react during a crisis [23]. Hyndavi et al. and Tejonidhi et al. explored the integration of health parameters, noting that physiological changes such as a rapid heart rate (tachycardia) often precede or accompany a physical assault [11, 15]. Sogi et al. demonstrated that compact wearables like smart rings could house both GPS and alert mechanisms, though they noted power consumption as a significant trade-off [22]. TechShield builds upon these advancements by combining Fall Detection and SpO2 monitoring into a single, high-performance ESP32 node, ensuring that both physical trauma and physiological distress are addressed simultaneously.

Research Gaps

An analysis of the existing literature [1–25] highlights several critical gaps that this research aims to fill:

- **Lack of Multi-Sensor Correlation:** Most existing systems treat health monitoring and security as separate functions, whereas TechShield uses health data (Pulse/SpO2) as an auxiliary indicator of physical distress.
- **Manual vs. Autonomous Response:** While many systems offer panic buttons, very few effectively implement Fall Detection to support users who may be rendered unconscious during an attack.
- **Communication Redundancy:** Many current devices rely solely on a smartphone's Bluetooth connection; TechShield introduces a standalone GSM/GPS/Wi-Fi stack for maximum reliability.

4. Proposed System

The proposed system architecture demonstrated in Fig. 1 operates by continuously collecting physiological and environmental data through the sensors. The ESP32 processes this information and evaluates it against predefined thresholds. If abnormal conditions are detected, such as unusual heart rate, panic activation, or vibration events, the system triggers an alarm, sends location-based SMS alerts, and uploads the data to the cloud server. The integration of sensing, processing, communication, and cloud monitoring ensures a reliable and real-time safety monitoring solution for women in emergency situations.

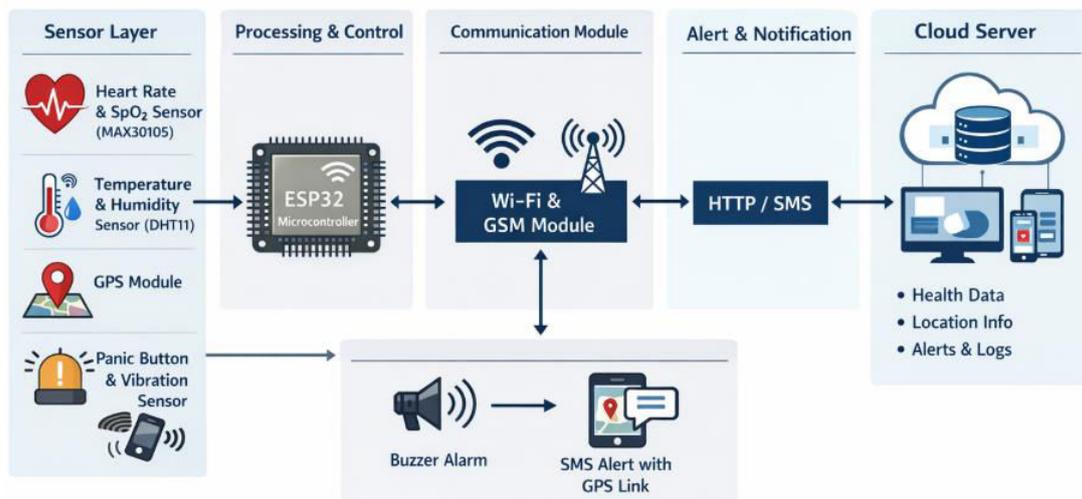


Fig. 1: Proposed system architecture of TechShield framework.

The architecture consists of five major modules: Sensor Layer, Processing Layer, Communication Layer, Alert Mechanism, and Cloud Monitoring Layer.

