IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 4, April 2025 Impact Factor: 7.67

Smart Stick for Blind People using Raspberry Pi

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Abstract: *The main purpose of this paper is to present a smart navigation aid designed to assist visually impaired individuals by enhancing mobility and safety. The goal of this project is to develop a smart stick using a Raspberry Pi, an efficient and versatile microcontroller platform. The smart stick is equipped with a Raspberry Pi Camera Rev 1.3, which captures real-time images of the surroundings and processes them using TensorFlow for object detection. The system detects obstacles such as walls, staircases, or furniture and provides immediate feedback to the user. A vibrator motor delivers tactile alerts, while a speaker provides audio warnings, ensuring a multi-sensory navigation experience. The smart stick is intended to be cost-effective, easy to develop, and adaptable. The proposed study results aim to improve independent navigation for visually impaired individuals, fostering confidence and safety in urban environments.*

Keywords: Raspberry PI Model 4B, Raspberry PI Camera Rev 1.3, Vibrator Motor, Speaker

I. INTRODUCTION

Innovations in assistive technology have significantly improved mobility and independence for visually impaired individuals, particularly in urban environments where navigation poses safety hazards and obstacles. Traditional mobility aids, such as white canes, offer limited tactile feedback and require extensive training to detect obstacles effectively. In response, researchers have explored smart navigation aids that integrate advanced technology to enhance real-time guidance. This study proposes a smart stick based on Raspberry Pi and TensorFlow, leveraging computer vision and multi-sensory feedback to assist visually impaired users. The system employs a Raspberry Pi Camera Rev 1.3 to capture real-time images, while TensorFlow processes the data to detect and classify obstacles such as walls, stairs, and furniture. The Raspberry Pi serves as the core processing unit, interfacing with a vibrator motor and speaker to deliver immediate tactile and auditory feedback. This multi-modal approach enhances situational awareness, improves user confidence, and promotes independent navigation. By demonstrating the practical application of computer vision and machine learning, this study contributes to the development of accessible and intelligent mobility solutions for visually impaired individuals.

II. LITERATURE SURVEY

Assistive technologies for visually impaired individuals have been a significant area of research, focusing on enhancing mobility, safety, and independence. Various solutions, including traditional white canes and guide dogs, have been widely used; however, these methods have limitations in detecting obstacles at a distance and providing real-time feedback. Recent advancements in computer vision, sensor- based navigation, and artificial intelligence have paved the way for smart navigation aids that offer improved assistance. Several studies have explored the use of ultrasonic sensors for obstacle detection. For instance, Jain et al. (2019) developed an ultrasonic-based smart cane that alerts users about obstacles using vibration feedback. While effective in short-range detection, ultrasonic sensors face challenges in identifying complex objects and differentiating between various obstacle types. With the rise of computer vision, researchers have integrated cameras into assistive devices. A study by Kumar and Sharma (2021) implemented a Raspberry Pi-based vision system for object detection, utilizing convolutional neural networks (CNNs) to identify obstacles with higher accuracy than ultrasonic methods. This approach demonstrated improved obstacle classification but required significant processing power. TensorFlow-based machine learning models have further enhanced real-time obstacle detection capabilities. Patel et al. (2022) proposed a smart navigation system that combined deep learning with

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a camera module, enabling the detection of stairs, walls, and furniture. Their findings indicated that computer vision-based approaches provided more detailed environmental information compared to traditional sensor-based systems. The integration of multi- sensory feedback has also been studied. Research by Smith et al. (2020) explored the effectiveness of vibro-tactile and audio feedback in navigation aids. Their study found that combining tactile and auditory cues significantly improved response time and user confidence in navigating urban environments.

Building on these findings, the proposed project aims to develop a cost-effective smart navigation aid using a Raspberry Pi and TensorFlow for real-time object detection. By leveraging a Raspberry Pi Camera Rev 1.3, the system can provide enhanced obstacle recognition while offering both vibrational and auditory feedback to assist visually impaired individuals in urban navigation. This project seeks to contribute to the ongoing development of assistive technology, ensuring greater accessibility and independence for users.

