

Smart AI-Based Navigation System for Visually Impaired

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Abstract : In today's Visually impaired individuals often encounter significant challenges in perceiving their surroundings and navigating safely in everyday environments. This paper presents a mobile-based assistive system designed to enhance real-time environmental awareness using computer vision and deep learning techniques. The proposed system employs a lightweight object detection model to identify surrounding objects through a smartphone camera and provides immediate auditory feedback to the user. To improve navigation safety, the system incorporates a decision-making mechanism that analyzes detected objects and determines appropriate guidance instructions such as moving left, right, or stopping based on obstacle position and proximity. A haptic feedback component is also integrated to provide vibration alerts in critical situations, ensuring timely user response. In addition to navigation support, the system includes an Optical Character Recognition (OCR) module for reading printed text and a currency recognition module for identifying Indian banknotes. Voice command functionality is implemented to enable hands-free interaction, thereby improving accessibility. The entire solution is developed on the Android platform using optimized models suitable for realtime performance on mobile devices. Experimental observations demonstrate that the system provides a practical and cost-effective assistive solution, contributing to improved mobility, safety, and independence for visually impaired users.

IndexTerms - Assistive Technology, Computer Vision, Object Detection, Deep Learning, RealTime Navigation, Safe Path Detection, Optical Character Recognition (OCR), Currency Recognition, Voice Assistance.

I.INTRODUCTION

In Navigation is a critical issue for people with visual impairments, particularly when they move through unfamiliar places. Traditional tools like white canes help in detecting nearby obstacles but do not provide complete awareness of the surroundings or guidance on safe paths. As environments continue to become more complex, there is a growing demand for assistive technologies that can offer accurate, real-time support while reducing dependence on others. Recent developments in sensing and intelligent systems have led to the creation of wearable devices that combine components such as cameras, LiDAR sensors, and processing units to improve environmental understanding. Voice-based guidance systems have become especially useful, as they deliver clear instructions instantly, helping users make quick decisions. The use of deep learning models further improves object recognition and scene interpretation, while combining audio with vibration feedback enhances safety and usability. These systems are designed to be hands-free and comfortable, making them more practical for everyday use and improving independence for visually impaired individuals [10]. Understanding surroundings is another major challenge faced by visually impaired people, which limits their ability to interact confidently with their environment. Conventional aids provide only partial assistance and often fail to deliver realtime contextual information. With the introduction of artificial intelligence, voice-driven systems have been developed to overcome these limitations. These systems respond to voice commands, capture images using cameras, and process them through machine learning models to generate meaningful descriptions. The output is then converted into speech, allowing users to better understand their surroundings. Such systems reduce reliance on external help and improve mobility and confidence in daily activities [11]. Apart from navigation, accessibility to graphical content is also a concern. Many existing tools require precise visual input and numerical coordinates, making them difficult for visually impaired users to operate. To address this, a simplified graphic description approach has been introduced, where users can create drawings using an object-oriented method instead of complex numerical inputs. This reduces difficulty and allows users to independently create and modify graphical content. Such innovations play an important role in making digital information more accessible and inclusive [12]. Obstacle detection remains a fundamental requirement for safe mobility. Sensor-based systems using ultrasonic and water detection technologies have been developed to identify obstacles in different directions and detect hazardous surfaces like water. These systems process sensor data using microcontrollers and alert users through sound signals. Additionally, GPS and communication modules allow users to send their location to caregivers during emergencies. While these systems improve safety, they mainly depend on basic sensors and lack advanced intelligence to fully interpret complex environments [13]. Urban navigation and access to transportation services present additional challenges. To support users in such environments, smart applications have been developed that provide real-time information about locations, public transport schedules, and environmental conditions. These systems use smartphone-based platforms combined with voice interaction and text-to-speech features to deliver information. Some systems also use open data sources to provide updates and alerts, while wearable components ensure user convenience. Although these solutions are practical, they rely heavily on connectivity and may not function effectively in offline or rapidly changing situations [14]. The integration of IoT technology has further enhanced assistive systems by enabling better connectivity between devices. Wearable solutions such as smart shoes use embedded sensors to detect obstacles and provide feedback to users. These systems aim to reduce hardware complexity compared to earlier designs and improve ease of use. However, issues such as cost, hardware