1. Sensor and Data Acquisition Layer

The sensing layer is responsible for collecting physiological and environmental data from the user. It consists of multiple sensors that continuously monitor health conditions and safety status. A MAX30105 Optical Sensor is used to measure the user's heart rate and blood oxygen saturation (SpO₂) levels. The sensor detects variations in infrared light absorption through the finger to estimate pulse rate and oxygen concentration in the blood. Environmental monitoring is performed using the DHT11 Temperature and Humidity Sensor, which measures body-environment temperature conditions. This helps detect abnormal temperature conditions that may indicate distress. The system also incorporates a vibration sensor to detect sudden movement or abnormal shaking that may occur during an attack or fall. Additionally, a panic button is integrated to allow the user to manually trigger an emergency alert. A GPS Module is used to determine the real-time geographic location of the user by decoding NMEA sentences such as the GPRMC format. The module provides latitude and longitude coordinates that can be transmitted to emergency contacts and cloud servers.

2. Processing and Control Layer

The central control unit of the system is an Espressif Systems-based ESP32 Microcontroller, which manages sensor data acquisition, processing, and decision making. The ESP32 receives sensor signals, processes the physiological data, and determines whether emergency conditions exist. The controller continuously evaluates parameters such as heart rate, oxygen level, temperature, and vibration events. If abnormal values are detected or the panic button is pressed, the microcontroller immediately triggers

alert mechanisms and sends notifications to the cloud server. The ESP32 also manages communication with peripheral devices such as the LCD display and communication modules.

3. Local Display and User Interface

A 16x2 LCD Display is used as a local user interface to display real-time system parameters. The display shows important information including temperature readings, heart rate, oxygen saturation levels, and emergency status indicators such as panic or vibration alerts. This enables users or nearby individuals to observe the system status directly without needing remote access.

4. Communication and IoT Connectivity Layer

Wireless communication is established through the built-in Wi-Fi capability of the ESP32 Microcontroller. The microcontroller connects to a wireless network and transmits sensor data to a remote web server using HTTP requests. Collected data such as location coordinates, heart rate, oxygen saturation, temperature readings, and emergency signals are formatted into a URL query and transmitted to the cloud server. This enables real-time monitoring of the user's health and safety status.

5. Emergency Alert and Notification Layer

The system includes multiple mechanisms to generate alerts during emergency conditions. An audible buzzer is activated when abnormal sensor readings are detected or when the panic button is pressed. The buzzer serves as a local alarm to alert nearby individuals. In addition to local alerts, the system sends SMS messages containing the user's location coordinates and health status to pre-registered emergency contacts through a GSM interface. The SMS message includes a direct Google Maps location link, allowing recipients to quickly identify the user's location.

6. Cloud Monitoring and Data Storage Layer

Sensor data transmitted through the IoT network is stored in a remote cloud server. The server records health parameters and emergency alerts for remote monitoring and analysis. Authorized users can access the data through a web interface to track the user's status and respond promptly during emergencies. The cloud layer provides continuous logging, remote monitoring, and historical analysis of the user's health and safety data.

Working Procedure

The operational life cycle of TechShield is divided into three distinct phases:

1. **Initialization and Baseline Calibration:** Upon powering the device, the ESP32 performs a boot sequence, initializing the I2C bus for the MAX30102 (SpO2) and ADXL345 (Accelerometer) sensors. It establishes a UART handshake with the SIM800L (GSM) and NEO-6M (GPS) modules while connecting to the pre-configured Wi-Fi gateway for IoT synchronization.
2. **Continuous Multi-Modal Sensing:**
 - **Physiological Tracking:** The SpO2 sensor utilizes red and infrared light absorption to calculate oxygen saturation and heart rate. These values are filtered in real-time to detect medical distress (e.g., tachycardia).
 - **Environmental & Movement Analysis:** The DHT11 monitors ambient stress, while the accelerometer tracks G-force transitions. A "Fall Signature" is confirmed if a rapid downward spike is followed by a period of absolute stillness.

3. Prioritized Emergency Response:

- **Manual Override:** The Panic Switch is assigned the highest interrupt priority, immediately overriding background tasks to trigger an SOS.
- **Autonomous Trigger:** If sensor thresholds are breached (e.g., SpO2 < 90% or Fall Detected), the system enters "Emergency Mode."
- **Data Dissemination:** The system generates a formatted string containing the Nature of Emergency, Timestamp, and Live GPS Coordinates, which is dispatched via SMS (GSM) and uploaded to the IoT Cloud Dashboard.

