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AI-Based Object Detection, Distance Measurement And Speaking System For Blind Stick

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Abstract: The sense of sight is central to the way that human beings perceive and interact with their environment. In visually impaired individuals, vision loss presents enormous difficulties in the ability to detect obstacles and measure distance, making daily navigation challenging and dangerous. In an effort to overcome these challenges, we suggest implementing an AI-based object detection, distance measurement, and sound feedback system into a smart blind stick. In contrast to other conventional systems, our system employs a cost-effective and lightweight Node-MCU microcontroller, three ultrasonic sensors, and a small speaker to provide real-time support. The ultrasonic sensors are well positioned to sense nearby objects and accurately measure the distance of the objects. Such information is read by the Node-MCU and converted into real-time voice signals through a speaker, which allows people to sense their environment via sound. Besides, AI aid is used in sophisticated navigation. The system has an easy-to-use interface and can be used for both outdoor and indoor environments. It provides increased mobility and independence to the blind users by integrating effective intelligent navigation distance measurement. The outcome is a low-power, reliable, and scalable solution that greatly enhances safety and independence in everyday life.

***Index Terms* -** Smart Blind Stick, Obstacle Detection, Ultrasonic Sensors, Node-MCU, Distance Measurement, Voice Feedback, AI Navigation, Assistive Technology, Visually Impaired Aid

I. INTRODUCTION

For the visually impaired, going through daily spaces without sight is a great challenge. White canes are limiting in their tactile feedback and demand direct physical contact with the obstacle, which can be dangerous and inefficient. To solve this, we come up with a smart blind stick with embedded AI-based object detection and proximity measurement. The system utilizes a Node-MCU (ESP8266) microcontroller, three ultrasonic sensors, and a speaker to identify obstacles and estimate proximity. Real-time audible warnings assist users by alerting them to objects around them. For loud environments, where speaker output can be ineffective, the system provides an earphone output for clear and confidential voice feedback. Simple AI reasoning assists in providing safer directions from obstacle data, improving navigation. The device is small, light, energy-efficient, and both indoor and outdoor use-friendly. The solution is intended to enhance the mobility and safety of visually impaired users through accessible, real-time assistance.

II. LITERATURE SURVEY

Modern assistive technologies for visually impaired individuals integrate a wide range of advanced features aimed at enhancing navigation, safety, and independence. Object detection models such as YOLOv5 and SSD are widely utilized in smart mobility aids due to their high speed and accuracy in identifying obstacles in real time. These models significantly contribute to a safer user experience by enabling timely avoidance of hazards. Complementing this, text-to-speech technology provides real-time auditory alerts, allowing users to interpret their surroundings without relying on touch or visual cues. Distance measurement using ultrasonic and LiDAR sensors further improves precision by informing users about the proximity of nearby objects.

IoT-enabled assistive devices are becoming increasingly prevalent, offering remote monitoring and location-sharing capabilities that enhance user safety. For instance, smart canes equipped with IoT technology can update caregivers about the user's location in real time. Meanwhile, wearable vision-aid devices combine object detection and audio feedback to enable hands-free navigation, making daily movement easier and more accessible. Emphasizing the importance of design, recent studies highlight the benefits of user-centered approaches that prioritize usability, simplicity, and customization—key factors in increasing user satisfaction and long-term adoption of these technologies.

Obstacle-detecting Electronic Travel Aids (ETAs) are critical in helping visually impaired individuals avoid collisions. These systems often use ultrasonic sensors, microcontrollers, and speech synthesizers to deliver real-time feedback. For example, Sharma et al. developed a "virtual eye" system using ultrasonic sensors, Arduino, and Raspberry Pi to detect obstacles in multiple directions. Mocanu et al. combined ultrasonic sensors with a smartphone camera and machine learning algorithms for obstacle detection, though limited to waist-height objects. Yi et al. designed a guide crutch that uses ultrasonic sensors to provide directional feedback through sound and vibration. Similarly, Mohammed A. Therib created a system that uses ultrasonic and moisture sensors to detect environmental hazards like stairs, holes, and wet surfaces, providing alerts via sound and vibration. Some solutions, such as RFID-based walking sticks, rely on RFID tags to guide users near sidewalks but require extensive infrastructure to function effectively.

