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AI Smart Walking Stick for Blind People

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Abstract:

For individuals who are visually impaired, this is a daily reality. Most commonly, they use a traditional walking stick to detect physical obstacles like steps, holes, uneven terrain, or objects in their path through tactile feedback. This project introduces a Smart Walking Stick built using the ESP32-WROOM microcontroller, designed to improve the independence and movement of visually impaired individuals by offering them instant awareness of their surroundings. system employs ultrasonic sensors to identify nearby barriers, stairs, and open pits, offering timely alerts to prevent accidents. Water detection sensors are included to identify slippery or wet surfaces. The system also integrates GPS technology to assist in identifying and guiding the best route to a destination. stick includes an SMS alert feature for emergency scenarios, adding another layer of safety. This project utilizes a Raspberry Pi integrated with a camera module to perform real-time object detection. The primary goal is to assist visually impaired individuals by detecting obstacles and providing audio alerts.

Keywords: Smart Walking Stick, ESP32-WROOM, Ultrasonic Sensors, Water Detection, GPS, Fall Detection, camera through object detection.

Introduction

Visually impaired individuals often face significant challenges in navigating their surroundings safely and independently. Traditional walking sticks provide limited assistance, primarily detecting obstacles through physical contact. With advancements in technology, there is a growing opportunity to enhance mobility aids using artificial intelligence and sensor based systems. This project introduces an AI-powered smart walking stick designed to support blind users by detecting obstacles, identifying hazards, and providing real-time feedback. Equipped with ultrasonic sensors, a water sensor, GPS, and a camera for object detection, the stick improves situational awareness and safety. The integration of these technologies aims to deliver a reliable, low-cost, and user friendly solution that enhances the independence and confidence of visually impaired individuals in daily life.

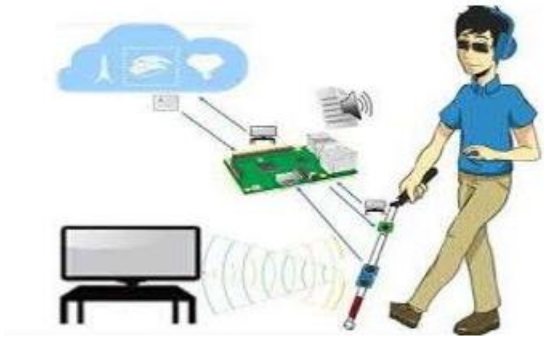

Fig:1 AI Smart Walking blind stick

According to statistics from the World Health Organization (WHO) and the International Agency for the Prevention of Blindness (IAPB), there are roughly 285 million people around the globe with visual impairments. Out of this population, 39 million are completely blind, while 246 million suffer from moderate to severe vision loss. Alarmingly, around 90% of these individuals reside in developing nations. Reports from WHO and IAPB predicted that the global number of blind individuals could double by 2024. Traditionally, visually impaired individuals rely on basic walking sticks to help them navigate their surroundings. These sticks function through tactile feedback, allowing users to detect fixed obstacles, stairs, pits, and uneven surfaces. While lightweight and easy to carry, their effectiveness is limited by their short range and inability to detect moving hazards. To enhance mobility and independence for the visually impaired, a Smart Walking Stick is proposed. This device aims to alert users to nearby obstacles such as holes, water, steps, and other potential hazards, thus reducing the risk of accidents. It will incorporate various sensors to detect environmental conditions and provide real-time feedback. Furthermore, GPS integration will enable users to select destinations and navigate routes safely and efficiently. By simulating a form of artificial vision, the Smart Walking Stick can significantly improve daily movement for visually impaired individuals.

Methodology

The AI-powered Smart Walking Stick aims to support visually impaired users by enabling safe and independent navigation of their environment. The methodology includes both hardware and software components integrated into a single system. The development process involves multiple phases: system design, sensor integration, data processing, obstacle detection, and route guidance.

A. System Design

The overall design consists of a lightweight walking stick embedded with sensors, a microcontroller, a power supply, and communication modules. The design focuses on ergonomics, portability, and durability to ensure user comfort during daily use.

