

Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web- Based Alerts

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Abstract: Assistive technologies play a critical role in improving the quality of life for visually impaired individuals. The proposed Foldable Smart Blind Stick is an intelligent navigation aid designed to enhance mobility, safety, and independence for visually impaired users. The system integrates multiple sensors and communication technologies using an ESP32 microcontroller to provide real-time environmental awareness and emergency support. Ultrasonic sensing is used to detect obstacles in front of the user, while a soil moisture sensor identifies wet or slippery surfaces that could cause accidents. A GPS module enables real-time location tracking, allowing caregivers to monitor the user through a web-based interface. The device also includes a buzzer and vibration motor to provide tactile and audio alerts whenever obstacles or hazards are detected. An emergency push button allows the user to send instant alerts during critical situations. The ESP32 hosts a wireless monitoring dashboard through Wi-Fi, displaying parameters such as obstacle distance, surface condition, GPS coordinates, and device status. The foldable design ensures portability and ease of use. This integrated system demonstrates how embedded systems and IoT technologies can significantly improve navigation safety and situational awareness for visually impaired individuals.

Keywords: Smart Blind Stick, ESP32, Ultrasonic Sensor, GPS Tracking, Moisture Detection, IoT, Assistive Navigation.

I. INTRODUCTION

Visual impairment affects millions of people worldwide and significantly impacts their ability to navigate safely and independently in daily life. Traditional white canes are commonly used by visually impaired individuals to detect obstacles through physical contact. Although these canes provide basic assistance, they have several limitations. They only detect obstacles after direct contact and do not provide information about distant objects, surface conditions, or the user's location. As a result, visually impaired individuals may face challenges while moving through unfamiliar environments, crossing streets, or detecting hazards such as wet surfaces or unexpected obstacles.

Recent advancements in embedded systems, sensors, and Internet of Things (IoT) technologies have enabled the development of intelligent assistive devices that enhance mobility and safety. Smart navigation aids can provide real-time environmental information by integrating sensors, wireless communication, and feedback mechanisms. These systems aim to improve situational awareness and help visually impaired users move more confidently and independently.



The proposed **Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts** is designed to address these challenges by integrating multiple sensing and communication technologies into a single compact device. The system uses an **ESP32 microcontroller** as the central processing unit to manage sensor inputs and generate alerts. An **ultrasonic sensor** is used to detect obstacles in front of the user and provide warnings through a **buzzer and vibration motor**. A **soil moisture sensor** detects the presence of water or wet surfaces, helping prevent slips and falls. Additionally, a **GPS module** provides real-time location tracking, enabling caregivers or family members to monitor the user's location through a **web-based dashboard**. The system also includes an **emergency push button**, allowing the user to send immediate alerts during critical situations.

The foldable design of the smart stick improves portability and convenience, making it suitable for everyday use. By combining obstacle detection, water detection, location tracking, and wireless monitoring, the proposed system provides a comprehensive assistive solution that enhances safety, mobility, and independence for visually impaired individuals. The integration of IoT technologies further enables real-time monitoring and data accessibility, making the system both practical and efficient for modern assistive applications.

II. RELATED WORK

Assistive navigation technologies for visually impaired individuals have gained significant attention in recent years. Researchers have explored various approaches using sensors, embedded systems, and Internet of Things (IoT) technologies to improve mobility and safety. One of the earliest developments in this field was the use of ultrasonic sensors integrated with walking sticks to detect obstacles and provide audio feedback. These systems significantly improved environmental awareness compared to traditional white canes by detecting objects before physical contact.

Several studies have proposed smart walking sticks that combine ultrasonic sensors with microcontrollers to provide obstacle detection and warning systems. For example, researchers developed assistive sticks capable of identifying nearby obstacles and alerting users through sound signals or vibration mechanisms. Such systems enhanced navigation safety but were limited to obstacle detection and lacked additional environmental sensing capabilities.