dependency, and performance in different environmental conditions still need to be addressed for wider adoption [15]. Advancements in smart cane technology have also contributed to improving mobility. Modern designs incorporate sensors to detect obstacles and camera modules to capture images of the surroundings. These systems provide alerts when obstacles are detected and can also assist in monitoring situations during emergencies. The inclusion of motion sensors helps in optimizing power usage by activating components only when needed. While these designs are practical and cost-effective, their performance depends on sensor reliability and environmental factors [16]. More advanced systems integrate multiple components into a single platform to provide comprehensive assistance. Intelligent systems combining wearable devices, sensors, and mobile applications offer improved navigation and object detection capabilities. These systems use deep learning techniques to identify obstacles and provide real-time guidance, while mobile applications enable additional features such as virtual navigation and system control. Although such systems show high performance, they may involve higher complexity, dependence on connectivity, and challenges in adapting to realworld conditions [17]. Overall, existing research shows significant progress in developing assistive technologies for visually impaired individuals. However, most systems focus on specific functionalities rather than providing a complete solution. Challenges such as cost, real-time performance, environmental adaptability, and user comfort still need to be addressed. Future developments should aim to create integrated, efficient, and user-friendly systems that can operate reliably in diverse realworld conditions and truly enhance the independence and quality of life of visually impaired people

II. LITERATURE REVIEW

SeveralRecent developments in assistive technologies have significantly contributed to improving the independence of visually impaired individuals. Vijaya Vardan Reddy S et al. (2023) proposed a system that uses a Raspberry Pi along with a camera and audio output to assist users in identifying obstacles. The system processes live video using deep learning techniques and provides voice-based guidance. Although the system demonstrates acceptable accuracy, its performance is affected in crowded environments and under poor lighting conditions. Moreover, aspects such as system scalability and long-term usability are not explored in depth [1].

Similarly, Saya Fathima Siby et al. (2023) introduced a smart cane that incorporates a convolutional neural network based on MobileNet to perform object detection efficiently on lowpower devices. The system also includes a webbased application that enables real-time location sharing and monitoring, enhancing user safety. While the design is practical, it may depend on continuous internet connectivity, and its performance in dynamic or complex environments is not thoroughly evaluated [2].

Addressing road safety, P. Usha Rani et al. (2024) developed a system that assists visually impaired individuals during pedestrian crossing by controlling traffic signals and providing both audio and vibration feedback. This approach improves safety in controlled environments such as intersections. However, its applicability is limited to specific locations, and it lacks the capability to assist users in general navigation scenarios. In addition, the absence of intelligent perception techniques restricts its adaptability [3].

Asha Ghodake et al. (2023) presented a smart glasses system that combines ultrasonic sensing with facial recognition capabilities. The device helps users detect obstacles and identify people in their surroundings. While this enhances situational awareness, the system relies on pre-stored data and sensor accuracy, which may reduce effectiveness in unfamiliar or rapidly changing environments. Furthermore, factors such as lighting variations and processing delays are not fully addressed [4].

In the domain of digital accessibility, Ahmad Alenezi (2023) proposed a framework aimed at enabling visually impaired users to perform online banking activities independently. The framework focuses on improving usability and security, reducing reliance on external assistance. Although initial results are promising, the system remains at a preliminary stage and requires validation with a larger user base. Practical challenges related to implementation are also not extensively discussed [5].

Zara Iqbal et al. (2023) addressed accessibility issues in CAPTCHA systems by proposing a machine learning-based approach designed for color-blind users. The system aims to provide a more inclusive verification mechanism while maintaining security standards. Despite its potential, further evaluation is needed to ensure effectiveness across diverse user groups and realworld applications [6].

For outdoor navigation, I-Hsuan Hsieh et al. (2023) developed a wearable system that uses deep learning-based scene segmentation along with depth information to guide users. The system analyzes the environment, determines safe walking directions, and provides voice instructions. While the results are effective, the use of high-end hardware increases cost and limits accessibility. Additionally, the system's performance in highly dynamic environments requires further investigation [7].

In indoor environments, Mouna Afif et al. (2023) proposed a system that detects signage and doors using deep learning techniques. The system achieves high accuracy in recognizing specific types of signs, which helps users navigate unfamiliar buildings. However, it is limited to predefined categories and may not generalize well to varied real-world scenarios. Issues related to real-time deployment and environmental variations are also not fully explored [8].

Chayma Zatout and Slimane Larabi (2020) introduced a tactile output device that communicates information through touch, offering an alternative to audio-based feedback systems. This approach enhances user interaction and can be applied in indoor navigation and scene understanding tasks. However, users may require training to interpret tactile signals effectively, and integration with other assistive systems remains a challenge [9].

