KeAi CHINESE ROOTS GLOBAL IMPACT

International Journal of Innovation Studies

IOT-BASED SMART BLIND STICK WITH LOCATION & OBSTACLE DETECTION

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ABSTRACT

Visually impaired individuals face significant challenges in navigating their surroundings safely and independently. Traditional white canes provide basic obstacle detection but lack advanced features such as remote monitoring and emergency location sharing. This project proposes an IoT-based smart blind stick designed to enhance mobility and safety for visually impaired users. The system is built around the ESP32 microcontroller integrated with an ultrasonic sensor for obstacle detection and a water sensor for identifying wet surfaces. A GPS module is used to obtain real-time location information. When the blind stick is powered on, the device automatically connects to Wi-Fi and sends an activation message to a predefined Telegram account. Additionally, when the user double-taps the switch, the current GPS location is transmitted via Telegram, enabling caregivers to track the user during emergencies.

The proposed solution is portable, low-cost, and easy to operate. By combining sensing, IoT connectivity, and real-time communication, the smart blind stick significantly improves the safety, confidence, and independence of visually impaired individuals.

Keywords: Smart Blind Stick, IoT, ESP32, Ultrasonic Sensor, GPS Tracking, Telegram Alert, Assistive Technology

1.1 INTRODUCTION

Visually impaired individuals encounter numerous challenges while navigating their environment independently. Traditional white canes provide basic support for obstacle detection; however, they lack intelligent features such as real-time alerts, environmental sensing, and remote location sharing. With the rapid advancement of Internet of Things (IoT) technology, assistive devices can be enhanced to provide smarter, safer, and more connected mobility solutions.

This project proposes an IoT-based smart blind stick designed to improve the safety and independence of visually impaired users. The system is built around the ESP32 microcontroller, which integrates sensing, processing, and wireless communication capabilities. An ultrasonic sensor is employed to detect obstacles in front of the user, while a water sensor is used to identify wet or puddle-prone surfaces that may pose a slipping hazard. These sensing mechanisms help users navigate more confidently in real-time.

To further enhance user safety, a GPS module is incorporated to provide real-time location tracking. When the blind stick is powered on, the system automatically connects to Wi-Fi and sends an activation message to a predefined Telegram account. Additionally, a double-tap action on the control switch triggers the transmission of the user's current GPS coordinates via Telegram, enabling caregivers or family members to monitor the user's location during emergencies.

By combining IoT connectivity, environmental sensing, and instant communication, the proposed smart blind stick offers a low-cost, portable, and efficient assistive solution. The system aims to reduce mobility risks, enhance user confidence, and support independent navigation for visually impaired individuals in real-world environments.

SYSTEM ANALYSIS

1.2.1 Existing System

The existing mobility aids used by visually impaired individuals primarily consist of the traditional white cane. While the conventional blind stick is simple, low-cost, and widely used, it provides only basic assistance for detecting nearby obstacles through physical contact. These systems lack intelligent sensing capabilities, real-time communication features, and remote monitoring support.

In the current scenario, visually impaired users must rely heavily on manual feedback and external assistance for safe navigation. Traditional sticks cannot detect obstacles at a distance, identify water or puddles on the ground, or share the user's location during emergencies. As a result, users remain vulnerable to accidents, especially in unfamiliar or crowded environments.

Some advanced electronic travel aids have been proposed, but many of them are expensive, bulky, or limited in functionality. Most existing solutions do not integrate Internet of Things (IoT) connectivity or instant alert mechanisms through modern communication platforms such as Telegram. Furthermore, real-time location sharing features are often absent or require complex standalone devices.

Traditional White Cane

The traditional white cane is the most commonly used mobility aid for visually impaired individuals. It helps users detect obstacles through physical contact with objects in their immediate path. The device is simple, lightweight, and affordable, making it widely accessible. However, it provides only limited functionality and relies entirely on the user's manual sensing ability.

Traditional white canes cannot detect obstacles at a distance, identify hazardous conditions such as water puddles, or provide any form of remote communication. They also lack real-time location tracking features that could assist caregivers in monitoring the user's safety during

emergencies. As a result, visually impaired users remain vulnerable to unexpected obstacles and environmental risks, particularly in unfamiliar surroundings.
Furthermore, conventional canes do not incorporate modern IoT capabilities or smart alert systems that can enhance independent navigation. These limitations highlight the need for an intelligent, sensor-based blind stick that can provide proactive obstacle detection, environmental awareness, and emergency location

Basic Electronic Blind Stick

Basic electronic blind sticks are enhanced versions of the traditional white cane that incorporate simple sensors such as ultrasonic modules for obstacle detection. These devices provide audio or vibration alerts when an object is detected within a certain range. While they represent an improvement over conventional canes, their functionality remains limited in several important aspects.