III. METHODOLOGY

The proposed smart navigation aid utilizes computer vision and machine learning to enhance mobility for visually impaired individuals. The system is built using a Raspberry Pi, chosen for its computational efficiency and affordability. A Raspberry Pi Camera Rev 1.3 captures real-time images of the surroundings, which are then processed using TensorFlow for object detection her model identifies obstacles such as walls, staircases, and furniture, providing accurate and timely navigation assistance. Upon detecting an obstacle, the system activates a multi-sensory feedback mechanism consisting of a vibrator motor and a speaker. The vibrator motor delivers tactile alerts to the user, while the speaker provides audio warnings regarding the obstacle's type and distance, ensuring an intuitive and accessible navigation experience. To optimize the system's accuracy, the object detection model is trained using a diverse dataset featuring indoor and outdoor obstacles. The smart stick undergoes rigorous testing in both controlled and real-world environments to assess its reliability, efficiency, and adaptability. By integrating advanced technology into a cost-effective and user-friendly design, the proposed system significantly improves the independence and safety of visually impaired individuals in urban environments.

IV. HARDWARE IMPLEMENTATION

Raspberry Pi 4B

The Raspberry Pi (Fig. 1) is a widely used single-board computer designed for embedded systems, IoT applications, and prototyping. As part of the Raspberry Pi family, it serves as an open-source hardware and software platform, providing an affordable and user-friendly development environment for both beginners and experts. Unlike traditional microcontrollers, the Raspberry Pi features a powerful processor capable of running full operating systems like Raspberry Pi OS, making it suitable for automation, machine learning, and computer vision applications.

The board includes 4GB RAM, a Quad-core ARM Cortex- A72 processor, GPIO pins, USB ports, HDMI output, an Ethernet connector, an audio jack, and, in some models, Wi-Fi and Bluetooth connectivity. It supports external peripherals such as cameras, sensors, and displays, enhancing its versatility. Powered via USB-C or micro-USB, it uses SD cards for storage. Due to its affordability, adaptability, and broad application in robotics, home automation, and education, the Raspberry Pi is a cost-effective choice for smart device development, making it easy to replace when needed.

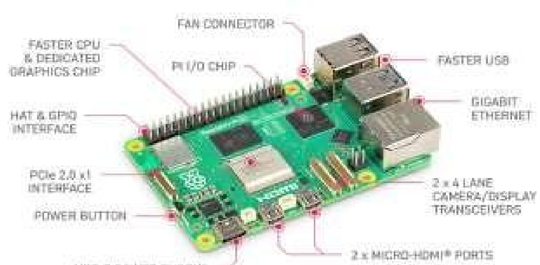

Fig. 1 Raspberry Pi 4B

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Raspberry Pi Camera Rev 1.3

The Raspberry Pi Camera Rev 1.3 (Fig. 2) is a compact camera module designed for use with Raspberry Pi boards. It features a 5-megapixel Omni Vision OV5647 sensor with a 54° field of view (FOV), capable of capturing high-resolution images (2592 × 1944 pixels) and recording 1080p HD video at 30fps, 720p at 60fps, and 480p at 90fps. The module connects to the Raspberry Pi via the CSI (Camera Serial Interface) port, ensuring fast data transfer for real-time image processing applications. This camera module is widely used in various projects, including computer vision, surveillance, robotics, and automation. It is compatible with popular programming libraries like Python, OpenCV, and TensorFlow, enabling developers to implement image recognition, motion tracking, and object detection tasks efficiently. Due to its affordability, compact form factor, and ease of integration, it is commonly utilized in smart navigation systems, facial recognition, and IoT-based vision applications. The Raspberry Pi Camera Rev 1.3 plays a crucial role in embedded vision projects where capturing and processing visual data with clarity and speed is essential.

