

# A Multifunctional Smart Footwear System Integrating Obstruction Detection, GPS Tracking, Panic Alert Messaging, and Health Monitoring with IoT-Based Environmental Data Logging

Raghunathachar Bhoomika<sup>1</sup>, Monisha M<sup>2</sup>, Akkavva Dange<sup>3</sup>, Pallavi Patil<sup>4</sup>

*Dept. of Computer Science and Engineering Sir M Visvesvaraya Institute of Technology Bengaluru, Karnataka, India*

**Abstract**—This paper presents the design and development of a multifunctional smart footwear system that integrates intelligent sensing, embedded electronics, and IoT connectivity to enhance user safety, mobility, and health awareness. The system is intended to support vulnerable user groups such as the visually impaired, women, children, and the elderly, addressing challenges related to navigation, emergency response, and real-time health monitoring. The proposed footwear incorporates four key functionalities within a compact wearable platform: obstruction detection, panic alert messaging, GPS-based location tracking with environmental data logging, and vital health monitoring. Obstruction detection is achieved through sensor-based feedback and a built-in audio alert mechanism. A dedicated panic button enables automatic transmission of a “Help Me” SMS to a predefined emergency contact. The system also records GPS coordinates, along with temperature and humidity, and uploads the data to the ThingSpeak IoT cloud platform for remote monitoring. Additionally, the footwear measures the wearer’s pulse rate and body temperature, displaying real-time values on an integrated LED screen. The results demonstrate that combining smart sensors, microcontroller-based processing, and IoT communication in a wearable form factor can provide a cost-effective assistive solution capable of improving personal safety, health awareness, and independent mobility. This work contributes to the advancement of human-centred, IoT-enabled assistive technologies.

**Index Terms**—Smart footwear, IoT, Obstruction detection, GPS tracking, Panic alert system, Environmental data logging, Health monitoring, Assistive device, Embedded systems.

## I. INTRODUCTION

Safe and confident mobility is essential for leading an independent life, yet many individuals—especially the visually impaired, elderly, women, and children—continue to face daily challenges that threaten their safety and well-being. Obstacles in the environment, lack of timely assistance during emergencies, and limited awareness of one’s surroundings often restrict their freedom of movement. Traditional aids such as walking sticks, basic alert devices, or simple mobile tools provide only partial support and fail to address the combined needs of navigation, safety, and health monitoring.

The rapid growth of IoT technologies, embedded systems, and smart sensing devices has opened new possibilities for assistive solutions that are intelligent, responsive, and portable. Among various emerging platforms, smart footwear stands out as a practical and ergonomic option. Since footwear is worn naturally and consistently, it offers an ideal medium to integrate sensing, communication, and safety mechanisms without adding extra burden or altering the user’s routine.

While previous research has explored individual features such as obstacle detection, emergency alerts, location tracking, and health monitoring, most solutions remain single-purpose, bulky, or difficult to scale. There is a clear gap for a unified system that can seamlessly combine multiple safety and monitoring functionalities in one compact design. To address this need, this work presents a multifunctional smart footwear prototype that

consolidates obstruction detection, panic alert messaging, GPS-based location logging, IoT-enabled environmental sensing, and vital health monitoring within a single wearable unit. The goal is to create an assistive platform that not only enhances safety and situational awareness but also provides real-time support during emergencies and daily activities.

By bringing together IoT connectivity, compact sensors, and user-centric design, this project demonstrates the potential of smart footwear to evolve into a comprehensive assistive technology. The proposed system aims to empower vulnerable individuals with greater independence, confidence, and safety while contributing to the growing field of intelligent wearable solutions.

## II. RELATED WORKS

Research on assistive footwear and wearable safety technologies has grown significantly in recent years, driven by the need to support visually impaired individuals, elderly users, and people requiring continuous safety monitoring. Early developments in this field primarily focused on obstacle-detection shoes, where ultrasonic sensors were embedded in footwear to alert users of nearby hindrances. These systems demonstrated the feasibility of foot-mounted detection, offering hands-free assistance compared to traditional white canes. However, most existing designs were restricted to basic proximity sensing and lacked comprehensive safety or communication features.

Another category of previous work explored wearable emergency-alert devices, particularly for women and children. These systems typically utilize GSM or GPS modules to send distress messages when activated. While valuable for personal protection, such devices are often standalone units—like wristbands, keychains, or pendants—requiring the user to carry an additional gadget. They do not support mobility assistance or real-time environmental and health monitoring, limiting their usefulness for vulnerable communities.