Most existing electronic blind sticks focus only on obstacle detection and do not include environmental sensing features such as water detection, which is crucial for avoiding slippery surfaces. Additionally, many of these systems lack Internet of Things (IoT) connectivity, preventing real-time communication with caregivers or family members.

Furthermore, current solutions typically do not provide location tracking or emergency alert mechanisms. In situations where the user requires assistance, there is no automatic way to share their live location. Some advanced models that include tracking features are often expensive and not easily affordable for widespread use.

These limitations indicate the need for a more comprehensive, low-cost, and connected smart blind stick that integrates obstacle detection, water sensing, and real-time location sharing through modern communication platforms.

Manual Navigation Methods

Many visually impaired individuals rely solely on manual navigation methods, such as using a traditional white cane and depending on personal experience or assistance from others while traveling. This approach is simple, inexpensive, and does not require any electronic components or technical knowledge. However, it provides only limited situational awareness and depends heavily on the user’s physical sensing ability and environmental familiarity.

Manual navigation methods are prone to human limitations and cannot provide early warnings for distant obstacles or hazardous conditions such as wet surfaces. They also lack any mechanism for emergency communication or real-time location sharing with caregivers. In unfamiliar or crowded environments, this reliance on manual sensing increases the risk of accidents and reduces user confidence.

Furthermore, these conventional practices do not leverage modern sensing or IoT technologies that could significantly enhance independent mobility. As a result, manual navigation remains less reliable and less safe compared to intelligent, sensor-based assistive systems.

Standalone Tracking Devices

Some visually impaired users and caregivers rely on standalone GPS tracking devices or mobile phone tracking applications to monitor user location. These tools can provide basic location information and may assist in emergency situations. They are useful for tracking purposes and can improve user safety to a certain extent.

However, these systems function independently and are not integrated with mobility aids such as the blind stick. As a result, they do not assist in real-time navigation or obstacle detection.

Users must carry and manage separate devices, which can be inconvenient and less practical during daily movement.
Moreover, standalone tracking solutions do not provide environmental awareness features such as obstacle detection or water sensing. They also typically lack smart trigger mechanisms (such as a double-tap emergency alert) that allow the user to quickly send their location when needed. This limited functionality reduces their effectiveness as a complete assistive solution.
These shortcomings highlight the need for an integrated smart blind stick that combines navigation assistance, environmental sensing, and real-time location sharing within a single portable device.

Limitations of the Existing System
Despite providing basic mobility assistance, existing systems for visually impaired individuals fail to deliver a comprehensive and intelligent navigation solution. Some key limitations are outlined below:

1. **Limited Obstacle Detection Range:**

Traditional white canes detect obstacles only upon physical contact, providing no early warning for objects at a distance. This increases the risk of collisions and reduces user confidence during movement.
2. Lack of Environmental Awareness:
Most conventional and basic electronic blind sticks do not detect hazardous conditions such as water puddles or wet surfaces. The absence of such sensing capabilities exposes users to slipping and safety risks.
3. No Integrated Location Sharing:
Existing mobility aids typically lack built-in GPS tracking and emergency communication features. In critical situations, users cannot easily share their real-time location with caregivers or family members.
4. Fragmented Assistive Solutions:
Some users rely on separate devices for navigation, obstacle detection, and location tracking. Managing multiple devices is inconvenient, increases system complexity, and reduces overall usability.
5. Lack of IoT Connectivity and Smart Alerts:
Many existing solutions do not utilize modern IoT platforms for real-time notifications. The absence of instant alert systems (such as Telegram messaging) limits remote monitoring and emergency response capabilities.
6. Cost and Accessibility Issues in Advanced Systems:
Some advanced electronic travel aids are expensive, bulky, or complex to operate, making them less accessible for widespread adoption among visually impaired users.

1.3 PROPOSED METHODOLOGY & ARCHITECTURE
The proposed IoT-based Smart Blind Stick aims to overcome the limitations of conventional mobility aids by integrating environmental sensing, real-time communication, and location tracking into a single portable device. The system is designed to enhance the safety, independence, and confidence of visually impaired individuals through intelligent automation and IoT connectivity.

