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AuraNav 360: A Wearable Guidance System for the Visually Impaired

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ABSTRACT: Navigating independently in both outdoor and indoor environments remains a significant challenge for individuals with visual impairments. Daily mobility often involves unpredictable surroundings, moving obstacles, and varying environmental conditions that demand constant awareness. Conventional assistive tools such as white canes, while reliable for detecting immediate ground-level barriers, offer limited information about objects beyond close proximity and cannot effectively identify dynamic obstacles approaching from different directions.

To address these limitations, this paper presents AuraNav 360, an AI-based assistive navigation system aimed at enhancing environmental perception through real-time object detection and audio feedback. The system focuses on providing meaningful contextual awareness by identifying surrounding obstacles and communicating their presence to the user through voice alerts. This approach allows visually impaired users to better understand their immediate environment without relying solely on physical contact-based tools.

AuraNav 360 is implemented using a Raspberry Pi Zero 2 W paired with a USB camera, enabling on-device processing of visual data through a YOLO-based object detection model. Detected objects are converted into audio cues and delivered via a Bluetooth neckband, ensuring hands-free operation. Additionally, the system architecture supports a theoretical 360-degree awareness model, where the same camera configuration can be extended to include rear-side detection for improved spatial coverage.

KEYWORDS: Assistive Technology, Computer Vision, YOLO, Raspberry Pi, Blind Navigation

I. INTRODUCTION

Independent mobility plays a crucial role in ensuring personal safety, confidence, and social inclusion for visually impaired individuals. The ability to move freely within unfamiliar or crowded environments directly impacts quality of life, access to education, and employment opportunities. However, navigating such environments remains challenging due to obstacles, traffic movement, and constantly changing surroundings.

Traditional assistive devices such as white canes are widely used and effective for detecting obstacles on the ground surface. Despite their usefulness, these tools provide limited spatial awareness and do not convey information about obstacles at chest height, moving objects, or hazards approaching from a distance. As a result, users must rely heavily on auditory cues from the environment, which may not always be sufficient.

Recent advancements in computer vision and embedded systems have enabled the development of intelligent assistive technologies. Vision-based navigation systems offer the potential to detect and classify obstacles in real time, providing richer environmental information. AuraNav 360 builds upon these advancements by integrating object detection, audio feedback, and mobile connectivity into a compact and wearable solution.

II. SYSTEM ARCHITECTURE

AuraNav 360 is designed as a modular system consisting of a wearable embedded unit, a mobile application, and an audio feedback mechanism. Each component plays a specific role in ensuring seamless operation and effective communication between the system and the user. The architecture emphasizes simplicity, portability, and real-time responsiveness.

The wearable embedded unit serves as the core processing component, responsible for capturing visual data and performing on-device object detection. Visual input from the camera is processed locally, reducing dependency on continuous internet connectivity and ensuring faster response times. This design choice enhances reliability, especially in outdoor or low-connectivity environments.

The mobile application complements the wearable unit by providing navigation assistance and real-time location tracking. It includes two distinct interfaces: one tailored for visually impaired users and another designed for family members or caregivers. This dual-interface approach allows users to navigate independently while enabling family members to monitor location and receive alerts when necessary.

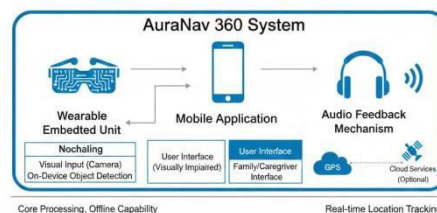


Figure 1: Overall System Architecture of AuraNav 360

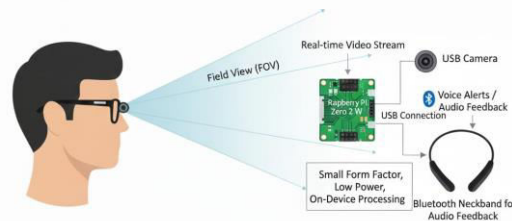
[Figure 1: Overall System Architecture of AuraNav 360]

III. HARDWARE DESIGN

The hardware design of AuraNav 360 prioritizes compactness, low power consumption, and ease of integration. At the center of the system is the Raspberry Pi Zero 2 W, selected for its small form factor and sufficient processing capability to run lightweight deep learning models. Its embedded wireless connectivity further supports seamless communication with external devices.