IoT-based smart footwear prototypes have also emerged, integrating cloud connectivity for location tracking or environmental data logging. These studies highlight the potential of IoT in creating remotely monitorable assistive systems. Yet, many of these prototypes focus on only one or two

functionalities and fail to incorporate vital-sensing capabilities, reducing their usefulness as a multi-purpose assistive tool.

Wearable health-monitoring systems represent another related domain, featuring pulse sensors, temperature monitoring, and gait analysis. Although these devices contribute significantly to personal healthcare, they are generally designed as wrist-based or chest-worn devices. Such systems do not address navigation challenges or emergency alert needs faced by visually impaired or elderly individuals.

Across all these categories, existing solutions tend to suffer from one or more limitations:

1. they offer single-purpose functionality
2. lack IoT-based continuous monitoring
3. do not integrate mobility assistance with health tracking
4. are not designed as a unified wearable solution.

The proposed work distinguishes itself by combining all key assistive features—obstruction detection, panic alert messaging, GPS tracking, IoT-based environmental logging, and basic health monitoring—into a single, compact footwear prototype. This integrated approach addresses the multidimensional needs of vulnerable users and advances the state of smart-footwear research by delivering a more holistic and user-centric assistive technology.

## III. PROBLEM STATEMENT

Many vulnerable groups—including visually impaired individuals, elderly users, women, and children—face significant challenges in maintaining safe and independent mobility. Real-world environments often present unexpected obstacles, unsafe conditions, and emergency situations, while conventional aids such as walking sticks, standalone GPS devices, or basic alert systems provide only limited support. These tools do not offer integrated sensing, do not deliver automated assistance during emergencies, and lack continuous environmental or health awareness features.

Although advancements in IoT and wearable electronics have enabled new forms of assistive technologies, existing solutions typically focus on a single function such as obstacle detection, location tracking, or health monitoring. The absence of a unified system that seamlessly combines all these

capabilities leaves a critical gap in providing comprehensive safety and support to users who rely on assistive devices.

This research addresses the need for a multifunctional wearable solution that can detect obstructions, send panic alerts, log GPS and environmental data through IoT, and monitor basic health parameters within a single prototype. The core problem is to develop a compact, affordable, and user-friendly system that enhances mobility confidence, improves emergency responsiveness, and supports continuous situational awareness for at-risk individuals.

#### IV. METHODOLOGY

The methodology adopted for developing the multifunctional smart footwear prototype follows a systematic sequence to ensure accurate sensing, reliable communication, and seamless integration of all functional modules. The development process is divided into four major stages: system planning, module development, prototype integration, and performance evaluation.

The process begins with defining functional requirements and mapping them to suitable hardware components such as sensors, communication modules, and processing units. A preliminary system layout is drafted to establish the data flow between the obstruction detection unit, panic alert mechanism, GPS-IoT data logger, and health monitoring sensors. Firmware requirements are outlined based on expected system behavior and real-time response needs.

In the next stage, each subsystem is developed and validated individually. The obstruction detection module is configured to sense nearby obstacles and trigger a voice alert through the speaker. The GSM unit is programmed to transmit an automated “Help Me” SMS upon activation of the panic button. GPS and environmental sensors are calibrated to collect coordinates, temperature, and humidity data and upload them to the ThingSpeak IoT cloud platform. Simultaneously, pulse and body temperature sensors are interfaced to capture vital readings, which are displayed on an LED screen for instant user feedback.

The third stage focuses on integrating all modules into a unified prototype. This involves designing a

compact wiring layout, implementing power management strategies, and refining the firmware to coordinate multiple operations without interference. Special attention is given to ensuring stable sensor readings, efficient communication timing, and smooth interaction between modules.

In the final stage, the prototype undergoes functional testing to verify accuracy, responsiveness, and reliability. Each module is tested under different conditions to assess system performance, identify inconsistencies, and make necessary adjustments. The observations from this phase help refine the overall design and ensure that the smart footwear prototype operates effectively as a multifunctional assistive device.

#### V. SYSTEM DESIGN AND IMPLEMENTATION

The design of the multifunctional smart footwear system focuses on creating an integrated assistive solution capable of detecting obstacles, sending emergency alerts, monitoring environmental conditions, and measuring key health parameters. The implementation combines the sensing, communication, and processing modules in a structured architecture that ensures reliable operation in real-world conditions.

