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Guideway-Navigation AID and Smart Obstacle Detection for The Visually Impaired

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ABSTRACT

The GuideWay system is a smart wearable designed to support visually impaired people in their everyday movements, especially in unfamiliar or crowded places. It uses a Raspberry Pi as the main controller, connected to ultrasonic sensors, a camera, and GPS so that it can sense obstacles and understand the user's surroundings in real time. With AI-based object recognition, GuideWay can recognize different obstacles, estimate how far they are, and then warn the user using clear audio messages and vibration patterns, helping them move safely both indoors and outdoors. Beyond navigation, GuideWay also cares about emergencies and daily routines. If the user falls or is in trouble, the device can automatically send their location to a caregiver through an emergency alert feature. It can also give spoken reminders, for example for taking medicines on time, which supports independent living. By bringing together embedded hardware, computer vision, and artificial intelligence in a compact wearable form, GuideWay aims to be affordable, reliable, and easy to use, ultimately improving the mobility, safety, and quality of life of visually impaired individuals.

Keywords: Visually Impaired, Smart Wearable Device, Obstacle Detection, Raspberry Pi, Computer Vision, Artificial Intelligence, Object Recognition, GPS Navigation.

1.INTRODUCTION

Visually impaired individuals often find it challenging to move safely through unfamiliar or crowded places, because tools like white canes and guide dogs only give limited, close-range feedback and cannot clearly tell them how far away an object is, what it is, or which direction it is in. GuideWay is designed to bridge this gap as a smart, wearable navigation system that brings together embedded hardware and artificial intelligence to provide real-time awareness of the surroundings and help the user make safe decisions while walking. In practice, GuideWay uses a Raspberry Pi connected to multiple sensors, a camera, and GPS to detect obstacles and assist with navigation. AI-based object recognition helps the device understand what objects are around the user, how far they are, and then share this information through spoken audio messages and vibration patterns, so the person can move confidently without needing to see. The device also includes an emergency feature that can automatically send the user's location to caregivers in case of a fall or accident, and it gives spoken reminders for tasks such as taking medication. Together, these features are meant to improve the user's mobility, safety, and independence in both indoor and outdoor environments.

1.1 PROBLEM DEFINITION

People with visual impairments often find it hard to move around safely on their own, especially in busy or unfamiliar places. Traditional tools like walking sticks only help when they physically touch an obstacle, so they cannot warn about things that are higher up, hanging in front, or moving quickly toward the user. Many modern assistive devices are either too expensive or miss important features like knowing exactly how far an obstacle is, what kind of object it is, or whether it is near the upper or lower body. Devices that depend only on vibrations or buzzer sounds can also be confusing or easy to miss in noisy, crowded environments. Because of these gaps, there is a clear need for an affordable, intelligent wearable device that uses multiple sensors and different types of feedback to give continuous, real-time, and reliable navigation support.

1.2 EXISTING SYSTEMS

Existing navigation options for people with visual impairments such as white canes, guide dogs, smart canes, and devices with ultrasonic sensors each have clear drawbacks. White canes and guide dogs give helpful, close-range, hands-on guidance, but they cannot warn about obstacles that are far away, higher up, or moving quickly, and guide dogs are also expensive and not easily available to everyone. Electronic aids improve on this by adding audio or vibration alerts, but most of them only monitor a limited area of the body and rely on just one type of signal, which can leave “blind spots” and become confusing in crowded or noisy places. On top of that, many of these devices do not use GPS for outdoor navigation or real-time location sharing, which reduces how useful they are in open or unfamiliar areas. Because of these issues, current systems still fall short of offering a complete, intelligent, and dependable navigation experience that truly supports both safety and independence.