B. Hardware Components:

1. Ultrasonic Sensor: Measures distance or detects obstacles. 2. Water Sensor: Detects the presence of water or moisture levels. 3. GPS Module: Provides location information. 4. Camera: Captures visual data, possibly for monitoring purposes. 5. Power Supply: Powers the entire system, including the Arduino and connected components. 6.Buzzer: Emits a sound as an alert or notification. 7.Panic Switch: A manual switch to trigger an alert or emergency action. 8. Vibrator: Produces vibration, likely as a form of feedback or alert. 9.IoT App: This app interfaces with the system, allowing users to monitor and control the system through a mobile or web application, likely connected via the cloud.

C. Software Implementation

1. Sensor Data Processing:

Raw data from sensors is collected and processed in real time to determine the presence and type of obstacles. Threshold values are set for accurate detection.

2. Obstacle Detection and Feedback:

Based on the proximity and nature of the obstacle, the system triggers vibration or sound alerts.

Different feedback patterns may be used to indicate obstacle distance and type.

3. Object Recognition with AI: If a camera module is used, image frames are processed using lightweight AI models to recognize objects like vehicles, signboards, and stairs.

4. Navigation via GPS: The GPS module works in conjunction with map APIs to guide the user to a chosen destination. Voice feedback or direction-based vibrations can be provided for navigation assistance.

5. User Interface A mobile app or simple interface can be developed for route selection, system configuration, and monitoring.

D. Testing and Evaluation

The prototype will be tested in various environments—indoor and outdoor settings, day and night conditions, and under different obstacle arrangements. User feedback will be collected from visually impaired individuals (if possible) to evaluate usability, comfort, and effectiveness.

Literature Survey

R. Singh and his team designed an advanced navigation aid called the Intelligent Smart Stick (ISS), which is specifically tailored for visually impaired users. This device integrates both GPS and GSM modules to provide accurate outdoor navigation and emergency communication. Ultrasonic sensors are employed to detect obstacles in the user's path, while the GPS module helps track the user's location. In the event of an emergency, the GSM system transmits the live location to a predefined contact, enhancing the user's safety during independent travel [1]. M. El-Zayat proposed a smart stick enhanced with wearable capabilities and camera-based object detection. Utilizing the OpenCV library and Raspberry Pi, this system captures images and processes them in real time to recognize surroundings. It then converts this information into auditory feedback, helping users identify complex elements in the environment, such as vehicles, signboards, or stairs, rather than just simple obstructions [2]. An innovative model developed by N. Prasad and colleagues introduces voice command capabilities into the AI-powered walking stick. This design allows users to switch between multiple operating modes based on the navigation context, such as indoor or outdoor use. It uses machine learning to continuously improve obstacle detection and refines voice response timing for better interaction and support [3].

