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Smart Cane for Visually Impaired Persons

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Abstract -. Time, safety, and navigation are critical challenges for visually impaired individuals, yet many assistive tools remain limited in capability, accuracy, or affordability. The objective of this project is to design and develop a Smart Cane Assistive System that enhances mobility, ensures safety, and provides real-time environmental awareness through a combination of sensor-based obstacle detection, computer vision, and emergency communication technologies. The system incorporates an IR sensor for short-range ground obstacle detection and an ultrasonic sensor for mid- and upper-level obstacle identification, both interfaced with an Arduino Uno that alerts the user through a buzzer. An ESP32-CAM module enables object identification and OCR, activated via dedicated switches, with results processed through a Python application and provided as audio feedback. An RFID reader supports automatic bus route identification without user input. For emergency situations, a second Arduino Uno is paired with a SIM800L GSM and NEO-6M GPS module, powered by a 3.7V Li-ion battery, to send an SMS containing the user's live location when the panic button is pressed. The system follows a modular design covering core functions such as sensing, vision processing, RFID-based alerts, and emergency communication. Multi-level testing validated the system's accuracy, performance, and user comfort. The results indicate that the smart cane significantly improves obstacle detection accuracy, enhances situational awareness, and provides reliable emergency communication support compared to conventional assistive devices. Future developments may include AI-based path prediction, Bluetooth connectivity for mobile integration, and onboard audio processing for fully offline operation

***Keywords*:**. Smart Cane, Assistive Technology, Obstacle Detection, Object Recognition, OCR, RFID Navigation, Emergency Alert System.

INTRODUCTION

Visual impairment makes it difficult for individuals to move safely and independently in their daily surroundings. Traditional tools like the white cane provide only basic information and cannot detect obstacles that are above ground level, identify objects, read text, or help during emergencies. Because of these limitations, visually impaired people often face safety risks and may lose confidence while traveling alone. With the improvement of embedded systems and low-cost sensors, there is a strong need for a smart assistive device that can give more awareness, support, and safety.

To address this need, this project develops a **Smart Cane Assistive System** that combines sensors, a camera, RFID technology, and an emergency alert mechanism into one easy-to-use device. The system uses a modular design, built using commonly available hardware components.

The first Arduino Uno controls the obstacle-detection system. Two sensors are used together to provide better accuracy. An **IR sensor** at the bottom of the cane detects ground-level obstacles like steps, potholes, and stones. An **ultrasonic sensor** placed higher on the cane detects mid-level and upper-level obstacles such as walls, signboards, vehicles, and people. When any obstacle is detected, the system immediately activates a buzzer to warn the user. This dual-sensor setup helps the user avoid accidents and improves navigation compared to a normal white cane.

For additional awareness, the cane includes an **ESP32-CAM** module. This module supports two main features: **object detection** and **text reading (OCR)**. The user can choose between these options using switches. The captured image is processed by a Python application on a laptop, which identifies the object or reads the text and then converts the result into audio. This helps visually impaired users understand their surroundings, read signboards, or identify everyday items.

The system also supports **bus route identification** using **RFID technology**. RFID tags placed on buses or bus stops store the route information. When the RFID reader on the cane comes close to a tag, it automatically reads the route number and announces it to the user. This makes public transportation easier and safer without needing help from others.

A separate **emergency alert system** is included for safety. It works on a second Arduino Uno powered by a rechargeable 3.7V Li-ion battery. This module uses a SIM800L GSM unit and an NEO-6M GPS module. When the user presses the emergency button, the system sends an SMS with the user's location to pre-saved contacts. This feature is very helpful during emergencies like falls, getting lost, or health issues.

Overall, the Smart Cane is designed to be simple, portable, and reliable. Each module—sensors, camera, RFID, and emergency system—plays an important role, and together they offer complete assistance. The system was tested to ensure proper sensor detection, stable camera performance, correct RFID reading, and dependable emergency messaging. This smart assistive device provides a modern alternative to traditional white canes by improving safety, independence, and confidence for visually impaired individuals.

LITERATURE REVIEW

The authors—L. A. Abdul-Rahaim, A. J. Mousa, A. H. Omran, and L. M. Kadhum—propose a system that integrates Internet of Things (IoT) technologies to elevate the functionality of traditional mobility aids. Their smart cane incorporates sensors and communication modules to detect obstacles, monitor the user's environment, and transmit real-time data. The system is designed to provide feedback through audio or vibration alerts, helping users avoid hazards such as walls, curbs, and moving vehicles. The integration of computer vision and machine learning enables the cane to recognize objects and adapt to dynamic environments, offering a more responsive and context-aware mobility aid. A key innovation in their approach is the use of IoT connectivity to enable remote monitoring and emergency support. The cane can transmit location data and status updates to caregivers or emergency services, enhancing user safety in outdoor or unfamiliar settings. The paper also discusses the system's architecture, which includes microcontrollers, ultrasonic sensors, GPS modules, and GSM communication units—all working together to deliver a responsive and intelligent assistive experience.