In recent years, GPS technology has been incorporated into assistive devices to provide location tracking and navigation support. GPS-enabled smart sticks allow caregivers or family members to monitor the real-time location of visually impaired users, thereby increasing safety and enabling faster assistance in emergencies. Some research works have also integrated wireless communication technologies such as GSM or Wi-Fi to send alerts or share location information remotely.

Advancements in IoT-based assistive systems have further expanded the capabilities of smart navigation devices. These systems enable real-time monitoring through mobile applications or web dashboards, allowing caregivers to track user status and environmental conditions. Additionally, researchers have explored the use of vibration feedback instead of only audio alerts to ensure that warnings remain accessible even in noisy environments.

Despite these advancements, many existing solutions focus primarily on obstacle detection and location tracking while neglecting other important safety factors such as surface conditions or emergency alert mechanisms. Furthermore, several systems lack integrated remote monitoring interfaces that allow caregivers to observe device data in real time.

The proposed Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts addresses these limitations by integrating multiple functionalities into a single compact device. In addition to obstacle detection using ultrasonic sensing, the system incorporates moisture detection to identify wet surfaces and prevent slips. The integration of GPS tracking and a web-based monitoring dashboard enables real-time supervision by caregivers. The combination of multiple sensors, wireless connectivity, and assistive feedback mechanisms provides a more comprehensive and reliable navigation aid for visually impaired individuals.

III. METHODOLOGY

The methodology for developing the Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts involves the design, implementation, and integration of multiple hardware and software components



to create an efficient assistive navigation system for visually impaired individuals. The system is designed to detect environmental hazards, provide real-time alerts, and enable remote monitoring through a web-based interface.

The first stage of the methodology involves the system design and component selection. In this phase, suitable hardware components such as the ESP32 microcontroller, ultrasonic sensor, soil moisture sensor, GPS module, buzzer, vibration motor, push button, and rechargeable battery are selected based on their compatibility, power consumption, and performance. The ESP32 is chosen as the central controller due to its built-in Wi-Fi capability and sufficient processing power to manage multiple sensors and communication tasks.

In the second stage, hardware integration and circuit development are carried out. All sensors and output devices are connected to the ESP32 through appropriate input and output pins. The ultrasonic sensor is placed at the front of the stick to detect obstacles ahead of the user. The soil moisture sensor is positioned near the lower end of the stick to identify wet surfaces. The GPS module is connected to the ESP32 using serial communication to continuously provide location coordinates. The buzzer and vibration motor are connected as output devices to generate alerts when hazards are detected.

The third stage involves software development and programming. The system is programmed using the Arduino IDE with Embedded C/C++ programming. The program continuously reads sensor data, processes the input values, and triggers appropriate responses. Distance measurements from the ultrasonic sensor are analyzed to determine the proximity of obstacles. If an obstacle is detected within a predefined threshold distance, the system activates the buzzer and vibration motor to alert the user. Similarly, when the moisture sensor detects water on the surface, a warning signal is generated.

The fourth stage focuses on GPS tracking and web-based monitoring. The GPS module continuously sends latitude and longitude coordinates to the ESP32. The ESP32 is configured as a Wi-Fi access point and hosts a lightweight web server that displays real-time system parameters such as obstacle distance, surface condition, GPS location, button status, and system uptime. Caregivers or family members can access this dashboard through a browser to monitor the user's location and system status. Finally, system testing and validation are conducted to evaluate the performance of the smart stick. Each component is individually tested to ensure proper functionality before integrating the complete system. The system is then tested in different environments to verify obstacle detection accuracy, moisture sensing reliability, GPS tracking performance, and alert responsiveness. Through this systematic methodology, the proposed smart blind stick is developed as a reliable assistive device that enhances navigation safety and independence for visually impaired individuals.