Hybrid ETAs integrate multiple functionalities, combining obstacle detection with GPS-based localization and communication features to offer comprehensive support. Dhod et al. developed a smart cane using GPS, GSM, IR, and water sensors to assist with navigation and send emergency alerts. Bharambe et al. introduced a system that pairs ultrasonic sensors with a mobile application to provide real-time obstacle alerts and navigational assistance. Swain et al. took this further by enabling the system to send alerts to emergency contacts using GPS and GSM modules. Ali J. Ramadhan designed a wearable solution that includes ultrasonic sensors, GPS, GSM, and an accelerometer to offer obstacle detection, fall detection, and emergency alerts. These hybrid systems demonstrate the potential of combining multiple technologies to significantly enhance mobility, autonomy, and safety for visually impaired persons.

III. PROPOSED SYSTEM

The Smart Blind Stick system is designed to enhance mobility and safety for visually impaired individuals by using a lightweight and cost-effective architecture. The system utilizes a **NodeMCU microcontroller** as its central processing unit, managing inputs from **three ultrasonic sensors** and a **water detection sensor** to provide real-time feedback on the surrounding environment. The **ultrasonic sensors**, positioned to cover the front and sides, continuously measure the distance to nearby obstacles. This allows the stick to detect walls, poles, or approaching objects and alert the user with varying **audio signals** through a **speaker**. The **water sensor** helps identify wet or slippery surfaces like puddles, alerting the user to potential hazards. The system communicates important navigation cues using pre-programmed **audio feedback**, providing simple yet effective assistance in obstacle avoidance. Its compact and low-power design makes it ideal for daily use, while future iterations may incorporate **Bluetooth** or **Wi-Fi** for smartphone connectivity, enabling updates or customization of alert sounds and sensor sensitivity. Overall, this version of the Smart Blind Stick focuses on **affordability, simplicity, and reliability**, offering essential navigational aid without the complexity of AI or visual processing, making it accessible and practical for wide-scale use.

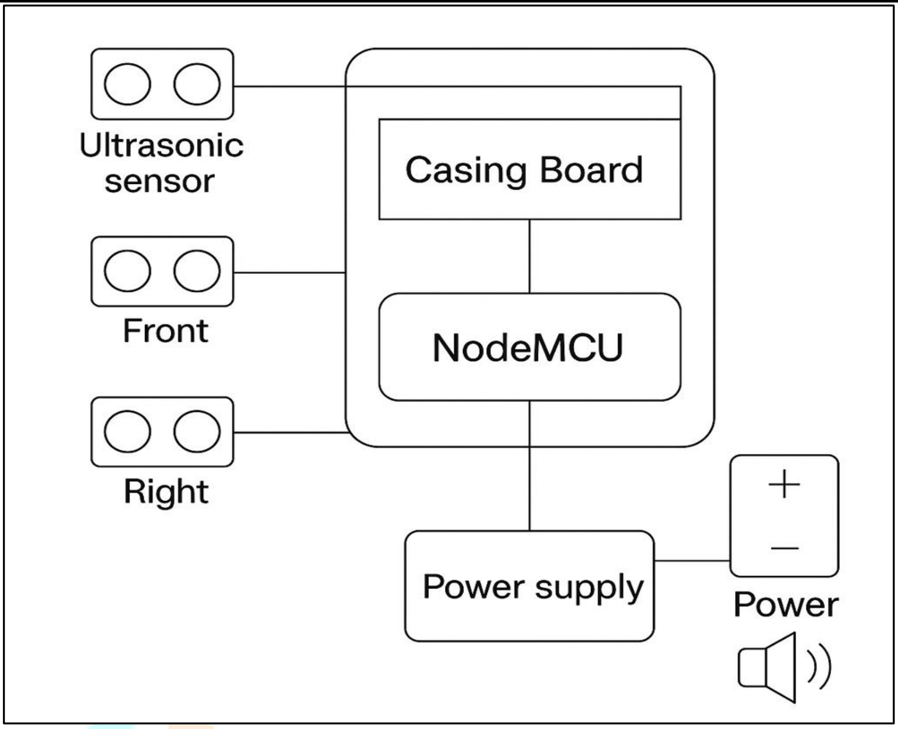

Figure 1: System Architecture

IV. METHODOLOGY

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The smart blind stick system is designed to enhance the mobility of visually impaired individuals by using a combination of low-cost sensors and a microcontroller to detect obstacles, water, and provide audio feedback. At the core of the system is the NodeMCU (ESP8266) microcontroller, which acts as the brain of the device. It is responsible for receiving input from various sensors, processing that data, and triggering appropriate responses. The NodeMCU is chosen for its compact size, built-in Wi-Fi capabilities (if future upgrades are considered), and ease of programming via the Arduino IDE.