The architecture of the proposed system is centered around the ESP32 microcontroller, which manages sensor data processing, wireless communication, and alert generation. The device continuously monitors the surroundings using multiple sensors and provides instant updates to caregivers via Telegram. The following are the key features and functionalities of the proposed system:

1. Obstacle Detection Using Ultrasonic Sensor
An ultrasonic sensor is mounted on the blind stick to detect obstacles in front of the user. The sensor measures the distance to nearby objects using echo reflection principles. When an obstacle is detected within a predefined threshold distance, the system can trigger an alert mechanism (such as buzzer or vibration in extended versions), enabling the user to avoid collisions safely.
2. Water Detection for Surface Safety
A water sensor is placed near the bottom of the stick to detect wet surfaces or puddles. When moisture is detected, the ESP32 processes the signal and can generate a warning alert. This feature helps prevent slipping accidents and improves environmental awareness, especially during rainy conditions.

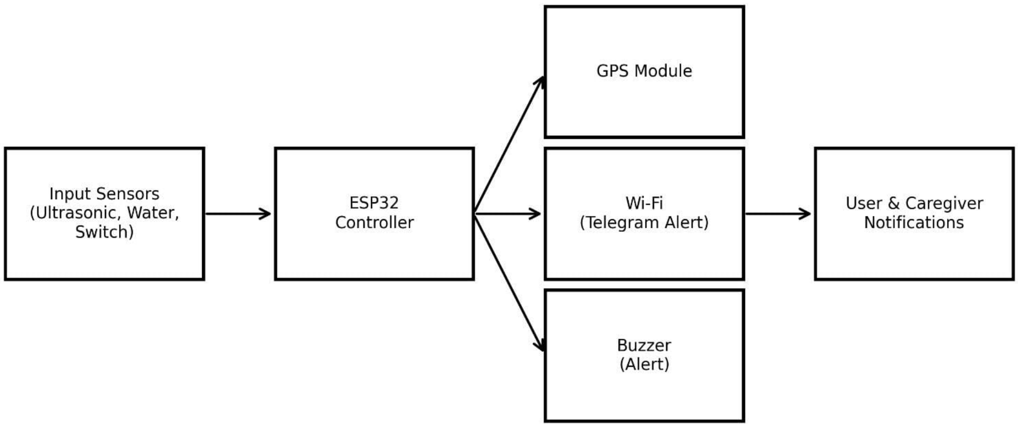
3. GPS-Based Location Tracking
The system integrates a GPS module to obtain real-time latitude and longitude coordinates of the user. This enables accurate outdoor tracking and enhances user safety. The location data is processed by the ESP32 and prepared for transmission when required.
4. Telegram Alert on Stick Activation
When the blind stick is switched ON, the ESP32 connects to Wi-Fi and automatically sends an activation message to a predefined Telegram account. This confirms that the device is active and allows caregivers to monitor usage status remotely.
5. Emergency Location Sharing via Double-Tap Switch
A smart double-tap detection mechanism is implemented using the control switch. When the user double-taps the switch, the ESP32 immediately retrieves the current GPS coordinates and sends the live location to Telegram. This provides a quick and simple emergency communication method.
6. IoT Connectivity and Real-Time Communication
Using the built-in Wi-Fi capability of the ESP32, the system maintains real-time communication with the Telegram platform. This IoT-based approach ensures instant alerts, remote monitoring, and improved response during emergency situations.
7. Portable Power Management System
The device is powered using a rechargeable battery system that includes a battery case, charging module, and buck converter for voltage regulation. The design ensures portability, energy efficiency, and reliable field operation.
Advantages of the Proposed System
Integrates obstacle detection, water sensing, and GPS tracking into a single compact device.

- Provides real-time alerts and remote monitoring through Telegram connectivity.
- Enhances user safety by detecting obstacles before physical contact occurs.

• Enables quick emergency assistance through double-tap location sharing.
• Portable, lightweight, and easy for visually impaired users to operate.
• Cost-effective compared to many advanced electronic travel aids.
• Reduces dependency on external assistance and improves independent mobility.
• Utilizes IoT technology for instant communication and smart functionality.

This comprehensive solution addresses the limitations of traditional mobility aids by offering an intelligent, connected, and user-friendly smart blind stick that significantly improves safety and confidence for visually impaired individuals.

Fig 1: Proposed System Architecture



1.3.2 Input Design

The proposed IoT-based Smart Blind Stick system integrates environmental sensing, user interaction, and location tracking to ensure safe and independent navigation for visually impaired users. The system consists of three main input modules: Obstacle Detection, Wet-Ground Detection, and User Trigger & Location Input.