##### *A. System Architecture Overview*

The overall architecture is divided into four core functional units:

1. Obstacle Detection Module,
2. Panic Alert and Communication Module,
3. GPS and IoT Environmental Data Logging Module, and
4. Health Monitoring Module.

These units work together to support continuous sensing, user feedback, communication, and data logging. The microcontroller-based control system manages all sensor inputs, executes decision-making logic, and activates the appropriate output responses.

##### *B. Obstacle Detection System*

The obstacle detection subsystem uses an infrared (IR) proximity sensor placed at the front of the footwear to identify nearby objects within a predefined distance. When the sensor detects an obstruction, the control unit immediately triggers a

pre-recorded audio alert through a compact speaker. This real-time feedback mechanism enables early awareness of hazards, improving navigation safety for visually impaired and elderly users.

*C. Panic Alert and Emergency Communication Unit*

To enhance personal safety, the footwear incorporates an emergency alert mechanism activated by a dedicated panic button. Upon pressing the button, the communication module sends a “Help Me” SMS to a predefined mobile number, providing rapid outreach during distress situations. This system is particularly beneficial for women, children, and individuals who often travel alone.

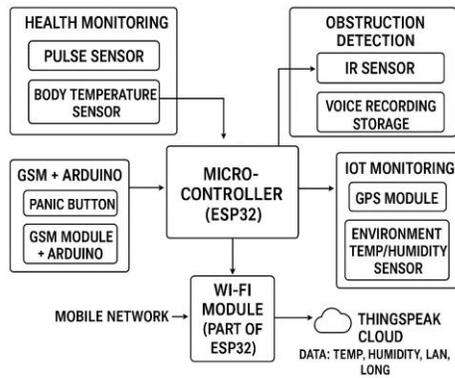


Fig. 1: Block diagram of the proposed system.

*D. GPS Tracking and IoT-Based Environmental Logging*

The environmental and location monitoring unit captures GPS coordinates, temperature, and humidity values in real time. These parameters are transmitted to the ThingSpeak IoT cloud platform, where they are securely stored and visualized. Remote users can access the data for tracking, environmental awareness, and situational assessment. The IoT integration ensures continuous, cloud-based monitoring without manual intervention.

*E. Health Monitoring Module*

The health monitoring subsystem includes sensors responsible for measuring pulse rate and body temperature. The sensed physiological parameters are processed locally and displayed on an LED screen attached to the system. This enables users and caregivers to obtain immediate health insights, adding a wellness-centric dimension to the footwear.

*F. Operational Workflow*

The system follows a structured workflow that

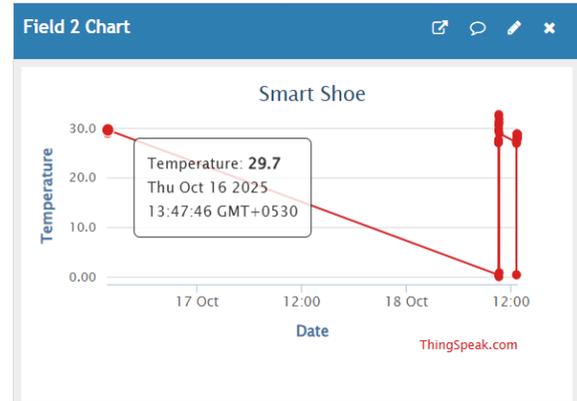
coordinates all sensing, feedback, and communication tasks. The control unit continuously monitors inputs from the IR sensor, health sensors, GPS module, and environmental sensors. Depending on detected events—such as an obstacle, health reading update, or emergency trigger—the system executes the appropriate response.

*G. Prototype Integration and Testing Approach*

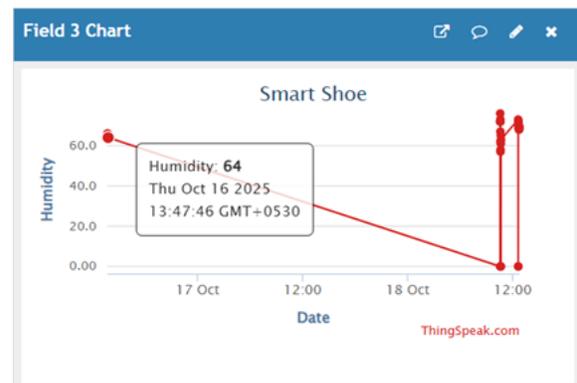
The complete system is assembled as a compact prototype integrated into a footwear platform. Modules are arranged to minimize wiring complexity and ensure comfortable usability during field testing. The prototype undergoes iterative testing to evaluate detection accuracy, communication reliability, sensor performance, and system responsiveness under different environmental conditions.