A USB camera is used to capture real-time video streams required for object detection. The camera is positioned to provide an optimal field of view for detecting obstacles in the user's path. This configuration ensures that objects such as people, vehicles, and environmental structures can be identified effectively during movement.

Audio feedback is delivered through a Bluetooth neckband, chosen for its comfort and hands-free usability. The neckband allows users to receive continuous voice alerts without obstructing environmental sounds, maintaining situational awareness while benefiting from system guidance.

**AuraNav 360
Hardware Design**

Camera positioned for optimal obstacle detection; Neckband
Neckband for hands-free audio guidance

Figure 2: Camera Placement and Field of View

[Figure 2: Camera Placement and Field of View]

IV. SOFTWARE IMPLEMENTATION

The software framework of AuraNav 360 is built around a YOLO-based object detection model optimized for edge devices. This model is capable of detecting various obstacles, including people, vehicles, animals, poles, walls, and stairs. The focus on lightweight optimization ensures that real-time detection can be achieved on low-power hardware. Captured video frames are processed locally on the Raspberry Pi, where detected objects are classified and prioritized. The system translates detection results into concise audio messages, enabling users to quickly understand potential hazards in their surroundings. This conversion from visual data to auditory feedback forms the core interaction mechanism of the system.

The mobile application software supports two user roles, ensuring usability for both visually impaired users and their family members. While users receive navigation-related assistance, family members can access real-time location data and system alerts, enhancing overall safety and peace of mind.

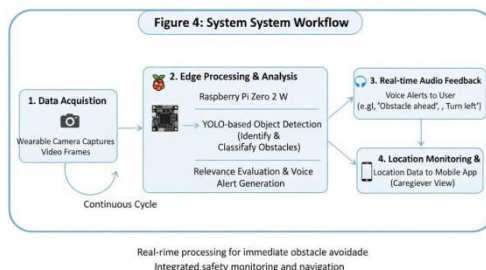
V. WORKING METHODOLOGY

The working methodology of AuraNav 360 follows a continuous perception and feedback cycle. The camera mounted on the wearable unit continuously captures video frames as the user moves through an environment. These frames are forwarded to the Raspberry Pi for immediate processing.

Using the YOLO-based detection model, obstacles within the camera's field of view are identified and classified. The system evaluates the relevance of detected objects and generates corresponding voice alerts. This real-time processing ensures that users receive timely warnings about obstacles in their path.

Simultaneously, location data is shared with the mobile application to support monitoring and navigation features. This integrated workflow allows AuraNav 360 to function as both a real-time assistive device and a safety monitoring solution.

AuraNav 360: Continuous Perception & Feedback Cycle



[Figure 4: System Flow Diagram]

VI. SYSTEM SPECIFICATIONS

Component	Specification	Purpose
Processor	Raspberry Pi Zero 2 W	Embedded AI processing
Camera	USB Camera	Real-time object detection
AI Model	YOLO (Lightweight)	Obstacle classification
Audio Output	Bluetooth Neckband	Voice alerts
Connectivity	Bluetooth	App communication

VII. RESULTS AND DISCUSSION

Experimental testing demonstrates that AuraNav 360 is capable of detecting obstacles in real time with acceptable latency on low-power embedded hardware. The system maintains consistent detection performance across common indoor and outdoor environments, validating its practical usability.

Voice-based feedback enables intuitive interpretation of the surroundings without overwhelming the user. The audio alerts are concise and informative, allowing users to react quickly to potential hazards. This interaction model supports independent mobility while preserving awareness of environmental sounds.

Additionally, the family tracking feature enhances user safety by providing real-time location visibility. This functionality adds an extra layer of security, particularly in unfamiliar or crowded environments, without interfering with the core navigation experience.

VIII. CONCLUSION

AuraNav 360 presents a professional and cost-effective assistive navigation solution tailored for visually impaired individuals. By combining real-time object detection, audio guidance, and mobile connectivity, the system addresses key limitations of traditional assistive tools.

The integration of embedded AI processing with wearable hardware ensures portability and responsiveness. The system's modular architecture also allows future enhancements without altering its core design. Overall, AuraNav 360 contributes toward improving independent mobility, safety, and confidence for visually impaired users.

IX. ACKNOWLEDGMENT

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