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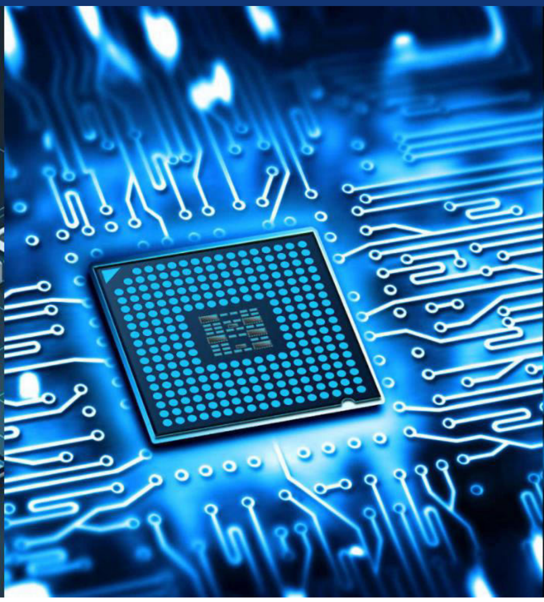

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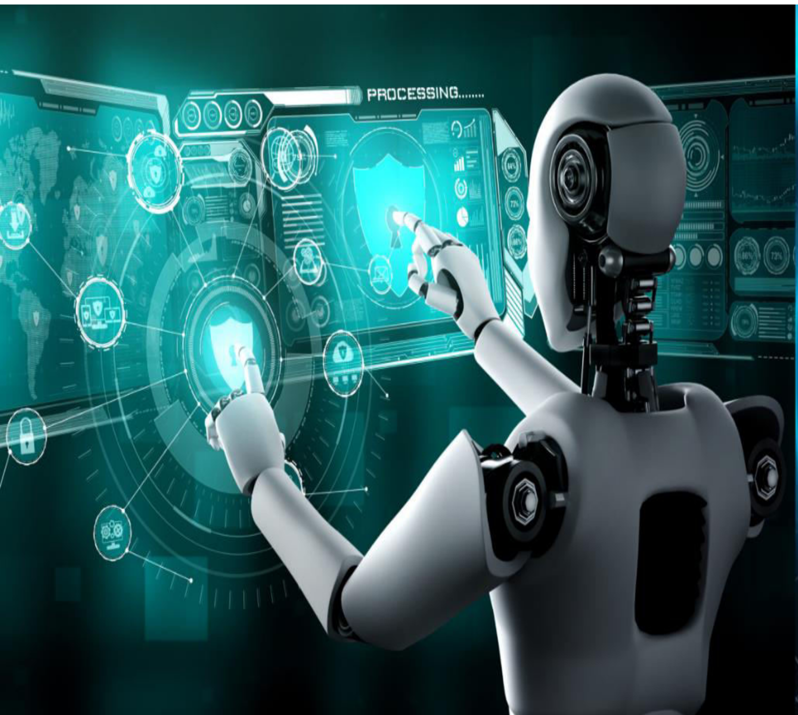