AI-Powered Smart Cane: Intelligent Navigation for the Visually Impaired Presented at the 2025 International Conference on Computing and Communication Technologies (ICCCT) in Chennai, India, this paper by V. Remya et al. introduces an AI-driven smart cane system designed to enhance navigation for visually impaired users. The system leverages artificial intelligence algorithms to detect and classify obstacles in real time, providing intelligent feedback through audio or haptic alerts. Smart Assistive Stick with Enhanced Mobility and Independence for the Visually Impaired Using Ultrasonic, GPS, and GSM Technologies This paper, presented at the 2024 International Conference on IT Innovation and Knowledge Discovery (ITIKD) in Manama, Bahrain, outlines a smart assistive stick developed by M. V et al. The system combines ultrasonic sensors for obstacle detection, GPS for location tracking, and GSM modules for emergency communication.

A Low-Cost Assistive Device for the Visually Impaired Published by W. K.Wohiduzzaman et al. in EAI in January 2023, this paper presents a cost-effective solution aimed at improving mobility for visually impaired individuals. The device incorporates basic sensors and feedback mechanisms to detect obstacles and guide users safely. The emphasis is on simplicity, affordability, and accessibility, ensuring that the technology can reach underserved populations. While the system may not include advanced AI or IoT features, its practical design and low production cost make it a valuable contribution to inclusive technology development.

METHODOLOGY

The Smart Cane system is a comprehensive assistive solution designed to enhance navigation and safety for visually impaired individuals through the integration of multiple technologies. It employs both ultrasonic and infrared sensors connected to an Arduino Uno to detect obstacles at various heights—ultrasonic sensors identify mid- and upper-level hazards like vehicles and walls, while IR sensors detect ground-level threats such as steps and potholes. A buzzer provides immediate alerts when obstacles are detected. For visual processing, an ESP32-CAM streams live images to a laptop, where object detection using a YOLO model and OCR via Py Tesseract are performed. These features allow users to receive audio feedback about nearby objects and read printed text. Additionally, an RFID reader identifies bus routes by scanning tags placed on buses and stops, triggering audio announcements for route information. Serial communication between the Arduino and laptop ensures synchronized operation through predefined command signals. A separate emergency module, powered independently, uses GPS and GSM to send SMS alerts with location data when activated, ensuring user safety even if the main system fails. All

components are integrated into a unified, semi-portable system, combining sensor-based detection, vision processing, and wireless communication to deliver a robust and intelligent mobility aid.

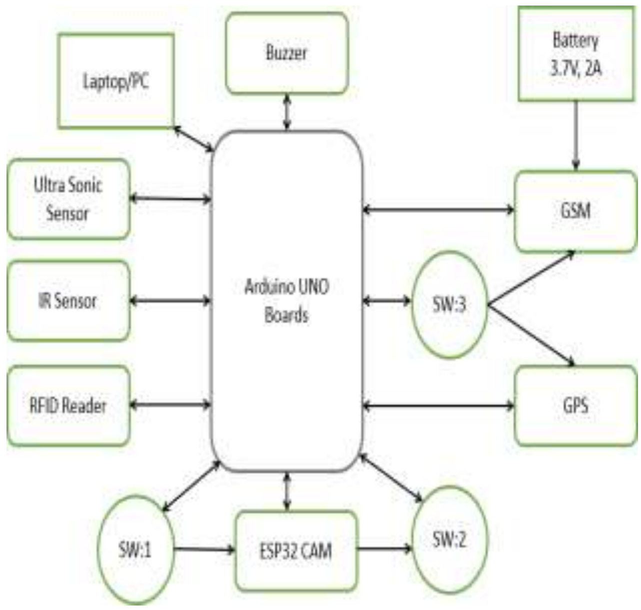

Fig1: Block Diagram

The proposed system integrates multi-sensor obstacle detection, camera-based vision processing, bus route identification, and an independent emergency alert subsystem to assist visually impaired users. The complete methodology is organized into five core stages: sensing, processing, communication, decision-making, and alert generation.