To detect physical obstacles, the system uses **three ultrasonic sensors (HC-SR04)** strategically positioned on the front, left, and right sides of the stick. These sensors emit ultrasonic waves and measure the time taken for the waves to reflect back after hitting an object. The NodeMCU calculates the distance using the time of flight and the speed of sound. If an object is detected within a certain predefined range (e.g., less than 1 meter), the system determines its direction (front, left, or right) based on which sensor is triggered and initiates a corresponding alert. This multi-directional sensing allows the user to be aware of not just the presence of an obstacle but also its location relative to them, which greatly enhances their spatial awareness.

In addition to obstacle detection, a water sensor is placed near the base of the stick to detect puddles or spills, helping prevent slips in wet conditions. When water is detected, it sends a signal to the NodeMCU, which triggers an immediate audio alert. The audio feedback system, using a speaker or buzzer, provides real-time voice messages or tones to inform the user about nearby obstacles and hazards. A rechargeable battery powers the entire system, with a voltage regulator ensuring stable performance. The components are mounted on a standard walking stick, making the device lightweight, portable, and practical. Overall, this low-cost system enhances safety and independence for visually impaired individuals by combining obstacle detection, water sensing, and spoken alerts.

V. Problem Statement

Visually impaired individuals encounter numerous obstacles when attempting to navigate their surroundings, especially in unfamiliar, complex, or crowded settings. Traditional mobility aids, such as the white cane, offer only a rudimentary level of support. They rely solely on tactile feedback, identifying obstacles only upon direct contact, and fail to provide users with adequate information about their environment—particularly concerning objects that are elevated or at a distance. This creates a high risk of accidental collisions, disorientation, and falls. Such limitations not only jeopardize personal safety but also erode the user's confidence and sense of autonomy. Over time, these challenges may result in social withdrawal, dependence on caregivers, and a reduced quality of life, as basic tasks like commuting or moving through public spaces become stressful and potentially dangerous.

To address these critical concerns, the development of an intelligent mobility aid is both necessary and timely. By leveraging advancements in artificial intelligence, computer vision, and sensor technologies, it is now possible to engineer a smart blind stick that provides real-time feedback from the user's environment. This enhanced device would integrate features such as AI-driven object recognition, ultrasonic distance sensing, and voice-guided alerts to help visually impaired individuals perceive their surroundings more fully and respond proactively. Such a system would not only detect obstacles before contact but also distinguish between different types of hazards—stationary or moving, low or elevated—and communicate this information clearly through audio cues. The result would be a transformative solution that empowers users to navigate independently, safely, and confidently, ultimately fostering a more inclusive and accessible world.

VI. Objective

To design and develop an AI-driven blind stick system that can detect obstacles and provide real-time feedback for visually impaired users.

 To implement precise distance measurement functionalities to inform users of obstacle proximity, helping with safer navigation.

 To incorporate a text-to-speech system that audibly communicates information on detected obstacles and distances, enhancing user awareness.

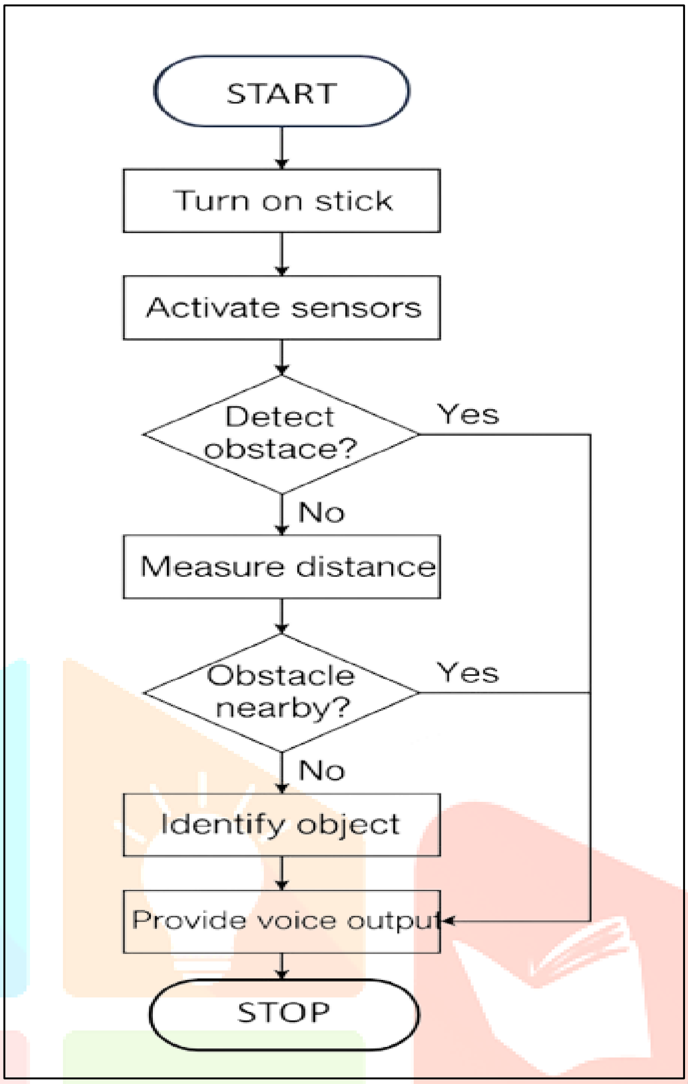
 To ensure the system is lightweight, user-friendly, and cost-effective, making it accessible and practical for daily use.