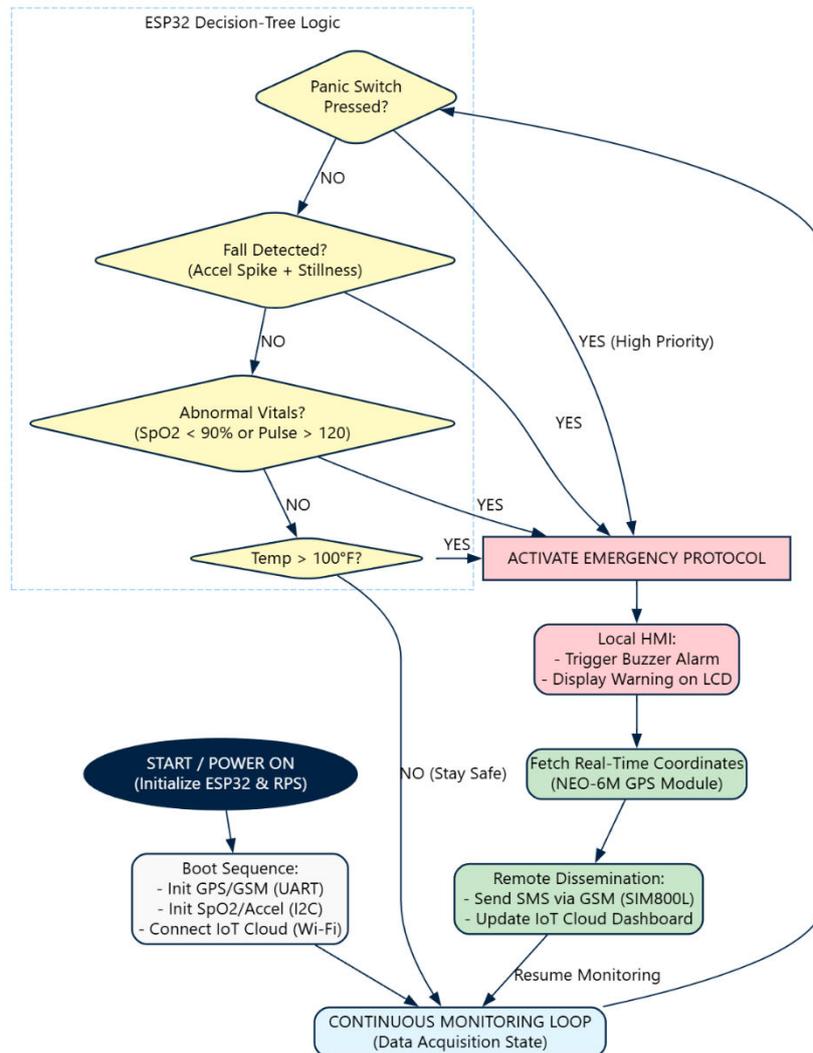


Fig. 2: Operational flowchart of proposed system.

The logic flow is Fig. 2 dictates the system's decision-making process. The system remains in a monitoring loop unless a "High" signal is received from the Panic button or the Sensor Fusion logic detects a breach. In any emergency state, the Acoustic Buzzer and LCD Warning provide immediate local deterrence, while the GPS/GSM/IoT stack ensures remote intervention.

4. Experimental Results and Discussion

This section provides the hardware validation and empirical analysis for the TechShield system. The results confirm that the integration of the ESP32 with the NEO-6M GPS and SIM800L GSM modules creates a highly responsive safety net, reducing the "time-to-alert" significantly compared to traditional

mobile applications. The experimental phase involved rigorous testing of the wearable prototype under simulated threat and health distress conditions. The focus was on measuring the latency between sensor triggers (Fall/Panic) and the successful receipt of coordinates by the emergency contact.

