A Survey on AI-Powered Smart Assistive cane for visually impaired using IoT and computer vision

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***Abstract*—This project introduces a smart cane designed for visually impaired individuals, leveraging Artificial Intelligence (AI) and Internet of Things (IoT) technologies to provide safe and independent navigation. The cane features a camera module and ultrasonic sensors that work together to detect nearby obstacles and approaching vehicles. Using AI-based processing, it identifies potential threats in real time and alerts the user through a Bluetooth-connected earpiece. For added safety, an optional mobile application allows guardians to monitor the user's location and receive notifications, ensuring remote support when needed.**

The cane operates offline using Edge AI, eliminating the need for constant internet connectivity—making it highly reliable, especially in regions with poor network coverage. Designed for practical, everyday use, it is lightweight, water-resistant, and rechargeable. Unlike many concept-stage academic projects, this smart cane is developed as a fully functional and scalable solution with real-world deployment in mind. Its goal is to provide a meaningful assistive tool that can genuinely improve the daily lives of visually impaired individuals.

I. INTRODUCTION

This report outlines the development of a smart assistive cane designed to improve mobility and safety for the visually impaired, a community of over 4.8 million in India. Traditional white canes are limited as they only detect obstacles through physical contact, and no existing affordable solutions offer early vehicle detection or offline navigation. Our proposed smart cane integrates AI, IoT, camera vision, and sensor fusion to address these gaps. Specifically developed with local usability for Kerala's environments in mind, the device provides AI-based obstacle and vehicle detection, delivering alerts via a Bluetooth earpiece. It features an offline mode using Edge AI for navigation without internet and an optional app for guardian support, making it a scalable and functional assistive tool.

A. Background

The proposed Smart Cane project directly addresses the mobility challenges faced by over 4.8 million visually impaired individuals in India. Traditional white canes offer limited functionality, detecting obstacles only through direct physical contact, while existing market solutions often fall short in affordability, early vehicle detection, voice guidance, and offline navigation—creating a significant usability gap, especially under Indian conditions. To overcome these limitations, the Smart Cane integrates AI, IoT, camera vision, and sensor fusion technologies to enhance user safety and independence. Designed specifically for local environments such as those found in Kerala, the cane features AI-powered obstacle and vehicle detection using a camera and ultrasonic sensors, with real-time alerts delivered through a Bluetooth connected earpiece. A standout feature is its offline capability via Edge AI, eliminating the need for continuous internet access. Additionally, an optional mobile application enables guardians to monitor the user's location for added support. The device is engineered to be rechargeable, lightweight, and water-resistant, making it a practical and scalable assistive solution for daily use.

B. Problem Statement

Visually impaired individuals in India face significant challenges in navigating public spaces, particularly when crossing roads where the risk of accidents is high. Their ability to detect obstacles and moving vehicles is limited, and many struggle to access app-based support due to unreliable or unavailable internet connectivity. Existing assistive solutions in the market fall short in several critical areas. Most lack dependable, real-time detection capabilities for dynamic environments, making them ineffective in fast-changing or crowded settings. Furthermore, many devices do not offer offline functionality, which restricts their usability in regions with poor network coverage. Additionally, these solutions are often not tailored to the practical realities of Indian conditions, such as uneven terrain, unpredictable traffic, and varied weather, resulting in a substantial gap between technological offerings and user needs. Addressing these deficiencies is essential for developing inclusive, contextaware assistive technologies.

C. Motivation

India's 4.8 million visually impaired individuals face serious mobility risks due to the limitations of traditional white canes and the inaccessibility of existing tech solutions. Most advanced aids are costly, lack key features like early vehicle detection and offline navigation, and depend on internet access—making them impractical in many Indian settings. This project aims to develop an affordable, AI-powered smart cane tailored for real-world use in Kerala, bridging critical usability gaps and empowering users with safer, more independent mobility.