A broader analysis of these studies reveals that most systems focus on specific use cases such as obstacle detection, navigation, or digital accessibility, rather than providing a unified solution. While deep learning and embedded systems have improved performance, challenges such as high computational requirements, cost, and energy consumption continue to limit widespread adoption. Many solutions also lack robustness when deployed in real-world conditions, where factors like lighting, weather, and crowd density can affect performance. Another important limitation observed across existing works is the lack of user-centered design considerations. Factors such as comfort, ease of use, adaptability, and long-term usability are often not given sufficient attention. In addition, there is limited integration of multiple functionalities into a single system, which restricts the practicality of these solutions in everyday life. Overall, although significant progress has been made in developing assistive technologies for visually impaired individuals, there is still a need for more comprehensive, affordable, and adaptable systems. Future research should focus on combining multiple features into a single platform, improving real-time performance, and ensuring that solutions are practical and accessible for realworld use

III. METHODOLOGY

The The proposed system is a mobile-based assistive application designed to support visually impaired individuals by providing real-time environmental awareness and navigation assistance. The system operates using a smartphone camera and integrates multiple functional modules, including object detection, safe path analysis, text recognition, and currency identification.

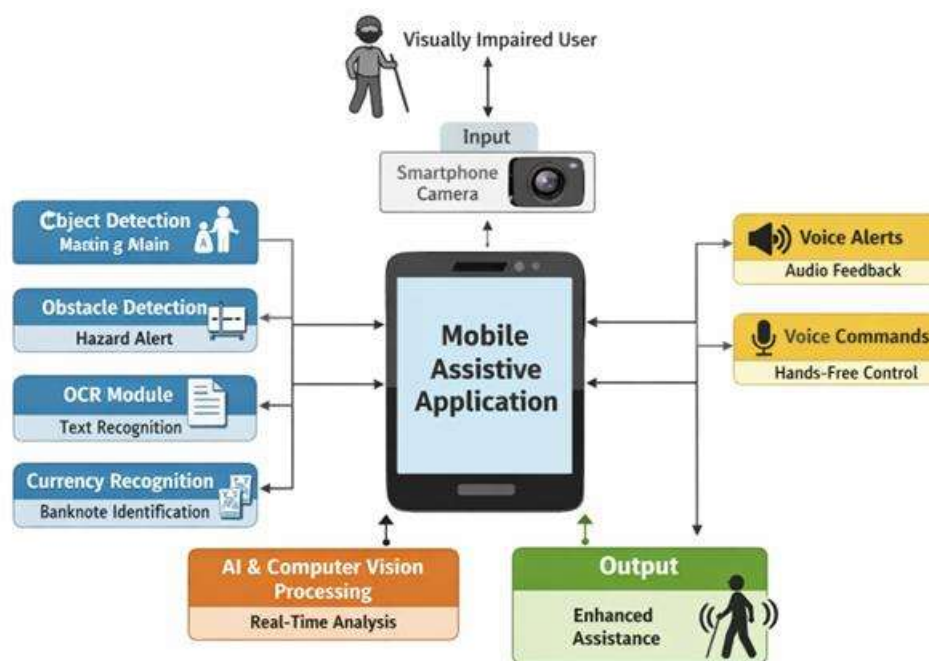


FIG. 1. System architecture Diagram

The proposed assistive system is organized into multiple interconnected modules, each responsible for a specific functionality that contributes to realtime environmental awareness and navigation support. The modular design ensures scalability, efficient processing, and ease of integration across different components of the application.

1. Image Acquisition Module:

This module is responsible for capturing continuous visual input from the smartphone camera. It operates in real time, providing a stream of frames that serve as the primary input for all subsequent processing stages. The captured frames are pre-processed to ensure compatibility with the underlying models, including resizing and orientation correction where necessary.

2. Pre-processing Module: Before analysis, the captured images undergo basic pre-processing operations such as scaling, normalization, and rotation adjustment. These steps help maintain consistency in input format and improve the accuracy and performance of the machine learning models used in the system.

3. Object Detection Module:

This module employs a lightweight deep learning model to detect and classify objects present in the environment. It identifies multiple objects simultaneously and provides information such as object labels, confidence scores, and bounding box coordinates. The module is optimized for mobile deployment to ensure low latency and efficient resource utilization.

4. Obstacle Detection and Navigation Module:

This module interprets the output of the object detection model to identify potential obstacles. It estimates the relative distance of objects based on their size in the image and determines their position within the frame. The scene is logically divided into left, center, and right regions, enabling the system to evaluate which path is safer for movement. Based on this analysis, the module generates navigation instructions such as “move left,” “move right,” or “stop,” thereby assisting the user in avoiding collisions.