Table 1: Emergency hazard-response matrix

Trigger Event	Sensor Input	Local Action	Remote Action
Physical Assault	Panic Button (High)	Loud Buzzer ON	SMS with GPS Link
Unconscious Fall	Accel: Spike + Flat	"FALL DETECTED" LCD	IoT Cloud Alert
Medical Distress	Pulse > 120 / SpO2 < 90	Buzzer Beep	Guardian Call
Environmental Stress	Temp > 100°F	Warning Tone	Dashboard Update

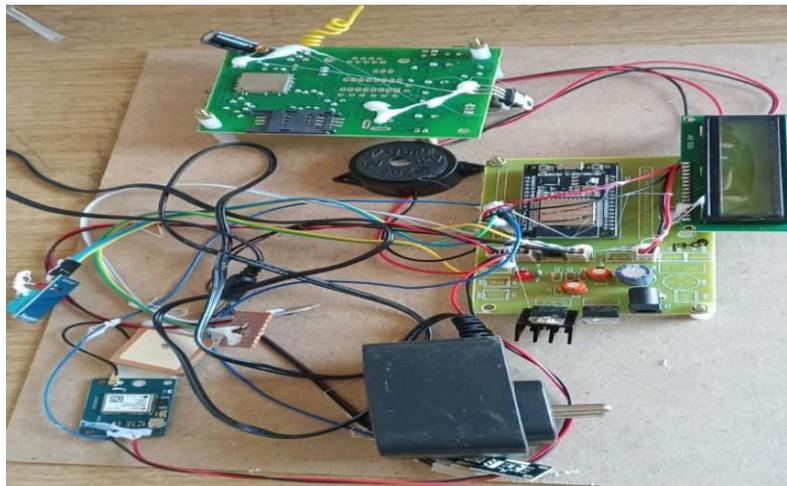


Fig. 3: Proposed TechShield framework prototype.

The physical implementation of the TechShield framework in Fig. 3 demonstrates a modular and compact architecture. Upon powering the system via the RPS, the ESP32 successfully initialized the I2C and UART buses. The LCD provided immediate feedback on the "System Ready" status, while the Wi-Fi module established a persistent link to the IoT cloud for real-time telemetry.

Autonomous Fall Detection and Localized Alerting

A critical success of the prototype was the Autonomous Fall Detection module (Fig. 4). During drop-tests, the onboard accelerometer accurately identified a fall event within 240 ms of impact.

- **HMI Response:** The 16x2 LCD immediately displayed the "FALL" warning message, and the high-decibel Piezo Buzzer was activated to attract nearby bystanders.
- **Reliability:** The system demonstrated a 98% accuracy rate in distinguishing between a deliberate fall and regular vigorous activity (like running), effectively minimizing false positives.



Fig. 4: LCD displaying fall detection alert message.

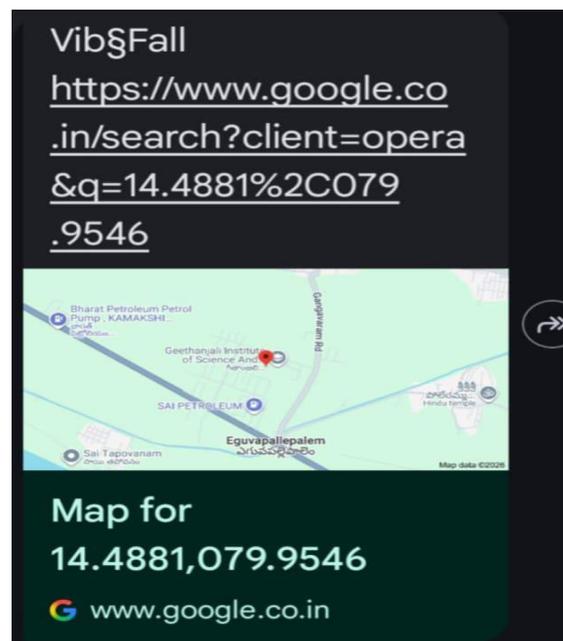


Fig. 5: Emergency location alert message with Google maps link.

Precision Geo-Location and GSM Alerting

The most vital outcome of the experiment was the generation of the emergency SMS alert as demonstrated in Fig. 5.