K. Jadhav and his research team presented the Deep Learning Assistive Stick (DLAS), which incorporates YOLOv4 for high speed object detection. With the help of a high-definition camera and deep learning technologies, the stick can identify various objects—such as pedestrians, vehicles, or walls—and provide personalized voice alerts. This results in a more intelligent understanding of the surroundings [4]. T. Akhtar introduced a smart cane with integrated Internet of Things (IoT) features, enabling real-time location tracking and cloud connectivity. A mobile application supports remote monitoring, and the device includes environmental sensors that detect fire, gas leaks, and temperature fluctuations. Notifications are shared through GSM or Wi-Fi modules, contributing to both navigational support and environmental safety [5]. To make assistive technology more accessible, S. Mehta developed an affordable smart stick for use in low-income or rural communities. The device runs on an Arduino Nano and incorporates ultrasonic sensors for obstacle detection. Instead of complex processing units, it uses an SD card module to store and play voice alerts, keeping costs low while maintaining essential functionality [6]. B. D'Souza and his team proposed a hybrid navigation system combining RFID and ultrasonic technologies. This dual-sensor system enhances accuracy in crowded or indoor settings like train stations or malls. RFID tags placed in the environment assist with indoor localization, while ultrasonic sensors continue to monitor nearby obstacles, ensuring reliable navigation in dynamic spaces [7]. Nitish Sukhija introduced a Smart Stick designed for visually impaired individuals, incorporating ultrasonic sensors, infrared (IR) sensors, and a microcontroller. This device is programmed to follow a predetermined path and is both user-friendly and affordable [8]. Ashraf Anwar developed another version of a smart stick intended to aid the blind, which features ultrasonic, IR, and light sensors (LDR), along with an Arduino Uno R3 microcontroller, buzzers, and vibrators [9]. This model also includes voice-guided navigation and integrates fire and light sensors to enhance user safety and support. Kumar presented a budget-friendly smart stick designed for both blind and partially sighted individuals. The system utilizes a combination of ultrasonic, infrared, water, fire, and LDR sensors to detect various environmental conditions. It delivers information through voice instructions, vibrations, and buzzers, offering both auditory and tactile feedback for better guidance [10]. Like previous designs, it is easy to operate and economical. Additionally, the DBG Crutch-Based Sensor was developed using ultrasonic distance measurement to improve navigation assistance. A guidance system for visually impaired individuals was introduced in [11]. utilizing a measurement approach that assists users in detecting and avoiding obstacles located ahead, to the left, and to the right. This system incorporates a set of three ultrasonic sensors—where the top sensor identifies overhead obstructions, and the other two detect obstacles in the user's forward path. Additionally, the design includes ultrasonic transmission and reception modules, voice output, vibration feedback, and a switch to toggle between feedback modes. The entire setup is managed by an STC15F2K60S2 microcontroller [12] Radio Frequency Identification Walking Stick (RFIWS) was developed to support the navigation needs of visually impaired individuals. This stick functions by measuring the estimated distance between the user and the path boundary. The system relies on RFID technology to transmit and receive signals through radio waves, with RFID tags and readers forming the core components of the system [13]. Sharing Kumar introduced a Smart Stick equipped with multiple distance sensors to assist the visually impaired [14]. This model uses ultrasonic sensors for detecting obstacles, a Bluetooth module for connectivity, an Arduino UNO for control, and a vibration motor to deliver haptic feedback. It is capable of identifying both static and moving obstacles, regardless of their height, located in front of the user.[15] The BAWA Cane is another assistive tool designed for blind individuals, capable of detecting objects both above and below knee level while providing audio guidance [16]. It employs Bluetooth connectivity and ultrasonic sensors, and features voice navigation along with an emergency alert system to notify caregivers or loved ones in case of danger [17].

Block Diagram:

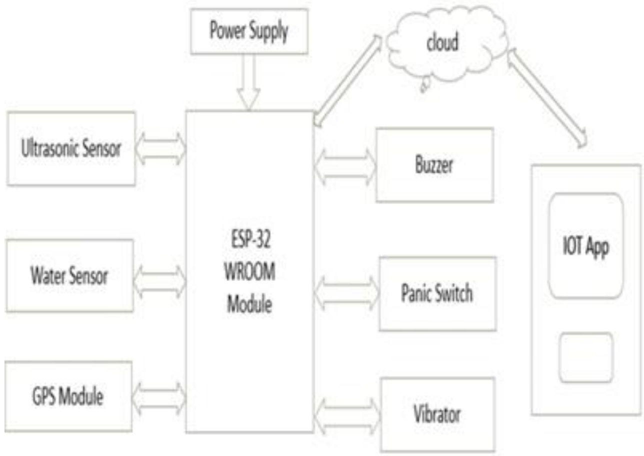

Fig. 2 Block Diagram

The block diagram represents the working architecture of an AI Smart Walking Stick designed for visually impaired individuals. At the heart of the system lies the ESP-32 WROOM Module, which functions as the central processing unit. It receives inputs from multiple sensors and controls various output devices. A power supply unit ensures the ESP 32 and all connected modules function effectively. The system also connects to the cloud for real-time data storage and communication, enabling access to data through an IoT-based mobile application. On the input side, the walking stick is equipped with three key sensors: an ultrasonic sensor for obstacle detection, a water sensor to detect wet or slippery surfaces, and a GPS module for real-time location tracking. These sensors feed their data into the ESP-32, which processes the information to detect potential hazards and the user's geographic position. The Panic Switch serves as a manual emergency trigger, allowing the user to send an alert instantly when they are in danger or need assistance. For output feedback, the ESP-32 activates multiple components. The buzzer provides audio alerts to warn the user about obstacles or hazards. A vibration motor gives haptic feedback, offering a non-auditory method of alerting the user, especially useful in noisy environments. The system’s connectivity with the cloud ensures that the user's live location and status can be accessed via the IoT mobile application, which can also send alerts to caregivers or family members in emergency situations. This architecture creates a robust, responsive, and user-friendly assistive device.

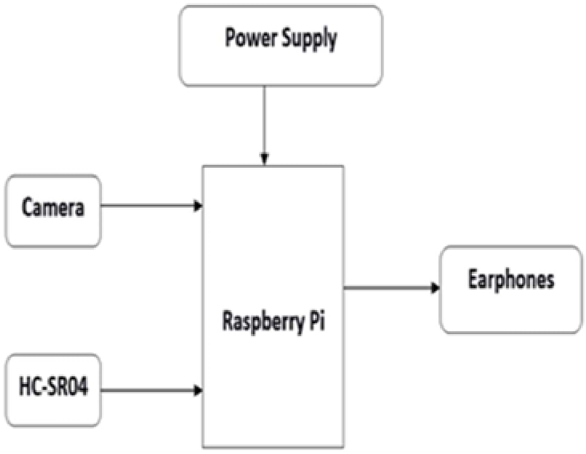

Fig. 3: Block diagram of camera through object detection using Raspberry Pi

III Proposed Method & Description

The Body:

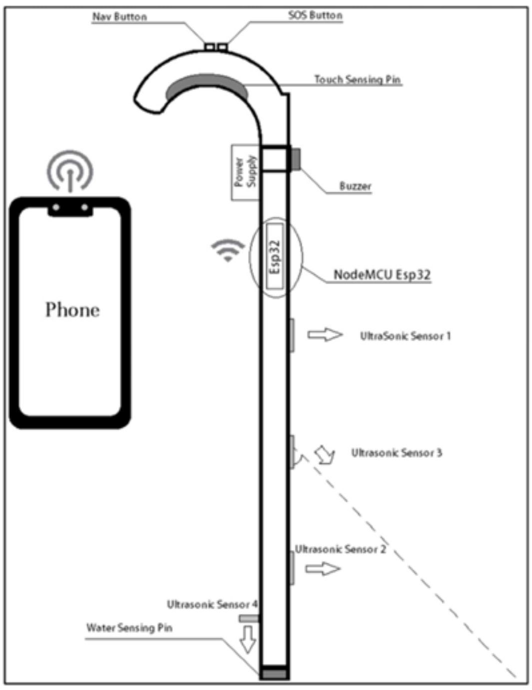

Fig. 4: Schematic Diagram of Smart

This block diagram illustrates a simplified vision-based assistive system for visually impaired users, using a Raspberry Pi as the central processing unit. The system is powered through a dedicated power supply, ensuring continuous operation of all connected components. A camera module is connected to the Raspberry Pi to capture real-time visual information from the user's surroundings. The Raspberry Pi processes the data from both the camera and the ultrasonic sensor to the environment. Based on the analysis, it generates appropriate audio feedback, which is delivered to the user through connected earphones. This setup enables the user to receive real-time verbal guidance, helping them navigate safely by being aware of objects or obstructions in their path. The compact and efficient design of this system makes it a practical solution for real-world navigation assistance.