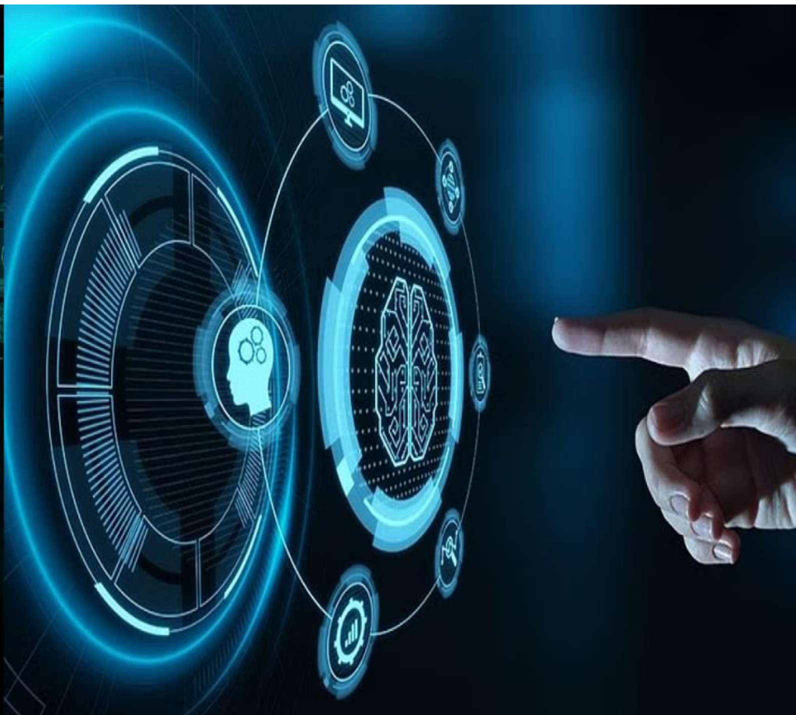

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Deep Learning Driven AR Navigation Assistant for Visually Impaired People with Real-Time Audio-Haptic Feedback

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ABSTRACT: People with visual impairments often face difficulties while navigating unfamiliar indoor and outdoor environments due to obstacles, changing surroundings, and limited awareness of nearby hazards. To address these challenges, this paper presents a Deep Learning Driven Augmented Reality (AR) Navigation System with Audio-Haptic Feedback that provides real-time navigation assistance and supports independent mobility. The proposed system uses YOLOv8 (You Only Look Once Version 8) for object detection and MiDaS (Mixed Datasets for Monocular Depth Estimation) for depth estimation to identify pedestrians, vehicles, furniture, obstacles, and other objects in the user's surroundings. Live video frames captured through a mobile device camera are continuously processed using a FastAPI backend to analyse the environment and determine safe movement directions based on obstacle location and distance. To improve accessibility, the system provides voice guidance in English, Hindi, and Telugu, along with vibration-based haptic alerts that help users respond to nearby obstacles and potentially unsafe situations. AR overlays such as bounding boxes and directional indicators are displayed on the screen to highlight detected objects and navigation regions, making the system useful for partially sighted users and system monitoring. Temporal smoothing techniques are applied to improve the consistency of navigation guidance and reduce unstable decisions during movement. Experimental evaluation demonstrated reliable obstacle detection and effective navigation decision generation under different environmental conditions. By combining deep learning, computer vision, speech interaction, and multimodal feedback, the proposed system offers a practical, affordable, and user-friendly assistive solution that helps visually impaired users navigate more safely, confidently, and independently.

KEYWORDS: Visually Impaired Navigation, YOLOv8, MiDaS, Object Detection, Depth Estimation, Augmented Reality, Audio-Haptic Feedback, Computer Vision.

I. INTRODUCTION

People with visual impairments often encounter difficulties while navigating indoor and outdoor environments, particularly in unfamiliar or crowded areas. Everyday activities such as avoiding obstacles, crossing roads, locating safe walking paths, and moving independently can become challenging without adequate assistance. Traditional mobility aids, including white canes and guide dogs, provide valuable support; however, they may not always offer sufficient information about the surrounding environment or detect obstacles beyond their immediate range. Consequently, maintaining safe and independent mobility remains a significant challenge for many visually impaired individuals.

The increasing availability of smartphones equipped with cameras and powerful processing capabilities has created new opportunities for developing assistive navigation solutions. Camera-based navigation systems can analyse the surrounding environment, identify nearby objects, estimate their distance, and provide guidance to users in real time. Despite the progress made in this area, many existing systems focus primarily on obstacle detection and do not provide a comprehensive solution that combines environmental understanding, distance estimation, multilingual communication, and multiple feedback mechanisms. As a result, there is a need for navigation systems that can deliver more reliable and practical assistance in real-world situations.