1.3 PROPOSED SYSTEM

GuideWay is designed as a smart wearable navigation aid that tackles the above limitations by blending embedded hardware, computer vision, and AI in a single system. A Raspberry Pi acts as the “brain” of the device, working with ultrasonic sensors to measure distance and a camera module to see the surroundings, so that obstacles near both the upper and lower body can be detected. Using AI-based object recognition, GuideWay can recognize what an obstacle is, estimate how far it is, and then share this information with the user through two types of feedback: spoken audio instructions for direction and context, and vibrations of different intensities to show how close the obstacle is, which helps even in noisy environments. Built-in GPS supports outdoor navigation, live location tracking, and turn-by-turn voice guidance. In case of a fall or emergency, the device can automatically send the user’s coordinates to a registered caregiver, and it can also give regular spoken reminders to help with daily activities, such as taking medicines on time. By combining sensor fusion, computer vision, and AI-based decision-making in a compact, modular wearable form, GuideWay aims to be affordable, upgrade-friendly, and effective at improving mobility, safety, and independence for visually impaired users, both indoors and outdoors.

2. LITERATURE SURVEY

Comprehensive Navigation Solutions for Visually Impaired Users: Features and Implementation of Smart Blind Sticks by Vivek A, Abhilash N Pillai, Adwaith A. Nair, and Parthiv Bijumon Bhasker (2025, IEEE) reviews the state of the art in smart blind stick designs [1]. It summarizes how ultrasonic and IR sensors, GPS, and different user alert mechanisms have been adopted over time, and discusses how these choices impact cost, usability, and wireless connectivity.

Smart Glasses: Portable Navigation Aid for the Visually Impaired with Object Detection and Monocular Depth Estimation by Suraj Sharma and Sanika Bihani (2025, IEEE) presents a wearable smart glasses system that enhances navigation by processing video from a USB camera on a Raspberry Pi [2]. The system uses the YOLOv10 model for object detection and MiDaS for depth estimation, achieving about 93% detection accuracy and reliable distance estimates, while providing real-time audio feedback that was positively received by blind participants for its comfort and ease of use.

VisionAid Smart Cane: A Guardian in Mobility for the Visually Impaired by Mrs. R. Sarala, Shobika R J, and Keerthiga J S (2025, IEEE) proposes a powerful BeagleBone Black–based smart cane that integrates multiple sensing and assistive features [3]. It combines an IR sensor for obstacle detection, an ADLX sensor for surface irregularities, GPS for navigation, and AI-based functions like environment recognition and fall detection, along with heart rate and SpO2 monitoring and solar charging, offering a multi-purpose mobility and health tool in a portable form.

IoT-Enabled Smart Shoes for Visually Impaired Navigation and Safety by Vavilapalli Joyce, Ashamgari Saipriya, Akki Karthik, and M. Lakshmi Prasad (2025, IEEE) introduces a smart shoe system built around an Arduino Nano with ultrasonic and infrared sensors for real-time obstacle detection [4]. The shoes work without internet connectivity and send alerts via Bluetooth to a web app, achieving high detection accuracy, supporting fall detection, and being designed to feel natural for everyday walking so they can be worn like regular footwear.

Smart Navigation Aid: An IoT-Driven Intelligent Stick for Enhanced Mobility of the Visually Impaired by Likhit Yammanuru, Valupadasu Srujan, et al. (2025, IEEE) presents an intelligent stick aimed at addressing limitations of traditional canes [5]. It combines ultrasonic and IR sensors for layered obstacle detection and uses a dedicated voice module to deliver clear, customizable spoken feedback.

Integrated Online Localization and Navigation Device with Voice Assistive and Vision Sensing for the Visually Impaired by Sudhamshu G, Jithaksha Sai Prakash, et al. (2024, IEEE) describes an Arduino-based smart cane that uses three ultrasonic sensors for directional and terrain awareness [6]. It can detect potholes and humps, provide intuitive spoken cues like “move right” or “depth detected” through an MP3 module, and support IoT-based live location alerts, resulting in richer guidance than simple distance-only warning systems.