D. Contributions

This survey paper aims to:

1. The project aims to significantly improve the safety and mobility of visually impaired individuals by creating a smart cane that offers real-time detection of both static obstacles and moving vehicles.
2. A core objective is to create an affordable and scalable assistive tool that is practical for real-world use, particularly within Indian conditions like Kerala's environments.
3. Designing it to be lightweight, rechargeable, and water-resistant for practical daily use.

II. RELATED WORKS

A. Sensor-Based Systems:

This reliance on ultrasonic and infrared sensors in foundational smart canes and wearables means the devices primarily function as advanced proximity alarms rather than true navigation aids. These sensors operate by emitting signals (either sound or light) and measuring the time it takes for those signals to bounce off an object and return, effectively gauging distance. While this is highly effective for immediate, binary alerts—notifying the user that *something* is within a set range—the data they provide is fundamentally one-dimensional. To these sensors, the dense, static surface of a concrete wall, the softer, smaller profile of a person who might move, or the metallic, potentially hazardous form of a car are all simply "obstacles." The user receives the same alert (often a beep or vibration) for each, leaving them without the crucial contextual information needed to determine the *nature* of the object and make an appropriate decision, such as stopping, stepping aside, or exercising extreme caution.

B. Computer Vision and AI Systems:

More advanced solutions incorporate cameras with AI models like YOLO and MobileNetV2 for real-time object detection. These systems can identify specific objects (e.g., cars, pedestrians, stairs) and provide more detailed audio feedback.

However, their performance can be hindered by high computational requirements, dataset limitations, and sensitivity to poor lighting conditions.

C. *Advanced Navigation Systems (LiDAR/SLAM)*:

Some research explores the use of LiDAR and SLAM algorithms for precise indoor mapping and navigation. While powerful, these systems are often bulky, heavy (around 2.5kg), expensive, and primarily tested in controlled indoor settings, making them less practical for outdoor, everyday use. Some research explores the use of LiDAR and SLAM algorithms for precise indoor mapping and navigation. While powerful, these systems are often bulky, heavy (around 2.5kg), expensive, and primarily tested in controlled indoor settings, making them less practical for outdoor, everyday use.

D. Multi-Functional and IoT Devices

Other projects aim to create comprehensive solutions by integrating features like GPS, health monitoring (SpO2, heart rate), and emergency alerts via GSM modules. A key challenge with these complex designs is the potential for increased cost, user training difficulty, and network dependency for features like guardian tracking.

Table 1 summarizes and compares the advantages and limitations of the smart cane reviewed in this paper.

System Type	Benefits	Limitations
IoT	Monitoring, Tracking , Support	Dependency, Sharing, Manipulation
Camera vision	Recognition, Alerts, Safety	Lighting Power, Accuracy
sensors	Proximity, Detection, Effective	Contextless Indiscriminate , Limited
Bluetooth earpiece	Auditory, Wireless , Real-time	Power, Connectivity, Occlusion

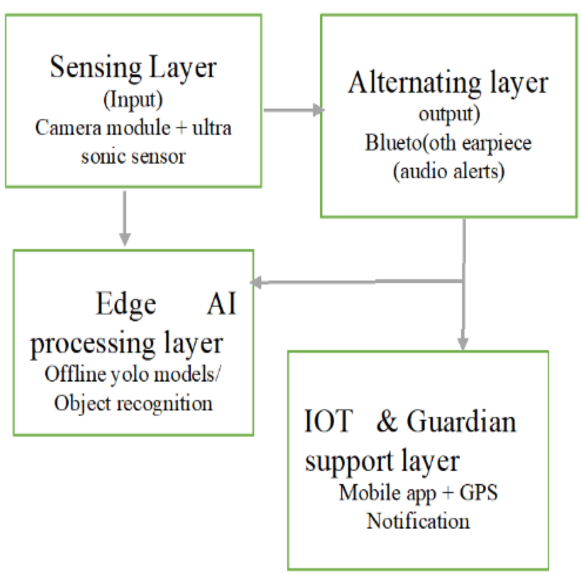

Figure 1: Conceptual framework of an AI-powered smart cane integrating mobile app, IoT modules, and backend processing.