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To address these challenges, this work presents a Deep Learning Driven Augmented Reality (AR) Navigation System with Audio-Haptic Feedback for visually impaired users. The proposed system uses YOLOv8 for object detection and MiDaS for depth estimation to identify nearby objects such as pedestrians, vehicles, furniture, and other obstacles while estimating their relative distance from the user. Live video frames captured through a camera are processed using a FastAPI backend to generate navigation instructions based on environmental conditions and obstacle proximity. The system provides voice guidance in English, Hindi, and Telugu, together with vibration-based alerts to improve accessibility and user awareness. AR overlays, including bounding boxes and directional indicators, are displayed on the screen to highlight detected objects and navigation regions, making the system useful for partially sighted users and system monitoring. Temporal smoothing techniques are also employed to improve the consistency of navigation guidance during movement. Overall, the proposed system offers a practical, affordable, and user-friendly navigation aid that supports safer, more confident, and independent mobility for visually impaired individuals.

II. RELATED WORK

A. Augmented Reality-Based Navigation Systems

Augmented Reality (AR) has emerged as a promising technology for improving navigation assistance for visually impaired individuals. Yang and Saniie [1] proposed an indoor navigation framework based on AR markers and computer vision techniques to provide location-aware guidance. Similarly, Fathi et al. [2] developed an AR-based navigation system using Microsoft HoloLens 2, where auditory three-dimensional feedback was employed to improve environmental awareness and navigation assistance. Lo Valvo et al. [3] introduced ARIANNA+, a smartphone-based navigation solution that combined augmented reality and computer vision to guide users without requiring physical markers. Although these systems demonstrated the potential of AR in assistive navigation, many of them relied on specialized hardware or focused primarily on indoor environments.

B. Deep Learning-Based Obstacle Detection and Scene Understanding

Recent advances in deep learning have significantly improved obstacle detection and environmental perception for assistive navigation. Said et al. [4] proposed a deep learning-based obstacle detection system that utilized Neural Architecture Search (NAS) to improve detection performance while maintaining computational efficiency. Kuriakose et al. [5] presented DeepNAVI, a smartphone-based navigation assistant that employed EfficientDet for real-time obstacle detection and scene understanding. Wang et al. [6] introduced YOLO-OD, an enhanced YOLO-based framework designed to improve obstacle detection performance in complex outdoor environments. While these studies achieved promising object detection results, most focused primarily on obstacle recognition and provided limited support for distance estimation and navigation decision generation.

C. Multimodal Feedback for Assistive Navigation

Providing information through multiple feedback channels can significantly improve navigation support for visually impaired users. Skulimowski et al. [8] developed a wearable navigation system that combined audio and haptic feedback using stereo vision cameras, speakers, and vibration mechanisms. Their findings showed that multimodal feedback improved environmental awareness and user confidence during navigation. Similarly, Sehrawat et al. [9] proposed VISNAV, an AI-powered navigation aid that integrated augmented reality, voice guidance, and haptic feedback to assist users in different environments. Although these approaches improved accessibility, they often depended on specialized hardware and lacked detailed obstacle distance analysis and multilingual feedback support.

D. Vision-Based Assistive Navigation Research

A comprehensive review conducted by Yao et al. [7] highlighted the growing adoption of computer vision and artificial intelligence techniques in assistive navigation systems. The study discussed various navigation aids, obstacle detection frameworks, wearable devices, and smartphone-based applications developed for visually impaired users. The review also identified several open challenges, including reliable scene understanding, real-time deployment, depth perception, and multimodal feedback integration.

E. Limitations of existing Systems

Existing assistive navigation systems often address individual functionalities such as obstacle detection, AR visualization, or feedback generation, while lacking a unified and practical navigation framework. To overcome these limitations, the proposed system combines YOLOv8 object detection, MiDaS depth estimation, multilingual audio guidance, haptic feedback, AR visualization, and temporal stabilization within a smartphone-based solution for visually impaired users.

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III. PROPOSED METHODOLOGY

The proposed system assists visually impaired users by combining computer vision, deep learning, and real-time feedback for safe navigation. It processes environmental information through six interconnected layers to detect obstacles, understand the scene, and provide navigation guidance.