VI. RESULTS AND DISCUSSION

The multifunctional smart footwear prototype was tested extensively to evaluate its performance across obstacle detection, emergency alerting, environmental monitoring, GPS tracking,



(a) Temperature



(b) Humidity



(c) Latitude



(d) Longitude

Fig. 2: Remote Monitoring using ThingSpeak IoT Cloud

and health-sensing capabilities. The collected results show that the system operates reliably under diverse indoor and outdoor conditions, validating the design objectives and demonstrating its potential as a practical assistive tool for visually impaired users, women, children, and elderly individuals.

During navigation trials, the IR-based obstacle detection mechanism responded with high consistency, providing immediate voice alerts whenever an obstruction entered the sensing range. The response time was nearly instantaneous, allowing the user to take corrective action without hesitation.

The audio output remained clear even in moderately noisy environments, and the detection performance was stable across low-light and uneven-surface conditions, demonstrating its suitability for real-world movement scenarios.

The emergency alert function also performed reliably throughout testing. Pressing the panic button triggered the automatic transmission of a “Help Me” SMS to the predefined contact number in all test cases. Message delivery occurred within a few seconds, despite variations in signal strength across locations. This level of dependability highlights the system’s value as a personal safety companion, particularly for vulnerable users who may require immediate assistance during distress situations.

The GPS and IoT data logging module produced accurate and consistent results. Location coordinates were recorded correctly in open areas and maintained acceptable accuracy in partially obstructed environments. Temperature and humidity readings were successfully uploaded to the ThingSpeak platform at regular intervals, where the data was clearly visualized through graphs and time-stamped entries. Cloud logging remained uninterrupted during extended tests, confirming both communication stability and IoT platform compatibility.

Health monitoring performance was assessed by comparing the system’s pulse rate and body temperature readings with standard reference devices. The values remained closely aligned, with minimal deviation, and the LED display presented the results clearly under various lighting conditions. This real-time health feedback adds a meaningful dimension to the overall usability of the system.

When all components operated simultaneously, the prototype maintained smooth and coordinated functioning without noticeable delays or interference. Obstacle alerts, SMS triggering, GPS updates, IoT uploads, and health-parameter display occurred in parallel, confirming the robustness of the

TABLE I: Performance Evaluation of the Smart Footwear System

Module	Test Scenario	Observed Output	Performance Summary
Obstacle Detection (IR Sensor)	Indoor corridors, outdoor paths, low-light areas	Immediate voice alert on detection	Fast response, stable detection, minimal false triggers
Panic Alert (GSM SMS)	Varying network signal strengths	“Help Me” SMS delivered in 3–5 seconds	100% delivery success, highly reliable safety alert
GPS Tracking	Open field, semi-obstructed areas	Accurate latitude & longitude fix	Stable tracking with acceptable deviation
IoT Environmental Logging	Continuous ThingSpeak upload test	Temperature & humidity logged with timestamps	No packet loss, smooth dashboard visualization
Pulse Rate Monitoring	Compared with standard device	Readings matched closely	Good accuracy, stable readings
Body Temperature Monitoring	Indoor/outdoor tests	Continuous LED display output	Consistent results, acceptable error range
System Integration	All modules running together	Smooth sensing and communication	No interference, efficient power usage