1. Obstacle Detection Module

The ultrasonic sensor continuously captures distance measurements of objects in front of the user. The sensor transmits ultrasonic waves and receives the reflected echo to calculate the distance to nearby obstacles. The ESP32 reads this data in real time and compares it with a predefined threshold value. If an obstacle is detected within the unsafe range, the system activates the buzzer to alert the user.

2. Wet-Ground Detection Module

The water sensor is placed near the bottom of the blind stick to detect the presence of water or wet surfaces. When the sensor probes come into contact with moisture, an electrical signal is generated and sent to the ESP32. The controller processes this input and triggers an audio alert through the buzzer, warning the user about slippery ground conditions.

3. User Trigger and Location Input Module

A push switch is used both for powering the device and for emergency triggering through a double-tap mechanism. The GPS module continuously acquires satellite data and provides real-time latitude and longitude coordinates to the ESP32. When a double-tap is detected on the switch, the controller fetches the current GPS location and prepares it for transmission to Telegram via Wi-Fi.

The system integrates these input modules within the ESP32-based embedded platform. Sensor readings and user-triggered events are processed in real time to generate appropriate alerts and notifications. The design ensures fast response, low power consumption, and reliable operation for assistive mobility applications.

DATA FLOW DIAGRAM

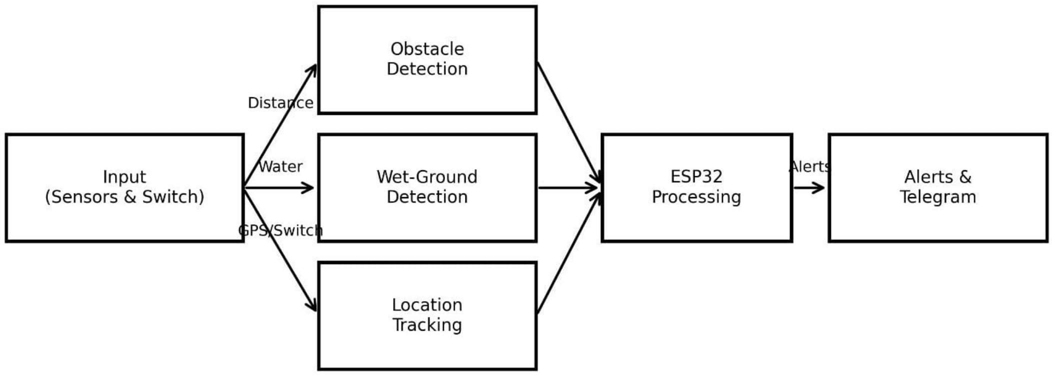


Table Design

The Smart Blind Stick system maintains structured data records for device activity, sensor readings, and alert notifications. The following tables are designed to manage system data efficiently.

1. Device Status Table

- Device_ID: Unique identifier for each blind stick device.
- Activation_Time: Timestamp when the stick is powered ON.
- WiFi_Status: Connection status (Connected / Disconnected).
- Battery_Level: Current battery percentage (if monitored).

2. Obstacle Detection Table

- Record_ID: Unique identifier for each reading.
- Timestamp: Date and time of detection.
- Distance_Value: Measured distance from ultrasonic sensor (in cm).
- Obstacle_Status: Safe / Obstacle Detected.

3. Water Detection Table

- Record_ID: Unique identifier for each reading.
- Timestamp: Date and time of detection.
- Water_Status: Dry / Wet Detected**.**