Fig. 2 Raspberry Pi Camera Rev 1.3

DC Vibrator Motor

The vibrator motor (Fig. 3) is a small electromechanical device used to generate vibrations for haptic feedback in various applications. It operates using an eccentric rotating mass (ERM) or a linear resonant actuator (LRA), which creates motion when an electrical current is applied. These motors are commonly used in mobile phones, wearables, gaming controllers, and assistive devices to provide tactile alerts. In assistive technology, vibrator motors play a key role in smart navigation aids for visually impaired individuals by offering real-time haptic feedback to indicate obstacles or navigation cues. It is lightweight, energy-efficient, and easily programmable, making it compatible with microcontrollers like Raspberry Pi and Arduino. The motor’s compact design allows for seamless integration into embedded systems, ensuring effective yet silent user communication. Due to its affordability and reliability, the vibrator motor is widely used in haptic communication, robotics, accessibility solutions, and wearable technology.

Fig. 3 DC Vibrator Motor

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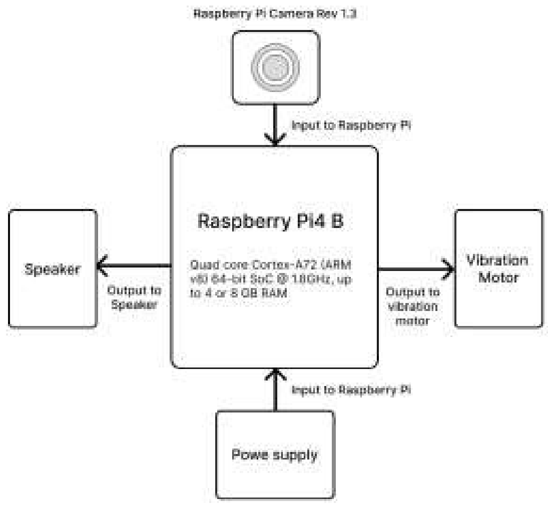

Fig. 6 Block Diagram

V. IMPLEMENTED SYSTEM OF PROJECT

Fig. 7 Prototype of Object Detection System

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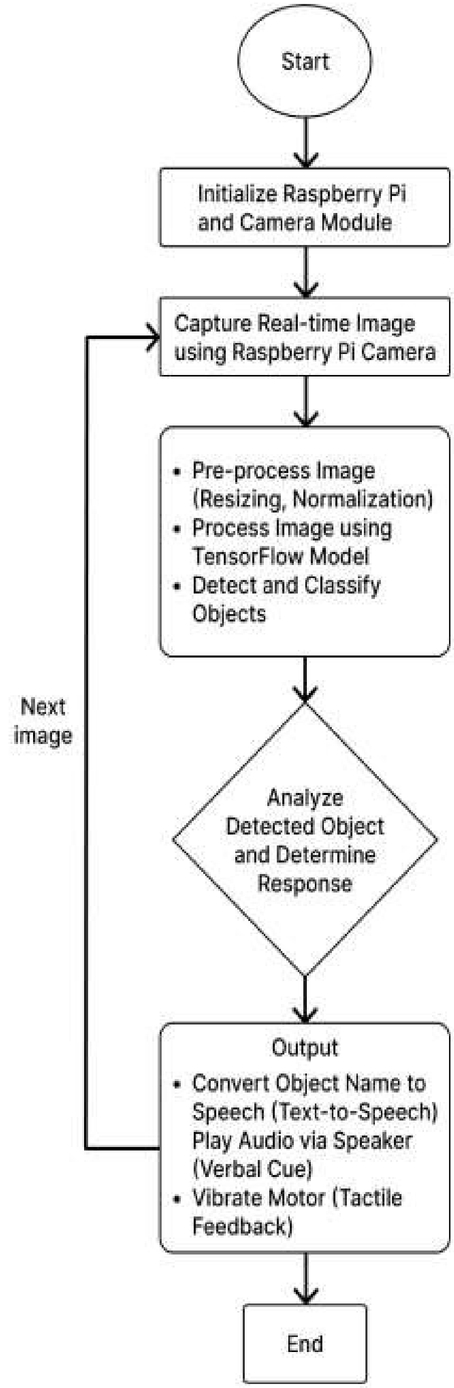

Fig.8 Object Detection flowchart

Explanation of the Object Detection (Fig. 8)

The proposed system integrates a Raspberry Pi and a Camera Module Rev 1.3 to detect objects and provide navigation assistance for visually impaired users.