Affordable Navigation Aid: A Smart Walking Stick for the Visually Impaired by Muhammed Suhair K, Shanid Malayil, et al. (2024, IEEE) focuses on cost-effective accessibility with a simple ESP8266-based stick using a single ultrasonic sensor, buzzer, and vibration feedback [7]. Programmed in MicroPython and assembled for about 740 INR, it prioritizes low cost and ease of construction so that basic obstacle detection can be made available to a wider population of visually impaired users.

IoT-Empowered Innovative Smart Cane for the Visually Impaired Individuals by Aditi Sonker, Mohd Faizan Ahmad, et al. (2024, IEEE) extends smart cane design with an Arduino Uno and a rich set of sensors including ultrasonic, LiDAR, GPS, GSM, and a raindrop sensor housed in recycled CPVC [8]. It offers dual alerts (for example via buzzer and other feedback) to communicate hazards clearly, illustrating how combining advanced sensing with sustainable materials can create a feature-rich yet cost-conscious navigation aid.

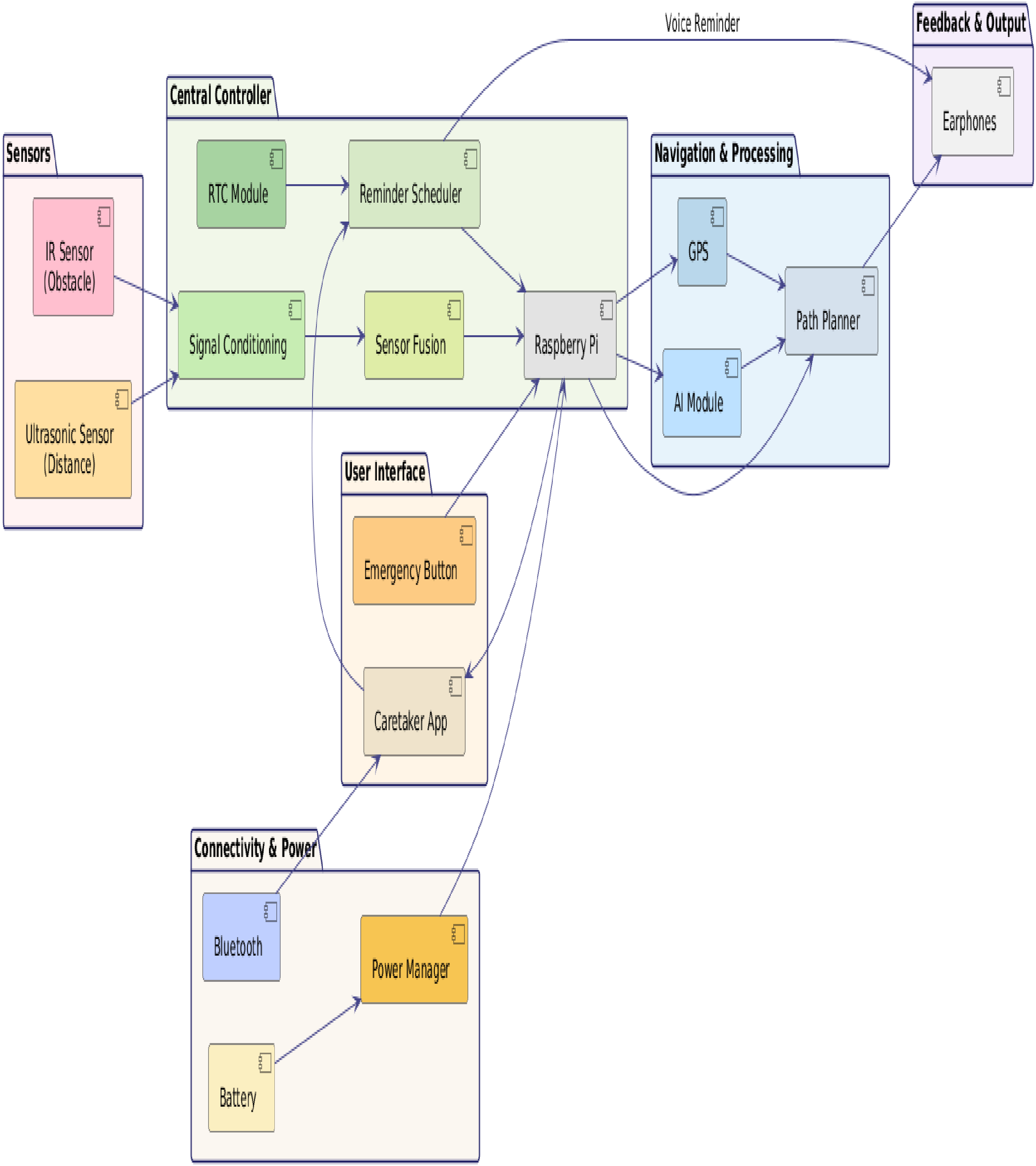
SMART SHOE FOR VISUALLY IMPAIRED PERSON BASED ON IOT by K. Mahalakshmi, S. Arunbalaji, et al. (2024, IEEE) proposes an IoT-based smart shoe integrating ultrasonic and water sensors, a piezoelectric plate for tactile feedback, and a solar panel for power [9]. Controlled by an Arduino Nano and paired with a Bluetooth-enabled mobile app, the design aims to seamlessly blend obstacle and water detection into normal footwear while reducing charging needs through solar energy.

