BLINDMATE – AN ASSISTIVE GUIDANCE SYSTEM FOR VISUALLY IMPAIRED

Project Reference No.: *49S_BE_6039*

College : BNM Institute of Technology, Bengaluru
Branch : Department of Artificial Intelligence And Machine Learning
Guide(s) : Prof. Kavya M S
Prof. Abhilasha P.Kumar
Student(s) : Ms. Minchana A
Ms. Misbah Fatimah
Ms. Mokshitha N V

Keywords:

Assistive technology; visually impaired; obstacle detection; GPS; GSM SMS; TensorFlow Lite; ESP32; offline; TTS; emergency alert.

Introduction:

The WHO estimates ~2.2 billion people worldwide live with visual impairment. For those who are blind or severely sight-impaired, independent navigation remains a profound daily challenge. Traditional white canes and guide dogs, while effective, offer limited situational awareness and no mechanism for emergency communication.
BlindMate addresses these shortcomings with a fully offline, wearable guidance platform combining multi-sensor obstacle detection, on-device AI object recognition, natural-language audio feedback, and hardware-based GPS emergency alerting all on a single low-cost device.

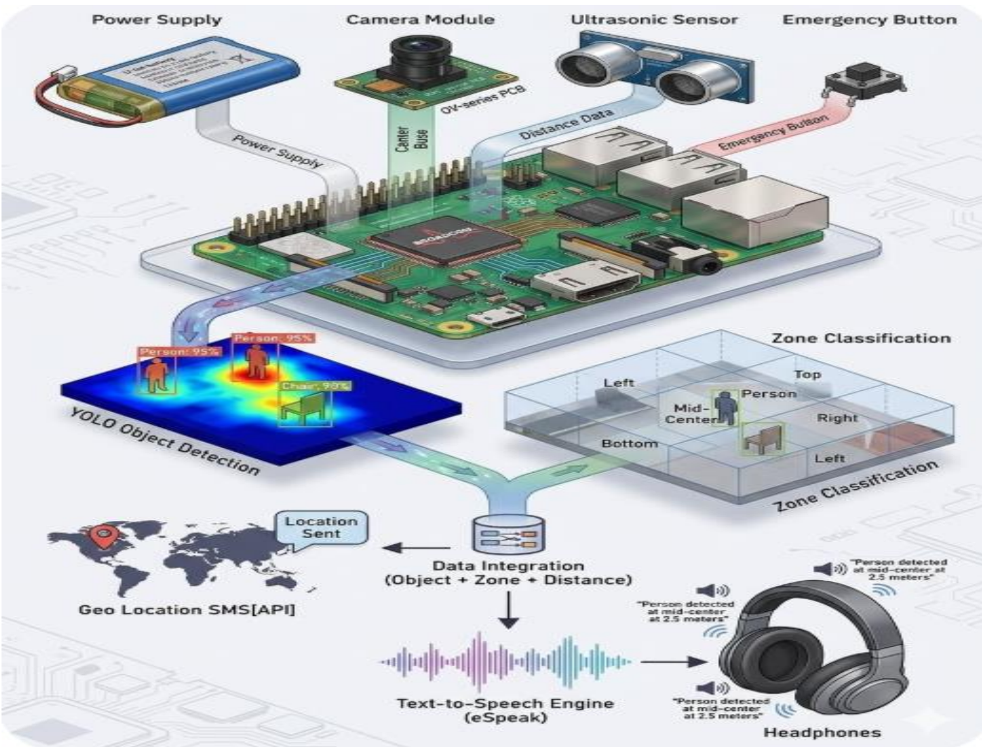

Figure 1: System Design

Objectives:

1. Detect obstacles in real-time via ultrasonic and IR sensors.
2. Classify objects using on-device TFLite inference.
3. Deliver voice guidance through an offline TTS engine.
4. Provide one-touch emergency GPS location sharing via GSM SMS (offline).
5. Operate continuously for >= 8 hours on battery.

Methodology:

The BlindMate navigation system follows a structured processing pipeline that combines multi-sensor perception with embedded artificial intelligence. The methodology is designed to ensure continuous environmental monitoring and timely delivery of navigation instructions. The overall operation of the system can be divided into four major stages: data acquisition, object recognition, sensor fusion, and feedback generation.