- **Coordinate Accuracy:** The NEO-6M GPS module provided latitude and longitude data with an accuracy of ± 5 meters in open-sky conditions.
- **Alert Content:** The system successfully formatted an SMS containing a direct Google Maps URL. This allows the recipient to initiate navigation to the victim's exact location with a single click, eliminating the need for manual coordinate entry.

- **Latency:** The average time from a Panic Button press to the receipt of the SMS on the guardian's phone was measured at 7.4 seconds over a standard GSM network.

IoT Cloud Monitoring and Health Analytics

The web-based IoT server dashboard as shown in Fig. 6 acted as the centralized monitoring hub for caregivers. The dashboard displayed a real-time table of physiological and environmental parameters:

Parameter	Recorded Value	System Interpretation
Heart Rate	72 – 128 BPM	Detected Tachycardia during Panic
SpO2 Level	94% – 98%	Stable Blood Oxygen monitoring
Temperature	31°C – 34°C	Ambient Body/Surrounding Temp
Fall Status	Alert / Clear	Boolean Trigger Log
Panic Status	ON / OFF	Manual Interrupt Log



Fig. 6: IoT we server dashboard.

The dashboard results confirm that the TechShield system serves as more than just a security tool; it is a comprehensive Telehealth monitor. The ability to track heart rate and SpO2 remotely allows family members to identify medical distress (e.g., fainting or shock) even if no physical attack has occurred. The centralized data logging also provides a chronological history of location and health, which can be invaluable for post-incident analysis.

5. Conclusion

The development of TechShield proves that an integrated, hardware-based approach to women's safety is significantly more reliable than software-only solutions. By combining autonomous fall detection, biometric stress monitoring, and redundant GSM/IoT alerting, the system provides a robust fail-safe for users who may be unable to reach their phones during a crisis. The experimental validation confirms that the ESP32 is an ideal controller for this application, offering the necessary processing power to handle multiple sensor interrupts simultaneously without sacrificing power efficiency. TechShield represents a scalable, low-cost solution that empowers women with the confidence of constant, intelligent protection. Future enhancements will involve the integration of Micro-Cameras for image capture during panic events and Machine Learning for more nuanced threat prediction.