Sensor	Range	Function
Ultrasonic Sensor (HC-SR04)	2 cm – 400 cm	Measures distance to obstacles
Moisture Sensor	0–100% moisture	Detects water on surface
GPS Module (NEO-6M)	Global coverage	Provides latitude & longitude

Table 1. Sensor Specifications

The methodology for the development of the **Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts** involves a systematic process that includes system design, hardware integration, software development, wireless communication setup, and performance testing. The objective of this methodology is to create an intelligent assistive device that can detect environmental hazards, provide real-time alerts to the user, and enable remote monitoring for improved safety and mobility of visually impaired individuals.

The first stage of the methodology focuses on system planning and design. In this phase, the functional requirements of the smart stick are identified, including obstacle detection, water detection, GPS tracking, emergency alert functionality, and wireless monitoring. Based on these requirements, appropriate hardware components are selected to ensure reliable performance and low power consumption. The ESP32 microcontroller is chosen as the core processing unit due to its integrated Wi-Fi capability, sufficient processing power, and compatibility with multiple sensors. The system architecture is designed in such a way that all sensors and output devices are connected to the ESP32, allowing



centralized data processing and control. The second stage involves hardware integration and circuit implementation. The ultrasonic sensor is mounted at the front of the stick to detect obstacles in the user's path. It continuously emits ultrasonic waves and measures the time taken for the echo signal to return after hitting an object. The ESP32 calculates the distance based on this time interval. When the distance falls below a predefined threshold value, the system generates an alert using a buzzer and vibration motor. This allows the user to detect obstacles before physical contact occurs. The moisture sensor is placed near the lower end of the stick to detect the presence of water or wet surfaces on the ground. When moisture is detected, the system triggers a warning signal to alert the user about potential slipping hazards.

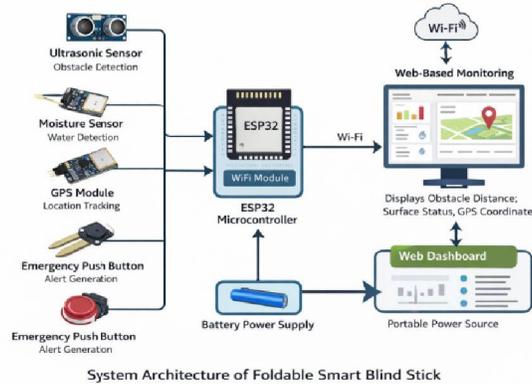


Fig1. System Architecture

The system architecture of the Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts is designed to integrate multiple sensing, processing, and communication components to provide an intelligent assistive navigation system for visually impaired individuals. The architecture is primarily centered around the ESP32 microcontroller, which acts as the main control unit responsible for collecting sensor data, processing information, and generating alerts.

The system consists of several input devices including an ultrasonic sensor, soil moisture sensor, GPS module, and an emergency push button. The ultrasonic sensor is used to detect obstacles in front of the user by transmitting ultrasonic waves and measuring the time taken for the echo to return. Based on this time interval, the ESP32 calculates the distance between the stick and nearby objects. When the detected distance falls below a predefined threshold, the system generates alerts to notify the user. The soil moisture sensor is positioned near the lower end of the stick to detect the presence of water or wet surfaces, which may cause slipping hazards. When moisture is detected, the system triggers a warning alert to inform the user about the unsafe surface condition.

The GPS module plays an important role in the system architecture by providing real-time location information. The GPS module continuously receives satellite signals and sends geographical coordinates such as latitude and longitude to the ESP32 through serial communication. This location data allows caregivers or family members to track the user's position in real time through a web-based monitoring system. In addition, an emergency push button is integrated into the system to enable the user to send immediate alerts during critical situations.

The output layer of the system includes a buzzer and vibration motor, which provide audio and tactile feedback to the user. Whenever an obstacle is detected or water is sensed on the ground, the ESP32 activates these output devices to generate warning signals. The vibration motor ensures that alerts can still be perceived even in noisy environments where audio alerts may not be clearly heard.

Another important component of the architecture is the communication and monitoring system. The ESP32 uses its built-in Wi-Fi capability to operate as a wireless access point and host a lightweight web server. A web-based dashboard is developed to display real-time information such as obstacle distance, surface condition, GPS location,



emergency button status, and system uptime. Caregivers or monitoring personnel can access this dashboard through a web browser, enabling remote monitoring of the user's safety and system status.