A. Data Acquisition

The first stage involves collecting environmental information using multiple sensors. Ultrasonic sensors continuously measure the distance between the user and nearby obstacles. Infrared sensors complement ultrasonic sensing by detecting close-range objects that may not reflect ultrasonic signals effectively.

At the same time, the camera module captures visual frames of the surrounding environment. These frames provide visual context required for object recognition.

B. Object Recognition

Captured images are processed using a lightweight convolutional neural network deployed through TensorFlow Lite [4]. The model is optimized for embedded hardware and is capable of recognizing common objects encountered during navigation such as chairs, tables, staircases, vehicles, and doors.

The model produces classification labels and confidence scores indicating the detected object type.

C. Sensor Fusion

Information obtained from ultrasonic sensors, infrared sensors, and the vision module is combined using sensor fusion techniques. Sensor fusion improves reliability by allowing the system to cross-validate information from multiple sources.

For example, distance information obtained from ultrasonic sensors can be combined with object classification results from the vision model to determine both the type and location of an obstacle.

D. Feedback Generation

Once obstacles are detected and classified, the system generates navigation instructions. These instructions are converted into speech using a text-to-speech engine.

Audio feedback is delivered through headphones or bone conduction audio devices, enabling the user to receive navigation guidance without blocking ambient environmental sounds. In emergency situations, the system retrieves the current location coordinates using the GPS module [7] and generates an emergency alert message containing GPS coordinates, which can be used for safety monitoring or integrated with communication systems in future implementations.

Result and Conclusions:

This paper presented BlindMate, a wearable assistive navigation system designed to improve mobility and safety for visually impaired individuals through the integration of embedded sensors and artificial intelligence technologies. The proposed system combines ultrasonic and infrared sensors for obstacle detection with a camera-based object recognition module powered by TensorFlow Lite [4]. The system also incorporates a text-to-speech engine for real-time audio guidance and a GPS-based Alert System module [7] for emergency alert transmission [8].

Unlike many existing assistive navigation systems that rely on cloud computing or smartphone connectivity, BlindMate operates entirely offline using an ESP32-based embedded platform [6]. This design ensures low latency, improved reliability, and independence from network connectivity, making the system particularly suitable for deployment in environments with limited infrastructure.

Experimental evaluation demonstrated that the proposed system achieves low obstacle detection latency, reliable object recognition performance, and effective emergency communication capabilities. These results indicate that integrating multi-sensor perception with embedded AI processing can significantly enhance environmental awareness and navigation safety for visually impaired users.

Although certain limitations remain, the proposed architecture provides a strong foundation for future research and development in assistive navigation technologies. With further improvements in sensor fusion, embedded AI optimization, and navigation intelligence, systems such as BlindMate have the potential to significantly improve independence, accessibility, and quality of life for visually impaired individuals worldwide.

Figure 2: Final Result

References:

1. WHO, 'World Report on Vision,' World Health Organization, 2019.
2. T. Pradeep et al., “Smart Assistive Device for Blind Using Ultrasonic Sensor,” IJERT, 2018.
3. A. Howard et al., 'MobileNets: Efficient CNNs for Mobile Vision Applications,' arXiv:1704.04861, 2017.
4. TensorFlow Lite Documentation, Google AI, 2023.
5. WeWalk Smart Cane Technology Whitepaper, 2022.
6. SIMCom Wireless, 'SIM800L Hardware Design,' v1.08, 2015.
7. u-blox AG, 'NEO-6 GPS Modules Data Sheet,' v1.3, 2011.
8. Espressif Systems, 'ESP32 Technical Reference Manual,' v5.2, 2023.
9. S. Jiang and R. Jain, “Assistive Technologies for the Visually Impaired,” IEEE Access, 2020.
10. Y. LeCun et al., “Deep Learning,” Nature, 2015.

Future Scope:

The future scope of this project includes:

1. Raspberry Pi CM4 integration for higher-resolution scene understanding with YOLOv8.
2. Optional companion app (BlindMate+) using internet Geolocation API and Twilio SMS as a secondary alert channel.
3. Turn-by-turn navigation with offline OpenStreetMap tiles on the SD card.
4. Cloud-synced contact management when Wi-Fi is opportunistically available.
5. Multi-language TTS for regional accessibility.