5. Decision-Making Module:

The decision-making module acts as the central logic unit of the system. It integrates inputs from detection and navigation modules, prioritizes critical objects, and filters out irrelevant or distant detections. It ensures that only meaningful and timely instructions are delivered to the user, reducing unnecessary alerts and improving usability.

6. Optical Character Recognition (OCR) Module:

This module extracts textual information from the captured frames. It processes images containing printed or displayed text and converts them into machine-readable format. The recognized text is then transformed into speech, allowing users to access written information such as signboards, labels, and documents.

7. Currency Recognition Module:

The currency recognition module identifies different denominations of Indian banknotes using a trained classification model. It processes captured images of currency and determines the corresponding value, providing audio feedback to assist users during financial transactions.

8. Voice Interaction Module:

This module enables users to interact with the application through voice commands. It supports hands-free operation by allowing users to activate specific features or switch between modules using spoken instructions. This enhances accessibility and ease of use, particularly for individuals with visual impairments.

9. Audio Feedback Module:

The audio feedback module converts system outputs into speech using text-to-speech technology. It delivers clear and concise instructions related to detected objects, navigation guidance, recognized text, and currency identification. This ensures that users receive immediate and understandable information.

10. Haptic Feedback Module:

In addition to audio output, this module provides vibration-based alerts to signal critical situations such as nearby obstacles. Haptic feedback serves as an additional layer of communication, especially in noisy environments where audio feedback may be less effective.

11. Real-Time Processing Module:

This module ensures that all operations are performed with minimal delay. It manages frame processing rates, optimizes computational workload, and maintains smooth performance on mobile devices. Efficient memory and resource management are implemented to support continuous real-time operation. Collectively, these modules form a comprehensive assistive system capable of delivering accurate, timely, and context-aware information. The integration of vision-based analysis, intelligent decision-making, and multi-modal feedback enables the system to significantly enhance mobility, safety, and independence for visually impaired users.

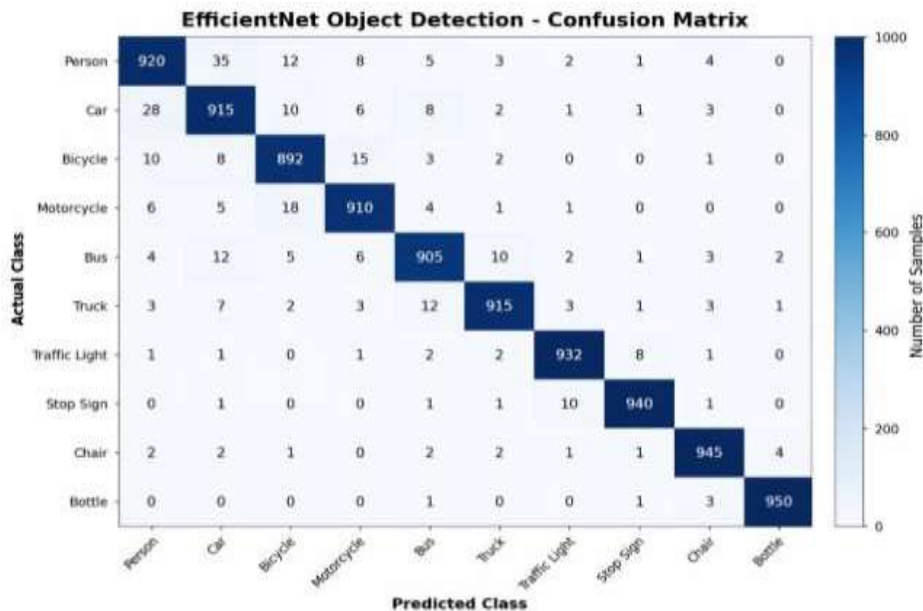


FIG.2.Confusion matrix for object detection

IV.RESULT

The proposed assistive system was implemented and tested on an Android smartphone under different real-world conditions to evaluate its performance and usability. The system was assessed based on its ability to detect objects, provide navigation guidance, recognize text, and identify currency accurately in real time. The object detection module demonstrated reliable performance in identifying common objects such as pedestrians, vehicles, and obstacles in indoor as well as outdoor environments. The system was able to process frames with minimal delay, allowing continuous monitoring of the surroundings. The navigation mechanism effectively analyzed the spatial distribution of detected objects and generated appropriate instructions such as “move left,” “move right,” or “stop.” This approach enabled users to receive clear and actionable guidance, improving their ability to navigate safely. The safe path detection strategy proved to be particularly useful in dynamic environments. By dividing the scene into regions and evaluating obstacle presence, the system could determine a relatively safer direction for movement. In scenarios where multiple obstacles were present, the system prioritized closer objects, ensuring timely alerts for potential hazards.