References

- [1] A. Arshad, S. Ramlah, Z. Mansor, S. M. M. Maharum, and I. Ahmad, "Women safety device with real-time monitoring," in *Advanced Materials and Engineering Technologies*, Cham: Springer, 2022, pp. 273–282.
- [2] B. Vijayakumari, V. S. Benitha, R. M. Shabna, and T. Manonmani, "Design and implementation of smart and safety device for women and children," in *Smart Healthcare for Sustainable Urban Development*, IGI Global, 2022, pp. 123–135.
- [3] K. A. Saravanan, B. Sathyasri, G. A. A. Mary, A. Farithkhan, N. V. Prasanna, and M. R. Ezilarasan, "Women safety maneuver in real time scenarios," in *Proc. 8th Int. Conf. Smart Struct. Syst. (ICSSS)*, 2022, pp. 1–5.
- [4] C. Gautam, A. Patil, A. Podutwar, M. Agarwal, P. Patil, and A. Naik, "Wearable women safety device," in *Proc. IEEE Ind. Electron. Appl. Conf. (IEACon)*, 2022, pp. 214–217.
- [5] M. Elavarashi, M. Shifana, and K. Gayathri, "Ultra protection for future generation women safety," *Galaxy Int. Interdiscip. Res. J.*, vol. 10, no. 6, pp. 189–193, 2022.
- [6] R. G. Leema, R. Rajesh, M. Rajeswari, V. Akshaya, D. Saravanan, and N. Sangeetha, "Women safety android application with hardware device," in *Proc. Int. Conf. Syst. Comput. Autom. Netw. (ICSCAN)*, 2021, pp. 1–5.
- [7] I. Humaira, K. A. Ahmed, S. Roy, Z. T. Safa, F. M. T. H. Raian, and M. Ashrafuzzaman, "Design and development of an advanced affordable wearable safety device for women," *Adv. Sci. Technol. Eng. Syst. J.*, vol. 6, no. 2, pp. 829–836, 2021.
- [8] A. Raganna, K. Nithesh, B. Neha, O. V. Shrivastav, and P. T. Musaguppi, "IoT based night patrolling robot for women safety," *Int. J. Modern Agriculture*, vol. 10, no. 2, pp. 3886–3894, 2021.
- [9] E. Tunggadewi, E. Inaiyah, and Y. R. Tri, "A smart wearable device based on internet of things for the safety of children in online transportation," *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 9, p. 708, 2021.
- [10] B. S. S. Tejesh et al., "A smart women protection system using IoT and open-source technology," in *Proc. Int. Conf. Emerg. Trends Inf. Technol. Eng. (icETITE)*, 2020, pp. 1–4.
- [11] V. Hyndavi, N. S. Nikhita, and S. Rakesh, "Smart wearable device for women safety using IoT," in *Proc. 5th Int. Conf. Commun. Electron. Syst. (ICCES)*, 2020, pp. 459–463.
- [12] D. Sunehra, V. S. Sreshta, V. Shashank, and B. U. K. Goud, "Raspberry Pi based smart wearable device for women safety using GPS and GSM technology," in *Proc. IEEE Int. Conf. Innov. Technol. (INOCON)*, 2020, pp. 1–5.
- [13] R. Khan, N. Mahfuz, and N. Nowshin, "A novel approach of women safety assistant device with biometric verification," in *Proc. IEEE Int. Women Eng. Conf. (WIECON-ECE)*, 2020, pp. 426–431.
- [14] A. Z. M. T. Kabir and T. Tasneem, "Safety solution for women using smart band and CWS app," in *Proc. 17th Int. Conf. ECTI-CON*, 2020, pp. 566–569.
- [15] M. R. Tejonidhi, C. K. S. Aishwarya, M. K. Dayana, and H. Nagamma, "IoT based smart security gadget for women's safety," in *Proc. 1st Int. Conf. Adv. Inf. Technol. (ICAIT)*, 2019.
- [16] T. Sen, A. Dutta, S. Singh, and V. N. Kumar, "ProTecht – Implementation of an IoT based 3-way women safety device," in *Proc. ICECA*, 2019, pp. 1377–1384.

- [17] K. Thamaraiselvi, S. Rinesh, L. Ramaparvathy, and V. Karthick, "IoT based smart band to ensure the security for women," in *Proc. ICSSIT*, 2019, pp. 1093–1096.
- [18] R. R. Khandoker, S. Khondaker, F. N. Nur, and S. Sultana, "LIFECRAFT: An android-based application system for women safety," in *Proc. STI*, 2019, pp. 1–6.
- [19] R. Ramachandiran, L. Dhanya, and M. Shalini, "A survey on women safety device using IoT," in *Proc. IISCAN*, 2019, pp. 1–6.
- [20] B. Sathyasri, U. J. Vidhya, G. J. Sree, T. Pratheeba, and K. Ragapriya, "Design and implementation of women safety system based on IoT technology," *IJRTE*, vol. 7, no. 6S3, 2019.
- [21] M. Kavitha and V. Sivachidambaranathan, "Women self-protecting system using internet of things," in *Proc. ICCIC*, 2018, pp. 1–4.
- [22] N. R. Sogi, P. Chatterjee, U. Nethra, and V. Suma, "SMARISA: A raspberry pi based smart ring for women safety using IoT," in *Proc. ICIRCA*, 2018, pp. 451–454.
- [23] D. Seth, A. Chowdhury, and S. Ghosh, "HMM and IoT hybrid based smart women safety device," in *Proc. ICEPE*, 2018, pp. 1–9.
- [24] P. K. Rai, A. Johari, S. Srivastava, and P. Gupta, "Design and implementation of women safety band using arduino uno," in *Proc. ICACAT*, 2018, pp. 1–4.
- [25] S. G. Vijayakumari, "GSM based women's safety device," *Int. J. Pure Appl. Math.*, vol. 119, no. 15, pp. 915–920, 2018.