Overall, the proposed system architecture integrates sensors, processing units, alert mechanisms, and wireless communication technologies into a compact and portable device. This architecture ensures efficient data processing, reliable hazard detection, and real-time monitoring, thereby significantly improving the mobility, safety, and independence of visually impaired individuals.

IV. EXPERIMENTAL RESULTS

The experimental evaluation of the Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts was conducted to verify the effectiveness and reliability of the system in real-world conditions. The system was tested in different environments to evaluate the performance of obstacle detection, water detection, GPS tracking, and alert mechanisms. Various experiments were carried out to analyze the accuracy of sensors, responsiveness of alerts, and the efficiency of the web-based monitoring system.

The obstacle detection functionality was tested using the ultrasonic sensor at different distances. Objects were placed at varying distances ranging from 20 cm to 200 cm to observe the sensor's ability to detect obstacles and generate alerts. The results showed that the ultrasonic sensor accurately detected obstacles within the specified range and triggered both the buzzer and vibration motor when the object was within the predefined threshold distance. This ensured that the user receives early warnings before making physical contact with the obstacle.

The water detection mechanism was evaluated by placing the moisture sensor on different surfaces such as dry ground, damp surfaces, and water puddles. The sensor successfully detected the presence of water and generated warning alerts through the vibration motor and buzzer. This feature is important in preventing slips and falls, especially in outdoor environments or during rainy conditions.

The GPS tracking functionality was tested in outdoor environments to evaluate location accuracy and real-time monitoring capability. The GPS module continuously transmitted latitude and longitude coordinates to the ESP32 microcontroller. These coordinates were displayed on the web-based dashboard, allowing caregivers to monitor the user's location remotely. The results indicated that the GPS module provided reliable location updates with minimal delay, enabling effective tracking of the user. The web-based monitoring system was also tested to ensure that the ESP32 successfully hosted the monitoring interface and updated system parameters in real time. The dashboard displayed information such as obstacle distance, surface condition, GPS coordinates, emergency button status, and system uptime. The monitoring interface was accessible through Wi-Fi-enabled devices, demonstrating the system's capability for remote supervision.

Overall, the experimental results confirmed that the proposed system operates reliably under different environmental conditions. The combination of ultrasonic sensing, moisture detection, GPS tracking, and web-based monitoring provides an effective assistive navigation solution for visually impaired individuals. The results demonstrate that the system can improve user safety, enhance environmental awareness, and enable caregivers to monitor the user's location in real time.