4. Location Alert Table

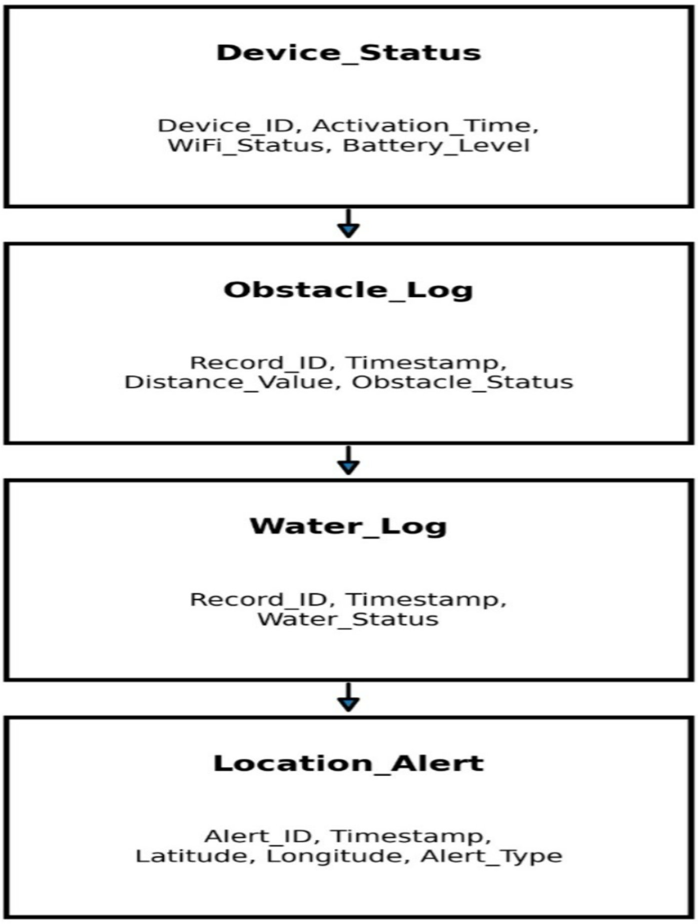
- Alert_ID: Unique identifier for each emergency alert.

- Timestamp: Date and time of alert.
- Latitude: GPS latitude value.
- Longitude: GPS longitude value.
- Alert_Type: Activation Alert / Emergency Location Alert.

5. Notification Log Table

- Notification_ID: Unique ID for each Telegram message sent.
- Timestamp: Date and time of notification.
- Message_Type: Activation / Obstacle / Water / Location.
- Delivery_Status: Sent / Failed.

UML DIAGRAM:



Input Design

The proposed IoT Smart Blind Stick system accepts real-time sensor and user-trigger inputs to ensure safe navigation and emergency communication. The system primarily processes three types of inputs:

1. Distance Data (Ultrasonic Sensor)

The ultrasonic sensor continuously captures distance measurements of objects in front of the user. The sensor sends trigger and echo signals to the ESP32, which calculates the distance in centimeters. This input is validated against a predefined safety threshold. If the measured distance falls below the safe limit, the system flags it as an obstacle condition.

2. Wet Surface Data (Water Sensor)

The water sensor detects the presence of moisture or wet ground near the tip of the blind stick. When water is detected, the sensor outputs a digital/analog signal to the ESP32. The controller validates the signal to avoid false triggering due to noise or brief contact and then classifies the surface condition as dry or wet.

3. User Trigger and GPS Location Data

A push switch provides user input for powering the device and initiating an emergency alert through a double-tap action. Simultaneously, the GPS module continuously receives satellite data and provides latitude and longitude coordinates. When a valid double-tap is detected, the ESP32 fetches the latest GPS data for transmission.

All incoming inputs are validated by the ESP32 firmware to ensure reliability and accuracy. Invalid readings, signal noise, or temporary GPS unavailability are handled through filtering and retry mechanisms to maintain stable system performance.

Implementation

The proposed Smart Blind Stick system is implemented using embedded C/C++ on the ESP32 platform, utilizing the Arduino IDE for firmware development. The ESP32 integrates sensor processing, Wi-Fi communication, and alert management into a single embedded solution. The system combines real-time sensing, IoT messaging, and location tracking to assist visually impaired users.

ESP32 Firmware:

The ESP32 acts as the central controller that reads inputs from the ultrasonic sensor, water sensor, GPS module, and user switch. The firmware continuously monitors sensor data, applies threshold logic, and manages alert generation. Wi-Fi connectivity is configured to enable communication with the Telegram Bot API.

Obstacle Detection Logic:

Distance data from the ultrasonic sensor is processed to identify nearby obstacles. If the measured distance falls below the predefined safety threshold, the ESP32 activates the buzzer to warn the user. Basic filtering is applied to reduce noise and false detections.

Wet Surface Detection:

The water sensor output is monitored to detect the presence of moisture. When wet ground is confirmed, the controller triggers an audio alert through the buzzer, helping the user avoid slippery areas.

GPS and Emergency Alert Integration:

The GPS module continuously acquires satellite data and provides latitude and longitude coordinates. A double-tap detection algorithm is implemented on the push switch. Upon detecting a valid double-tap, the ESP32 retrieves the current GPS location and sends it to the predefined Telegram account.

Telegram IoT Communication:

Using the built-in Wi-Fi capability, the ESP32 connects to the internet and communicates with the Telegram Bot API. The system sends:

Stick activation message when powered ON

Live location during emergency trigger

The integrated embedded approach ensures low latency, low power consumption, and reliable real-time performance, making the system suitable for practical assistive mobility applications

Testing

The proposed Smart Blind Stick system is evaluated through unit testing, integration testing, performance testing, and user acceptance testing to ensure reliability, accuracy, and real-time responsiveness.