1. Multi-Sensor Obstacle Detection Module

The primary Arduino Uno receives continuous input from three sensing units:

a) Ultrasonic Sensor

The ultrasonic sensor measures forward distance using time-of-flight reflection. The Arduino interprets the measured range and triggers alerts when obstacles are detected within a critical threshold (typically <30 cm). This supports detection of mid-level obstacles such as walls, vehicles, and standing objects.

b) Infrared (IR) Sensors

Two IR ground-level detection sensors are placed at the lower end of the cane. These sensors detect potholes, steps, or low-lying objects that may not be captured by the ultrasonic sensor. IR outputs are scanned in real-time to ensure quick response to sudden dips or bumps.

c) RFID Reader

An RFID reader is included to detect pre-installed RFID tags at bus stops. Each tag contains route information. When a tag is detected, the Arduino sends a unique character code to the laptop for voice output. The Arduino processes all these sensor inputs and generates a buzzer alert whenever an obstacle hazard is detected.

2. Vision-Based Processing Module

The vision-based processing module functions through the ESP32-CAM, which captures real-time images whenever the user presses one of the two tactile switches. When Switch 1 is activated, the system enters OCR mode, where the ESP32-CAM streams an image to the laptop. The laptop then performs Optical Character Recognition (OCR) using PyTesseract, and

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the extracted text is converted into speech for audio playback to the user. When Switch 2 is pressed, the system switches to Object Identification Mode. In this mode, the camera again transmits images to the laptop, where a YOLO-based deep learning model identifies persons, vehicles, animals, obstacles, and other important objects. The detected object names and their relative positions are converted into audio output, providing real-time situational awareness. All heavy image processing tasks run on the laptop to ensure accuracy and prevent overloading of the embedded hardware.

3. Serial Communication Between Devices

A reliable serial communication framework interconnects the various components of the system, including the Arduino Uno with the laptop or PC, the primary Arduino with the secondary Arduino, and the ESP32-CAM with the primary Arduino. The primary Arduino transmits specific character codes such as ‘a’, ‘b’, ‘c’, ‘d’, and ‘e’ to the laptop to indicate events like switch activation, RFID detection, or sensor readings. This structured communication protocol ensures synchronized operation between embedded modules and the external processing software, enabling smooth and coordinated system behaviour.

4. Emergency Alert and Location Tracking Module

The emergency subsystem is managed by a dedicated secondary Arduino Uno to ensure high reliability even if the primary module fails. When the SOS button (Switch 3) is pressed, the secondary Arduino collects real-time GPS coordinates and activates the GSM module to send an emergency SMS to predefined contacts. The message includes a standard alert text along with the user’s latitude and longitude, ensuring that the exact location is shared for timely assistance. This dedicated architecture enhances the safety and robustness of the system during critical situations.

5. Power System

The power system is designed to maintain stable operation, especially during emergencies. A 3.7V, 2A Li-ion battery exclusively powers the GSM module, ensuring uninterrupted SMS transmission without drawing power from the main controller. By isolating the emergency circuitry, the system guarantees that essential communication functions remain active under all conditions, even if the main power source becomes unstable.

RESULTS

To validate the functionality of the proposed Smart Cane system, a complete hardware prototype was developed and tested under real-world conditions. The assembled system integrates sensing, communication, and processing modules within the cane structure, ensuring coordinated operation across all assistive features. The prototype was evaluated for sensor responsiveness, object detection reliability, RFID recognition stability, and emergency alert activation. The physical arrangement of components is shown in Figure 1, with detailed views of both the upper and lower sections of the cane.

a b

Fig 2: a. Top section of the cane , b. Bottom section of the cane

Figure 2 represents the implemented Smart Cane prototype, showing both the upper and lower electronic subsystems integrated into the assistive device.

The top section of the cane (Fig. 2a) contains the primary control and sensing components. The ultrasonic sensor is mounted at the front to detect mid-level obstacles such as walls, vehicles, and standing objects. The ESP32-CAM module is positioned at the highest point, enabling real-time image capture for object identification and OCR tasks. The RFID reader is placed on the side to detect bus-route tags when the user approaches public transportation entry points. All these modules interface with the Arduino Uno, which serves as the central processing unit. Proper wiring separation is maintained to ensure stable power distribution and noise-free signal communication. The Emergency Alert Module is also controlled from the upper section. The emergency (SOS) switch is connected to the main Arduino, which communicates with a secondary Arduino for triggering GSM-based alerts. When the SOS button is pressed, the system activates the GSM and GPS modules to send a real-time emergency SMS containing the user’s location coordinates. This arrangement ensures rapid response during critical situations.

The bottom section of the cane (Fig. 2b) contains the IR sensors used for short-range and ground-level hazard detection. These sensors are positioned near the cane tip to detect potholes, stair edges, stones, and other low-height obstructions. Placing the IR sensors at ground level enhances user safety by enabling early detection of tripping hazards. The wiring is neatly routed along the cane structure to maintain ergonomics and durability during movement.