Smart Trolley with Navigation System for Assisting Visually Impaired Persons by S.S. Saravanakumar, C. Parthasarathy, et al. (2024, IEEE) introduces an assistive shopping trolley that uses Arduino, ultrasonic sensors, RFID tags for product identification, servo motors, and Bluetooth-based voice commands [10]. This system focuses on helping visually impaired users navigate stores and manage items more independently, showing how assistive navigation ideas can be adapted to specific contexts like shopping environments.

3. DESIGN METHODOLOGY OF GUIDEWAY

3.1 SYSTEM ARCHITECTURE OF GUIDEWAY

Figure 1: System Architecture diagram of Guideway



As shown in Figure 1:

1. Sensor Layer

- IR Sensor – Detects nearby obstacles at short range.

- Ultrasonic Sensor – Measures the distance to obstacles at different heights.
- Function: Continuously scans the surroundings for upper- and lower-body obstacles and sends the cleaned signals to the main controller.

2. Central Controller Layer

- Raspberry Pi – Main processing unit for the whole system.
- RTC Module – Keeps accurate time for reminders.
- Reminder Scheduler – Triggers spoken reminders at the right time.
- Function: Interprets sensor data and manages navigation, reminders, and alerts.

3. Navigation and Processing Layer

- AI Module – Uses the camera to detect and classify objects.
- GPS Module – Provides live location and outdoor navigation support.
- Path Planner – Suggests safer, obstacle-free paths.
- Function: Uses AI and GPS together to plan movement and guide the user.

4. User Interface Layer

- Emergency Button – Lets the user send an instant SOS.
- Caretaker App – Shows emergency alerts with the user’s GPS location.
- Function: Connects the user and caretaker for quick help in emergencies.

5. Connectivity and Power Layer

- Bluetooth Module – Handles wireless communication.
- Power Manager & Battery – Supply and regulate power to all modules.
- Function: Keeps the device powered and connected during use.

6. Feedback and Output Layer

- Earphones – Play voice guidance and reminders.
- Vibration Motor – Gives tactile feedback based on how close obstacles are.