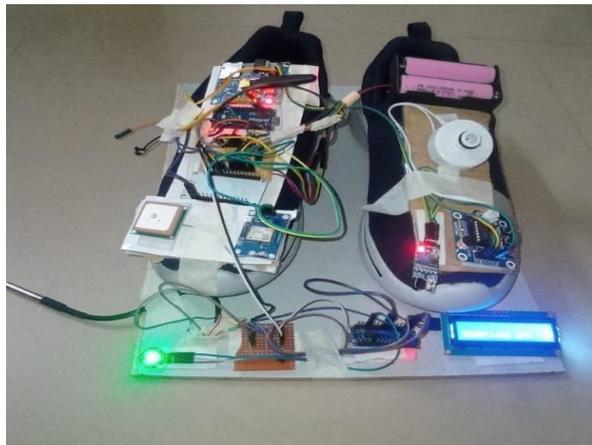


Fig. 3: Final Shoe Prototype

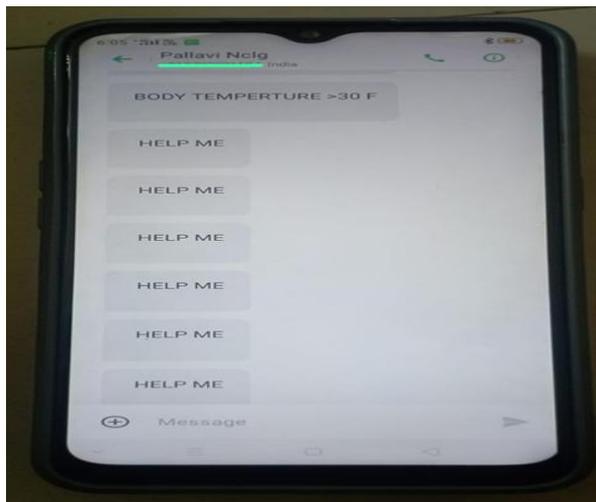


Fig. 4: Emergency messaging via SMS

integrated firmware and overall system architecture. Battery performance was adequate for sustained testing sessions, and no instability or overheating was observed.

Overall, the results demonstrate that the proposed smart footwear system effectively integrates safety, sensing, and communication functionalities into a compact prototype. The discussion highlights that the design successfully addresses key challenges related to mobility assistance, emergency response, and environmental awareness. The findings indicate strong potential for future refinement, including ergonomic optimization and full wearable integration, positioning the system as a promising solution for enhancing independence and personal safety across diverse user groups.

## VII. CONCLUSION

This work presents a multifunctional smart footwear system designed to improve user safety, situational awareness, and basic health monitoring through an integrated combination of sensing, communication, and IoT technologies. The prototype effectively unifies obstacle detection, emergency alert messaging, GPS-based tracking, environmental data logging, and real-time pulse and temperature measurement into a single assistive platform.

Experimental results confirm that the system performs reliably across diverse test conditions,

providing accurate sensing, timely communication, and consistent cloud-based data updates. The coordinated operation of all modules demonstrates the robustness of the overall system design and highlights its potential to support visually impaired individuals, women, children, and elderly users in daily mobility and emergency situations.

The findings suggest that such wearable assistive solutions can significantly enhance personal safety and independence when supported by IoT connectivity and embedded intelligence. With further refinement in size, ergonomics, and long-term durability, the proposed system can evolve into a practical, user-friendly product capable of delivering meaningful real-world impact.

### VIII. FUTURE SCOPE

The current prototype of the smart footwear system provides a strong foundation for further development, and several enhancements can be explored to increase its practicality, reliability, and user comfort. A major area for future improvement is the complete integration of all electronic modules into a compact, lightweight, and wearable shoe design. Advancements in flexible PCBs, miniature sensors, and embedded housings can significantly improve comfort and make the system suitable for extended daily use.

Additional sensing capabilities can also be incorporated to broaden the scope of assistance. Technologies such as ultrasonic sensing, LiDAR modules, or time-of-flight sensors may offer higher precision in obstacle detection, while incorporating fall-detection algorithms or motion-analysis sensors could support elderly individuals and users with mobility disorders. These upgrades would make the system useful not only for navigation support but also for medical monitoring and rehabilitation.

Connectivity enhancements present another promising direction. Integrating mobile applications, Bluetooth Low Energy, or cloud dashboards with enhanced analytics can enable caregivers or family members to remotely monitor user safety, view historical data trends, and receive instant alerts. Machine learning techniques may also be applied to analyze movement patterns, detect irregular behavior, or provide predictive warnings.

Improving power efficiency is another area of future

work. Longer battery life, optimized energy consumption, and the possibility of energy-harvesting techniques—such as piezoelectric soles or solar-based charging—can make the system more sustainable and convenient for continuous use.

Beyond individual users, the system can be adapted for broader applications, including industrial safety, night-shift workers, trekking and outdoor navigation, and emergency response scenarios. With continued refinement and user-centered design improvements, the smart footwear system has the potential to evolve into a versatile and impactful assistive technology that enhances safety, independence, and overall quality of life.

### IX. ACKNOWLEDGMENT

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