The OCR module successfully extracted readable text from printed materials such as signboards and documents under adequate lighting conditions. However, performance varied depending on factors such as text clarity, font size, and illumination. Similarly, the currency recognition module accurately identified Indian banknotes when the images were captured clearly, although recognition accuracy decreased when the notes were partially occluded or poorly aligned. The integration of audio and haptic feedback improved overall usability. Voice alerts provided descriptive information, while vibration signals offered immediate warning in critical situations. This combination was found to be effective, especially in noisy environments where audio feedback alone might not be sufficient. Despite its effectiveness, the system has certain limitations. Performance may degrade in low-light conditions or highly cluttered scenes where object detection becomes challenging. Additionally, the distance estimation is based on relative object size, which may not always provide precise measurements.

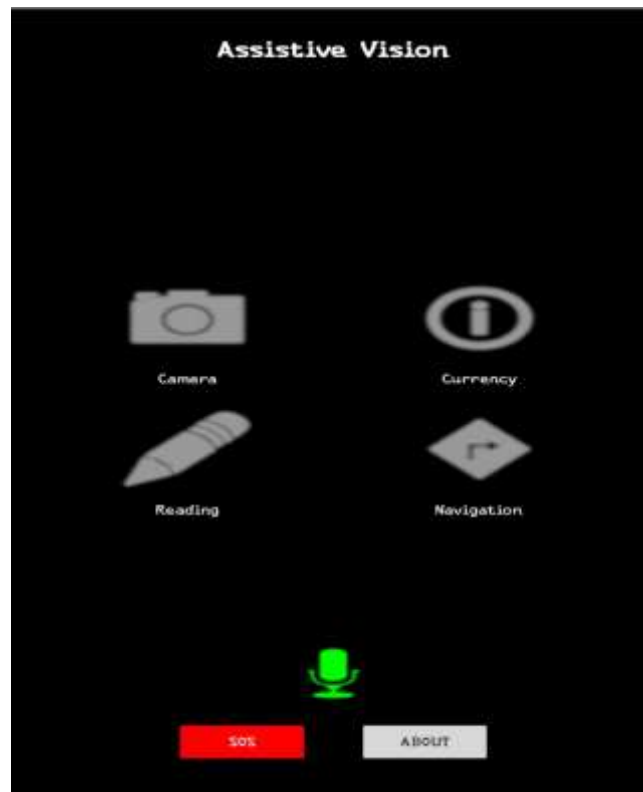


FIG.3. Output

V. CONCLUSION

This paper presented a mobile-based assistive system designed to support visually impaired individuals by enhancing their ability to perceive and interact with their surroundings. The proposed system integrates multiple functionalities, including real-time object detection, safe navigation guidance, text recognition, and currency identification, within a single Android application. By combining computer vision techniques with efficient deep learning models, the system is able to process visual information in real time and convert it into meaningful audio and haptic feedback.

The experimental results demonstrate that the system performs reliably in detecting objects, identifying currency, and reading text under normal conditions. The navigation component, supported by safe path analysis, provides intuitive guidance that helps users avoid obstacles and move safely. The inclusion of voice commands and vibration alerts further improves accessibility and usability. Overall, the system offers a practical, portable, and cost-effective solution that enhances independence and safety for visually impaired users in everyday environments.

VI. FUTURE ENHANCEMENT

Although the proposed system shows promising results, there are several opportunities for further improvement and enhancement. Future work can focus on improving performance in challenging conditions such as low lighting, crowded environments, and complex backgrounds by incorporating more advanced models and image enhancement techniques. The integration of depth estimation or sensor-based distance measurement can provide more accurate obstacle detection and navigation assistance. In addition, the system can be extended by incorporating GPS-based outdoor navigation to guide users along predefined routes. Indoor navigation support using Bluetooth beacons or WiFi positioning can further expand its usability. The inclusion of multilingual voice support would make the application accessible to a wider range of users. Future versions may also explore wearable implementations, such as integration with smart glasses, to provide a more seamless and hands-free experience. Continuous model optimization and dataset expansion can further improve accuracy, making the system more robust and reliable in realworld scenario

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