Trial No.	0.5 cm distance	1 cm distance	>3cm distance
1	Object detected	Object detected	Object not detected
2	Object detected	Object detected	Object not detected
3	Object detected	Object detected	Object not detected

Table1: IR Sensor readings

The ultrasonic sensor was evaluated at three distances (10 cm, 20 cm, and beyond 60 cm) to measure its obstacle detection capability. As shown in the table, the sensor reliably detected objects at 10 cm and 20 cm across all three trials, demonstrating consistent mid-range sensing performance. However, at distances greater than 60 cm, object detection failed in all trials, confirming that the effective sensing range of the module is limited to approximately 55–60 cm. These results validate the suitability of the ultrasonic sensor for detecting obstacles at upper body height within a practical walking distance for visually impaired users.

Trial No	10 cm distance	20 cm distance	>60 cm distance
1	Object detected	Object detected	Object not detected
2	Object detected	Object detected	Object not detected
3	Object detected	Object detected	Object not detected

Table2: Ultrasonic sensor readings

The IR sensor was tested at three close-range distances (0.5 cm, 1 cm, and beyond 3 cm) to evaluate its ground-level obstacle detection capability. As shown in the results, the sensor consistently detected objects at 0.5 cm and 1 cm in all trials, demonstrating high reliability for short-range hazard identification. However, for distances greater than 3 cm, the sensor failed to detect obstacles in every trial, confirming its effective operational range is limited to approximately 2–3 cm. This behavior is suitable for identifying immediate ground-level hazards such as stones, curbs, or sudden surface changes that pose tripping risks for visually impaired users.

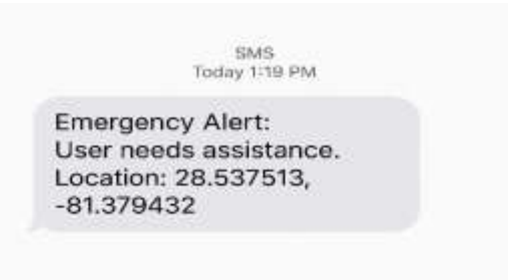

Fig3: Emergency SMS Image

The emergency alert output demonstrates the successful transmission of an SOS message containing the user's real-time GPS coordinates. When the SOS switch is pressed, the secondary Arduino triggers the GSM module to send an SMS to the predefined contact within a few seconds. The received message confirms that the emergency alert mechanism is functional, reliable, and capable of providing location-based assistance during critical situations.

FUTURE SCOPE

The Smart Cane system presents significant opportunities for future enhancement to further improve its autonomy, accuracy, and user experience. A major direction for advancement involves integrating more powerful edge-AI hardware, such as the ESP32-S3, Jetson Nano, or Raspberry Pi Zero 2 W, allowing all computer vision tasks—including object detection and OCR—to run directly on the cane without relying on an external laptop. This would make the system fully portable and user-friendly. The vision module can be upgraded with low-light or thermal imaging sensors to ensure reliable detection in poorly lit or nighttime environments. Additionally, incorporating LiDAR or Time-of-Flight (ToF) sensors could significantly increase obstacle detection accuracy, especially in complex indoor spaces. The system may also be enhanced by integrating indoor navigation features using BLE beacons, UWB positioning, or Wi-Fi RTT, enabling safe mobility in malls, hospitals, or bus stations where GPS signals are weak. Haptic feedback mechanisms, such as directional vibration motors or haptic belts, can be added to provide intuitive navigation cues without depending solely on audible alerts. A dedicated mobile application could introduce features such as real-time location sharing, emergency tracking, system diagnostics, and cloud-based data storage. Future versions can also explore power optimization techniques, including MPPT-based solar charging, sleep-mode algorithms, and improved battery management circuits to prolong operational runtime. Robust waterproofing and ergonomic enclosure design would further improve durability, making the system suitable for long-term outdoor use. Finally, machine learning–based user behaviour modelling could enable personalized guidance, adaptive sensitivity settings, and predictive safety alerts. These improvements collectively pave the way for a more intelligent, dependable, and inclusive assistive cane solution for visually impaired individuals.

CONCLUSION

The Smart Cane for Visually Impaired Persons was successfully designed and implemented to enhance user mobility, safety, and situational awareness. By integrating ultrasonic and IR sensors, the system provides reliable obstacle detection at multiple height levels, while the ESP32-CAM enables real-time object identification and OCR. The RFID module facilitates automatic bus-route recognition, improving public transport accessibility. Additionally, the emergency alert subsystem, powered by a dedicated Arduino with GSM and GPS, ensures that users can transmit their live location during critical situations.
Experimental results demonstrated consistent performance across sensing modules, accurate environmental detection, and reliable SMS alert delivery. The modular design also enables easy scalability and future enhancements. Overall, the developed system presents a practical, low-cost, and effective assistive technology that can significantly improve the independence and safety of visually impaired individuals

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