Flowchart:

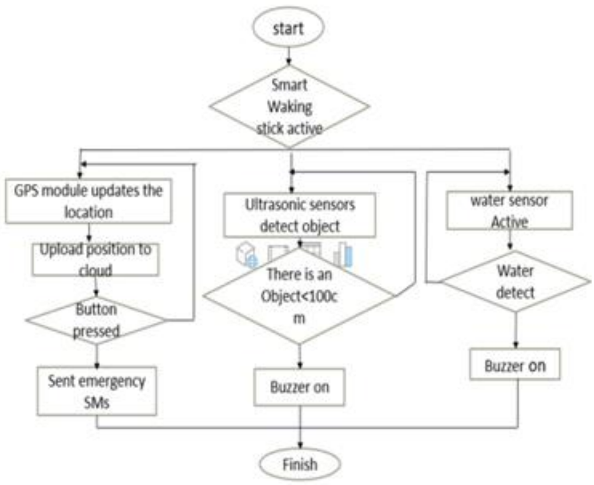

Fig. 5: General Flow Diagram

The flowchart outlines the working logic of a smart walking stick designed to aid visually impaired users. The process begins when the system is powered on and becomes active. Once the smart stick is operational, three main components begin functioning simultaneously: the GPS module, the ultrasonic sensor, and the water sensor. Each module monitors specific environmental conditions to ensure user safety and provide real-time feedback. The ultrasonic sensor continuously checks for nearby obstacles. If it detects any object within 100 cm, it triggers the buzzer to alert the user of a potential hazard in their path. In parallel, the water sensor checks for wet surfaces. When it senses the presence of water, it also activates the buzzer, warning the user of a potentially slippery area. These alerts help the user avoid collisions and unsafe walking conditions. Meanwhile, the GPS module constantly updates the user's location and uploads this information to the cloud. In case of an emergency, the user can press a panic button. When this button is activated, the system immediately sends an emergency SMS containing the user's current location. This ensures timely assistance from family members or caregivers. The entire system then loops back, continuing its monitoring cycle until manually turned off.

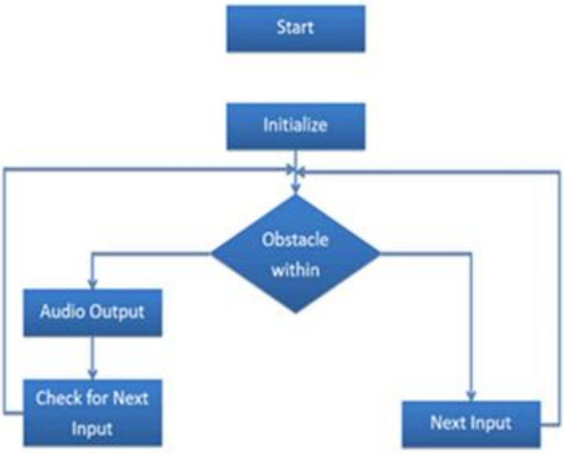

Fig 6: workflow of camera through object

Algorithm: Step1: Input Image

Step2: Sensor Reading

Step3: Input details processed by Raspberry Pi

Step4: Object detail feed by Earphone

This flowchart illustrates a basic decision-making process used in an obstacle detection system. The operation begins with a start command, followed by an initialization phase where all components and sensors are set up and activated. The system then checks for the presence of an obstacle using sensor input. At the core of the decision process is a conditional check that evaluates whether an obstacle is detected within a certain predefined range. If an obstacle is detected, the system proceeds to generate an audio output to notify the user about the obstruction. After the alert is delivered, the system loops back to check for the next input, ensuring continuous monitoring of the surroundings. On the other hand, if no obstacle is within the specified range, the process simply moves to the next input, skipping the audio alert, and continues the cycle. This logic ensures efficient, real time guidance to users, particularly beneficial for.

Result & Discussion

Performance Experiment

An AI smart walking stick for the blind people could offer features such as real-time location tracking (GPS), obstacle detection with sensors to avoid falls, an LED torch for low light visibility, and emergency assistance (SOS alert). Other functionalities might include health monitoring (like fall detection sensors), a built and voice guidance. These features aim to enhance safety, convenience, and independence for users.