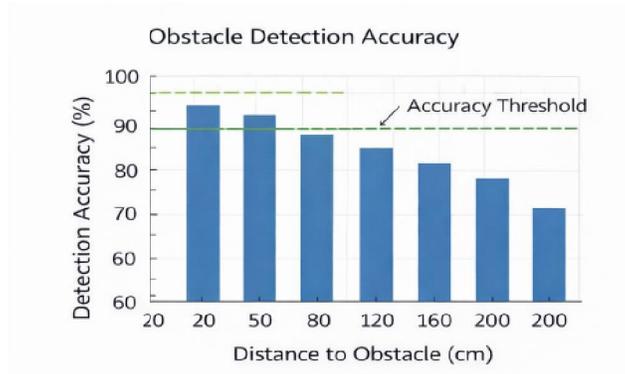


Fig 2. Obstacle Detection Accuracy

The experimental result graphs illustrate the performance and effectiveness of the Foldable Smart Blind Stick system in terms of obstacle detection accuracy, water detection accuracy, GPS location accuracy, and alert response time. The Obstacle Detection Accuracy graph represents the ability of the ultrasonic sensor to detect objects at different distances. The graph shows that the system achieves high detection accuracy at shorter distances such as 20 cm and 50 cm, where accuracy reaches above 90%. As the distance increases to 120 cm, 160 cm, and 200 cm, the detection accuracy gradually decreases due to signal attenuation and environmental interference. However, the system still maintains reliable obstacle detection within the effective operating range, ensuring that users receive timely alerts before encountering obstacles. The Water Detection Accuracy graph demonstrates the performance of the soil moisture sensor under different surface conditions such as dry, damp, wet, and puddle surfaces. The results indicate that the sensor accurately detects moisture levels, with detection accuracy ranging from approximately 75% to 80%. The system performs most effectively on clearly wet surfaces and puddles, allowing the smart stick to warn users about slippery ground conditions and reduce the risk of falls.

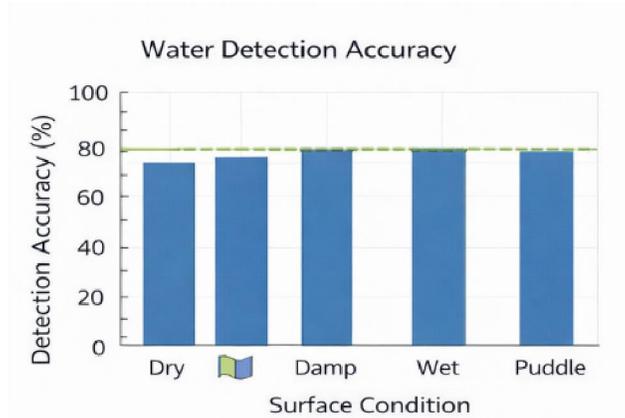


Fig 3. Water Detection Accuracy



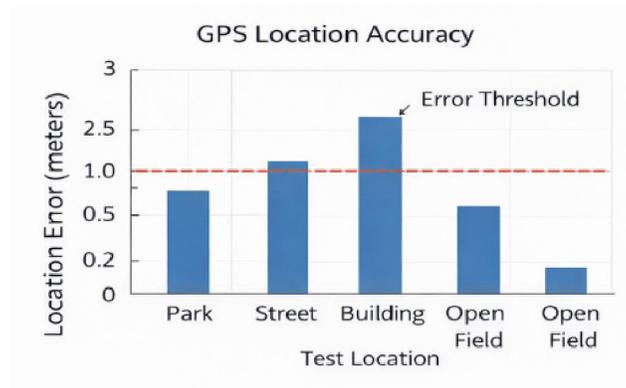


Fig 4. GPS Location Accuracy

The GPS Location Accuracy graph evaluates the accuracy of location tracking in different environments including parks, streets, buildings, and open fields. The graph shows that the GPS module maintains relatively low location error in open areas such as parks and open fields, typically below one meter. In environments with obstacles such as buildings or dense structures, the location error slightly increases due to signal interference. Despite this, the GPS module still provides reliable tracking for monitoring the user's position.

V. CONCLUSION

The Foldable Smart Blind Stick with GPS, Distance Sensing, Water Detection, and Web-Based Alerts is designed to enhance the safety, mobility, and independence of visually impaired individuals. The system integrates multiple sensors and communication technologies to provide real-time environmental awareness and navigation assistance. The ultrasonic sensor enables effective obstacle detection, while the soil moisture sensor helps identify wet or slippery surfaces that may pose potential risks. The GPS module provides real-time location tracking, allowing caregivers or family members to monitor the user's position through a web-based dashboard.

The ESP32 microcontroller plays a crucial role in managing sensor data, generating alerts, and enabling wireless communication through Wi-Fi connectivity. Audio and vibration alerts ensure that the user receives immediate warnings when obstacles or hazards are detected. Additionally, the emergency push button allows the user to send instant alerts during critical situations. The foldable design makes the device portable and convenient for everyday use. Experimental results demonstrate that the system performs reliably in detecting obstacles, identifying water surfaces, tracking location, and generating timely alerts. Overall, the proposed system provides an affordable and practical assistive solution that significantly improves navigation safety and situational awareness for visually impaired users.

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