1. Unit Testing

Unit testing is performed on individual hardware and software modules to verify their correct operation.

- Ultrasonic sensor distance measurement accuracy
- Water sensor wet/dry detection reliability
- GPS module location acquisition
- Double-tap switch detection
- Buzzer activation logic
- Wi-Fi and Telegram message transmission

Each component is tested independently to ensure proper functionality before system integration.

2. Integration Testing

Integration testing validates the coordinated operation of all modules when connected to the ESP32.

- Sensor data correctly processed by ESP32
- Obstacle detection triggers buzzer
- Water detection triggers buzzer
- Double-tap successfully sends GPS location
- Stick activation message sent to Telegram

This testing ensures smooth data flow and correct interaction between hardware and firmware components.

3. Performance Testing

Performance testing evaluates the system under real-world operating conditions.

- Response time of obstacle detection
- GPS fix time and accuracy
- Wi-Fi connection stability
- Telegram message delivery time
- Power consumption and battery backup

The goal is to ensure the system operates reliably with minimal delay and efficient power usage.

4. User Acceptance Testing (UAT)

User acceptance testing is conducted with trial users to evaluate usability and practical effectiveness.

- Ease of handling the smart stick
- Clarity of buzzer alerts
- Reliability of emergency location sharing

- Overall user confidence and safety improvement

Feedback from users is used to refine threshold values, alert behavior, and system responsiveness.

Testing Metrics

The system performance is evaluated using:

- Detection accuracy
- Alert response time
- GPS location accuracy
- Message delivery success rate
- Power efficiency

Errors and anomalies observed during testing are logged and iteratively corrected to improve overall system robustness and reliability.

1.4 CONCLUSION

In this project, an IoT-based Smart Blind Stick has been successfully designed and developed to enhance the safety and independent mobility of visually impaired individuals. The proposed system integrates the ESP32 microcontroller with an ultrasonic sensor, water sensor, GPS module, and buzzer to provide real-time environmental awareness and emergency communication capabilities.

The ultrasonic sensor effectively detects obstacles in the user's path, while the water sensor identifies wet or slippery surfaces, helping to reduce the risk of accidents. The integration of the GPS module enables real-time location tracking, and the implementation of Telegram-based IoT communication allows caregivers to receive instant notifications. The double-tap switch mechanism provides a simple and reliable method for users to send their live location during emergencies.

The system is portable, cost-effective, and easy to operate, making it suitable for practical real-world deployment. Testing results demonstrate that the smart blind stick responds quickly to environmental changes and reliably transmits alerts. By combining sensing technology with IoT connectivity, the proposed solution significantly improves user confidence, safety, and independence.

Overall, the developed smart blind stick represents an efficient assistive mobility solution. With further enhancements such as vibration feedback, GSM support, and improved indoor positioning, the system can be extended into a more robust and widely deployable assistive device for visually impaired users.

1.5 FUTURE ENHANCEMENTS

The proposed IoT Smart Blind Stick provides an effective assistive solution for visually impaired users; however, there is significant scope for further improvement and expansion. Future enhancements can focus on improving usability, reliability, and intelligent decision-making capabilities.

One potential enhancement is the integration of a vibration motor or voice feedback system to provide multimodal alerts in addition to the buzzer, thereby improving user awareness in noisy environments. The system can also be upgraded with a GSM or LTE communication module to

enable location sharing without relying on Wi-Fi connectivity, making the device more reliable in outdoor conditions.
Another important improvement would be the incorporation of advanced obstacle detection techniques such as camera-based object recognition using computer vision and machine learning. This would allow the system to classify obstacles (e.g., vehicles, stairs, potholes) and provide more context-aware assistance. Indoor positioning technologies such as Bluetooth beacons or ultra-wideband (UWB) could also be integrated to enhance navigation in GPS-denied environments.
Power management can be further optimized by implementing sleep modes and battery health monitoring to extend operational life. Additionally, the physical design of the blind stick can be improved to make it more lightweight, foldable, and ergonomically comfortable for long-term use.
Finally, a dedicated mobile application or caregiver dashboard could be developed to provide real-time tracking, device status monitoring, and configurable alert settings. With these enhancements, the smart blind stick can evolve into a more intelligent, reliable, and widely deployable assistive mobility solution for visually impaired individuals.

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