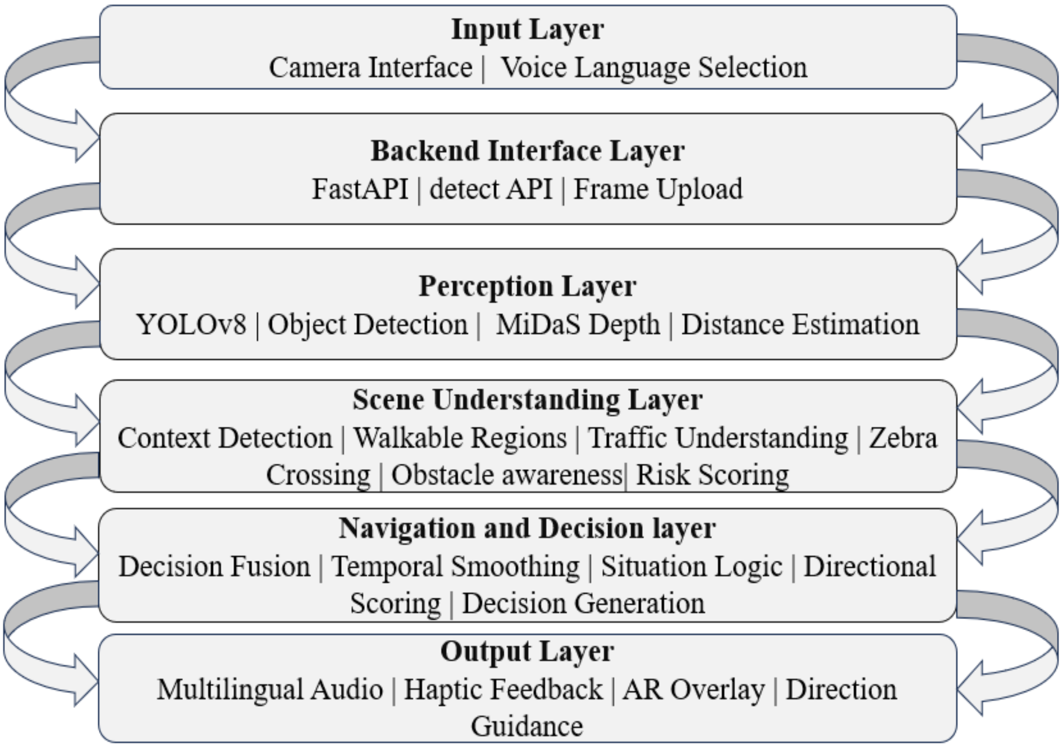

Fig 1: Architectural Representation of Proposed System

1. Input Layer: The Input Layer collects user preferences required for navigation. It captures live camera frames and allows users to select their preferred language for receiving navigation guidance.

2. Backend Interface Layer: The Backend Interface Layer acts as a communication bridge between the frontend and AI modules. It receives camera frames, performs preprocessing operations, executes AI models, and returns navigation responses.

3. Perception Layer: The Perception Layer analyses the surrounding environment using YOLOv8 object detection and MiDaS depth estimation. It identifies nearby obstacles and estimates their relative distance to improve environmental awareness.

4. Scene Understanding Layer: The Scene Understanding Layer interprets object and depth information to understand environmental conditions. It identifies walkable regions, detects potential hazards, and evaluates navigation safety.

5. Navigation and Decision Layer: The Navigation and Decision Layer combine information from previous layers to determine suitable navigation actions. It generates movement instructions such as Move Forward, Move Left, Move Right, Move Slowly, and Stop.

6. Output Layer: The Output Layer delivers navigation guidance through audio, haptic, and visual feedback. It provides multilingual voice instructions, vibration alerts, and AR overlays to improve user awareness and safety.

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IV. EXPERIMENTAL RESULTS

A. Evaluation Metrics

The performance of the proposed navigation system was evaluated using Accuracy, Precision, Recall, and F1-Score. These metrics were used to assess the effectiveness of the system in generating appropriate navigation actions under different environmental conditions.

B. Performance Results

The system was evaluated for four navigation actions: MOVE, STOP, CAUTION, and MOVE_SLOW. Table 1 presents the obtained Precision, Recall, and F1-Score values.