III. PROPOSED FRAMEWORK

Sensing Layer (Input): This is the cane's primary interface with the physical world, equipped with a camera module and ultrasonic sensors to capture real-time visual and proximity data from the user's surroundings.

Edge AI Processing Layer: This is the intelligent core of the cane. It facilitates real-time, offline object and vehicle recognition using AI-based processing to identify potential threats.

Alerting Layer (Output): This module is responsible for user communication. It delivers instant, clear audio alerts regarding detected hazards through a Bluetooth-connected earpiece.

IoT & Guardian Support Layer: An optional companion system for enhanced safety. It features a mobile application that allows guardians to remotely monitor the user’s location and receive important notifications.

Sensing Layer: Streamlines the collection of environmental data, using sensor fusion to provide a comprehensive view of potential obstacles and moving vehicles

Alerting Layer: Translates complex sensor data into simple, actionable audio guidance, ensuring the user can react to dangers quickly and effectively

IoT & Guardian Support Layer: Verifies the user's safety and location for a guardian, offering peace of mind and a remote support system when needed.

IV. SECURITY AND PERFORMANCE ANALYSIS

A. Security Analysis

The document briefly addresses security considerations in two key areas. Within the "Technology & Systems" section, it emphasizes the importance of implementing cybersecurity measures as part of effective operations management, indicating a foundational awareness of digital vulnerabilities and the need for protective protocols. Additionally, the literature review references a 2025 paper on an AI-powered smart cane, which identifies encrypted communication and biometric authentication as potential future enhancements. These suggestions imply that the current system lacks robust data protection and secure user verification mechanisms, highlighting areas where security could be significantly improved. While these mentions demonstrate an understanding of the relevance of security, the document does not provide a comprehensive analysis of specific threats, mitigation strategies, or compliance standards, leaving room for further development in future iterations.

B. performance analysis

The document briefly addresses security considerations in two distinct areas. Under the "Technology & Systems" section, it emphasizes the need to implement cybersecurity measures as part of effective operations management, signaling an awareness of digital vulnerabilities and the importance of protective protocols. Additionally, in the literature review of a 2025 paper on an AI-powered smart cane, "encrypted communication" and "biometric authentication" are identified as potential future enhancements. These suggestions imply that the current system lacks robust data protection and secure user verification mechanisms, highlighting areas where security could be significantly improved. While these mentions indicate a foundational understanding of security needs, the document does not provide a comprehensive analysis of threats, mitigation strategies, or compliance standards, leaving room for further development in future iterations.

V. FUTURE SCOPE

The future scope of the smart cane project lies in expanding its capabilities to offer even more intelligent, personalized, and connected assistance for visually impaired users. Upcoming enhancements could include advanced scene recognition using deep learning to classify obstacles and traffic signals, integration of haptic feedback for silent alerts, and voice assistant support for interactive guidance. Guardian connectivity can be strengthened through geo-fencing, emergency alerts, and two-way communication. The cane could also interface with smart city infrastructure, enabling real-time updates from public transport systems and vehicle-to-device communication for proactive safety. Hardware improvements like modular design, solar charging, and multilingual support would further increase accessibility and usability across diverse environments. These developments position the smart cane not just as a mobility aid, but as a comprehensive assistive ecosystem.

VI. CONCLUSION

The project demonstrates a strong financial and strategic foundation, with projections indicating a positive return on investment and a well-defined business plan that charts a clear path to profitability. A comprehensive implementation roadmap has been developed to guide the initiative through critical stages of market entry, ensuring structured progress and operational clarity. To further enhance and accelerate this trajectory, it is recommended that the company pursue strategic partnerships with local businesses and industry leaders. These collaborations are expected to amplify growth potential, facilitate resource sharing, and broaden market reach, thereby reinforcing the project's long-term sustainability and impact.

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