- TensorFlow is used for object detection, while a vibration motor and a speaker provide multi-sensory feedback.
- The Raspberry Pi Camera captures real-time images, which are processed to identify obstacles such as walls, stairs, and furniture.
- The algorithm reads image data and classifies objects using a pre-trained TensorFlow model. If no significant obstacle is detected, the system remains idle.
- If an obstacle is identified, the system determines its type, proximity, and position within a predefined quadrant (e.g., top-left, bottom-right).
- The system initializes by loading the necessary libraries, including OpenCV for image processing and Pyttsx3 for text-to-speech conversion.
- The Raspberry Pi Camera is activated, and image data is continuously captured and fed into the object detection model for analysis.
- The detected objects are classified, and their distance from the user is estimated to assess potential hazards.
- The system determines the object's quadrant using image segmentation, dividing the frame into four sections (top-left, top-right, bottom-left, bottom- right).
- If an obstacle is detected within a predefined range, the system activates the vibration motor to alert the user through tactile feedback.
- Simultaneously, the detected object's name and its position (e.g., "Chair in the bottom-left quadrant") are converted into speech using the text-to-speech engine and played through a speaker.
- The system loops continuously, capturing new images and updating the feedback based on real-time environmental changes.
- To ensure smooth operation, a brief delay is applied before processing the next frame, allowing the user to respond to the feedback.

VI. ADAVANTAGES AND APPLICATIONS

- Enhanced Mobility for Visually Impaired Users: The smart stick improves independent navigation by detecting obstacles using the Raspberry Pi Camera Rev 1.3 and TensorFlow, ensuring a safer and more efficient travel experience.
- Real-Time Multi-Sensory Feedback: Integrated with a vibrator motor for tactile alerts and a speaker for audio warnings, the device provides immediate feedback, enhancing user awareness and confidence.
- Affordable and Adaptable Design: Built with cost-effective components, the system is accessible to a wide range of users while allowing future enhancements with additional sensors or AI-based functionalities

APPLICATIONS

1. Assistive Technology for Visually Impaired Individuals: Enables safe and independent movement by detecting obstacles and providing real-time guidance.
2. Smart Navigation in Public Spaces: Helps users navigate malls, airports, and transportation hubs with improved safety and ease.
3. Educational and Research Tool: Supports learning and experimentation in fields such as AI, computer vision, and embedded systems for assistive technologies.

VII. CONCLUSION AND FUTURE WORK

This paper presents the design of a smart navigation aid for visually impaired individuals. The proposed system utilizes a Raspberry Pi, Raspberry Pi Camera Rev 1.3, vibrator motor, and speaker to detect obstacles and provide real-time feedback through multi-sensory alerts. By implementing computer vision and object detection algorithms, the system enhances mobility and safety in urban environments. The use of affordable and accessible components ensures that the device remains cost-effective and practical. The primary advantage of this system is its ability to assist visually impaired users in navigating unfamiliar surroundings with greater confidence. However, the current design is limited to detecting obstacles within the camera's field of view. Future enhancements could include 360-degree obstacle detection using multiple sensors, GPS integration for navigation assistance, and AI-based improvements for more accurate object classification. Despite these limitations, the developed prototype serves as a foundation for advancing assistive technologies for visually impaired individuals.

ACKNOWLEDGMENT

This project was supported by our college JSPMs Bhivarabai Sawant Institute of Technology and Research Pune, India. We express our gratitude towards Prof. Meenakshi Annamalai, JSPMs Management Team for providing us tremendous support and assistance. We also thank the teaching and non- teaching staff of JSPMs who guided us with their expertise that greatly assisted our project.

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