 To evaluate the system's performance, accuracy, usability, and reliability through testing and user feedback from visually impaired individuals. 1.4 Scope and Limitations.

 Portable and Lightweight Design: The device is intended to be compact, lightweight, and easy to handle for daily use without adding significant weight or inconvenience to the user.

 Cost-Effectiveness: By using readily available components and open-source software, the system is designed to be affordable, making it accessible to a wider user base.

VII. Flowchart



VIII. Functional Requirements

• Functional requirements define the essential behaviors the system must exhibit. These requirements specify the core functionalities that enable the system to meet the needs of the users effectively. The system must generate random paragraphs from a curated dataset that includes sentences of varying complexity and phonetic challenges. These paragraphs should be customizable based on user level (beginner, intermediate, advanced) to provide appropriate difficulty for improving pronunciation skills.
• Real-time Object Detection: The system must be capable of detecting obstacles and objects in real-time as the user navigates their environment. The object detection algorithm should classify and locate obstacles (e.g., walls, people, vehicles) in the path of the user. The detection should occur continuously with minimal delay.
• Distance Measurement: The system should measure and provide real-time distance readings to detected obstacles. Using ultrasonic sensors, the system will calculate the distance between the user and obstacles and update the information as the user moves. The distance should be displayed in both numerical and spoken formats.
• Audio Feedback System: The system must provide continuous audio feedback to inform the user about the location and proximity of detected objects. The feedback should be understandable and delivered with natural-sounding speech. It should dynamically adjust based on the user's movement and the changing distance to obstacles.
• User Interaction: The system should be simple to use, requiring minimal user interaction. The user should be able to power the device on and off easily and adjust audio volume if necessary. The feedback should not require user input, functioning autonomously.

IX. Non-functional requirements

Performance: The system should operate with low latency, providing near-instantaneous object detection and distance measurements. Any delays in feedback may hinder the user's navigation ability, which can be dangerous.

- **Reliability:** The system must be reliable and should function without failures or malfunctions under normal operating conditions. It must consistently detect objects and provide accurate distance measurements, especially in real-world environments where unpredictable obstacles may arise.
- **Power Efficiency:** Since the system is designed to be a wearable device, it must be power-efficient. It should be able to run for several hours on a single charge to ensure practical use throughout the day.
- **Usability:** The system should be user-friendly and intuitive for individuals with visual impairments. It should be easy to operate without the need for extensive training. The interface should be accessible, with clear auditory feedback.
- **Compactness:** The device must be lightweight and compact enough to be integrated into a blind stick without making it bulky or uncomfortable for the user to carry.

X. Conclusion

The development of the smart blind stick system successfully addresses key mobility challenges faced by visually impaired individuals by providing real-time obstacle and hazard detection using simple, low-cost components. By integrating the NodeMCU microcontroller with ultrasonic sensors, a water sensor, and an audio feedback system, the device enhances user awareness and safety during navigation. The use of directional ultrasonic sensors enables detection of obstacles from multiple angles, while the water sensor adds an important layer of safety in wet environments. Audio alerts, delivered through a speaker or buzzer, ensure that users receive immediate and understandable feedback without the need for visual cues.

The system is lightweight, energy-efficient, and cost-effective, making it suitable for daily use. Through practical testing, the prototype demonstrated its potential to improve independence and confidence among visually impaired users. Overall, this project contributes a practical, affordable, and user-friendly assistive technology solution, with the potential for further enhancement through future integration of GPS or AI for advanced navigation support.

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