Navigation Action	Precision	Recall	F1-Score
MOVE	1.00	0.93	0.96
STOP	0.77	0.91	0.83
CAUTION	1.00	0.78	0.88
MOVE_SLOW	0.75	0.90	0.82

Table 1: Evaluation Results

The proposed system achieved an overall accuracy of 90%, demonstrating reliable navigation decision generation under different environmental conditions. The results indicate strong performance for MOVE actions and consistent detection of STOP, CAUTION, and MOVE_SLOW scenarios.

C. Experimental Outputs

The following output screens demonstrate the proposed navigation system under different scenarios. Navigation guidance is provided through voice instructions generated from navigation actions in the user-selected language. AR overlays highlight detected objects and obstacles for scene understanding. The system also provides haptic feedback, where MOVE generates minimal vibration, MOVE_SLOW generates a short pulse vibration, CAUTION generates multiple repeated pulse vibrations, and STOP generates a continuous high-frequency vibration. These feedback methods help users navigate safely and effectively.

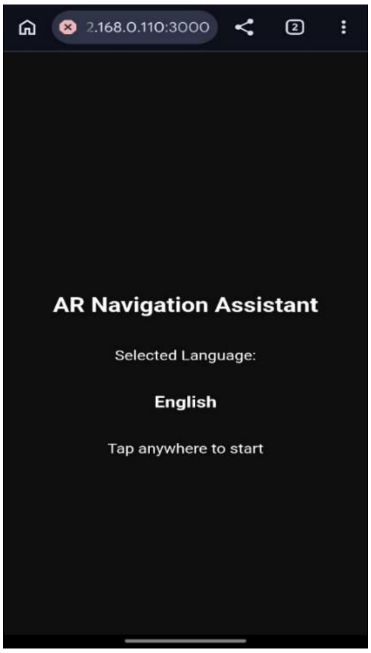

Fig 2: Welcome Page with English Language Selection

Fig 3: Welcome Page with Telugu Language Selection

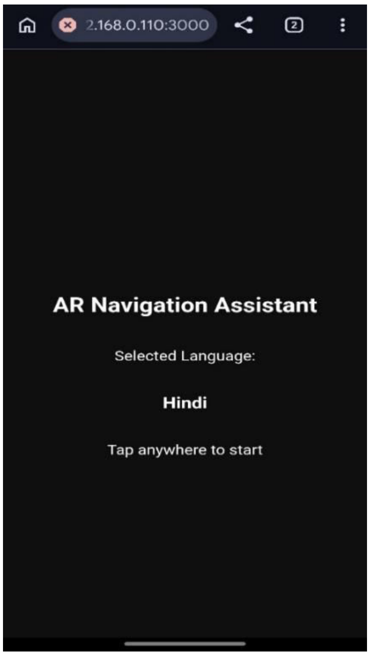

Fig 4: Welcome Page with Hindi Language Selection

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Fig 5: MOVE_SLOW Navigation Guidance in English

Fig 6: MOVE_SLOW Navigation Guidance in Hindi

Fig 7: Safe Path Detection with MOVE action in Telugu

Fig 8: MOVE action when path is clear

Fig 9: CAUTION action when obstacle nearby

Fig 10: STOP action when obstacle ahead

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V. CONCLUSION

This paper presented a Deep Learning Driven Augmented Reality Navigation System with Audio-Haptic Feedback to assist visually impaired users in indoor and outdoor navigation. The proposed system integrates YOLOv8 object detection, MiDaS depth estimation, multilingual voice guidance, haptic feedback, and AR-based visualization to improve environmental awareness and navigation safety. Experimental results demonstrated reliable obstacle detection and navigation decision generation, achieving an overall accuracy of 90% under different environmental conditions. The integration of computer vision, deep learning, and multimodal feedback enables the system to provide real-time navigation assistance in a practical and cost-effective manner. The proposed solution has the potential to enhance user safety, confidence, and independent mobility for visually impaired individuals.

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