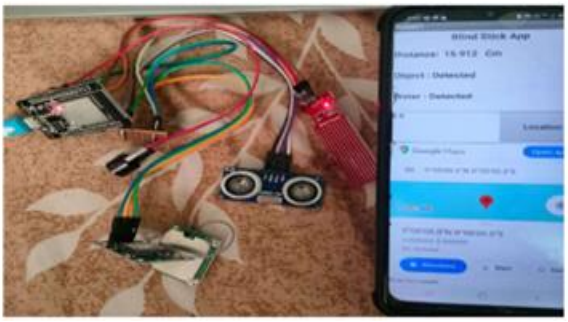

Fig 7. Hardware & Software Implementation

The developed smart walking stick was tested in various real world conditions to assess its effectiveness in aiding visually impaired individuals. The evaluation covered several core features: obstacle detection, water sensing, GPS tracking, and camera-based object recognition. In comparison to traditional mobility aids such as white canes, the AI Smart Walking Stick offers enhanced environmental awareness through early detection of obstacles and hazards. The inclusion of GPS and emergency communication adds a critical layer of safety. With further improvements, such as longer battery life and better low-light vision, the device can become a reliable companion for the visually impaired.

Fig 8. Blind Stick App

The image displays the interface of a mobile application designed for a smart blind stick system. The application successfully reads and displays the distance from an object (74.443 cm), confirms that no object is currently detected in the vicinity, and reports that there is no water on the path. Additionally, the coordinates (18.65268, 73.76107) are shown, suggesting that the GPS module is attempting to retrieve the location. However, despite the display of coordinates, an error message appears indicating

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that the app has been denied the "ACCESS_FINE_LOCATION" permission, which is essential for accessing precise GPS data.

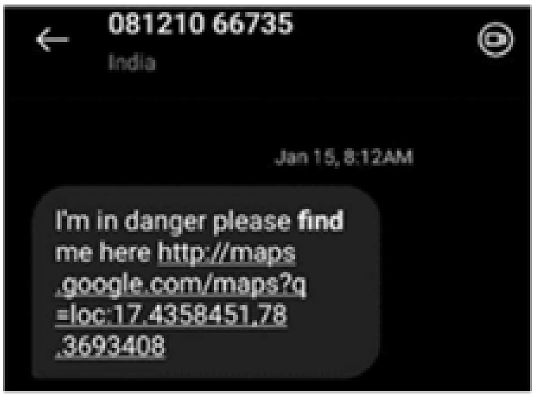

Fig 9. Message in emergency situation

The message contains an urgent plea for help, stating, "I'm in danger please find me here," followed by a Google Maps link with specific geographic coordinates (17.4358451, 78.3693408). This indicates a distress alert system where a user can share their real-time location in an emergency situation, allowing responders or trusted contacts to quickly locate and assist them. This feature is crucial in enhancing personal safety.

Fig 10. Camera Through Object Detection

The AI Smart Walking Stick shown in the image uses a camera connected to a Raspberry Pi board to help visually impaired users detect nearby objects. The camera captures live visuals, which are processed using AI tools like OpenCV and TensorFlow. Models such as MobileNet identify obstacles like people, vehicles, or stairs. This information is then delivered to the user through earphones, allowing them to move safely and avoid obstacles in real time.

Fig 11.AI Smart Walking Stick

The image shows a working model of an AI-based Smart Walking Stick made to help blind or visually impaired people. It uses electronic parts like an ultrasonic sensor to detect obstacles, a GPS module for location tracking, and a microcontroller (probably ESP32) to control everything. These parts are fixed in a transparent box attached to the stick, and the system runs on a rechargeable battery. A mobile phone nearby displays an app that gives real-time updates like how far an object is, whether something is detected, and if there is water or a fall ahead. This helps the user walk safely and with more confidence.

Conclusion:

This project aims to help people who are blind or have difficulty moving by making their environment easier and safer. From the results, we can see that this device is low-cost, easy to use, and helpful for blind people. It can detect many types of objects, so it can even be used during games or daily activities to improve their experience and make life better for them. In the future, the system can be trained to recognize familiar faces, so users will know when someone they know is nearby. It can also be improved to read books and words out loud, so blind users can listen to the content instead of reading it. As technology continues to improve, we can expect more advanced features like object detection and face recognition to work even better in small devices.

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