3.2 CLASS DIAGRAM OF GUIDEWAY

Figure 2: Class diagram of Guideway

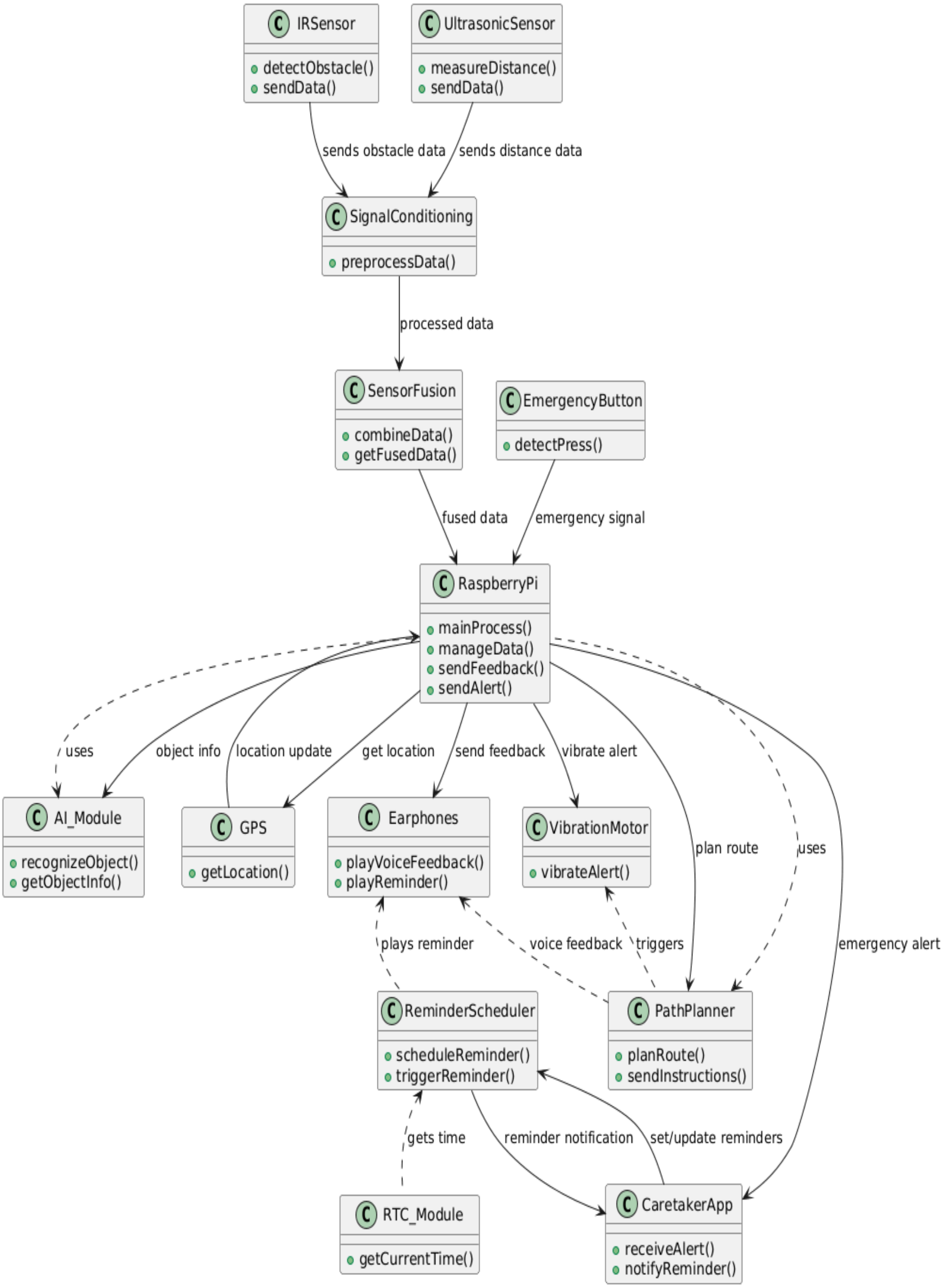


Figure 2 shows how the hardware and software in GuideWay work together to help a visually impaired user navigate safely. The IR and ultrasonic sensors first detect obstacles and measure how far they are. Their raw readings are cleaned by the signal conditioning stage and then combined in the sensor fusion block to get more accurate information about the surroundings. The Raspberry Pi, acting as the main controller, receives this fused data and coordinates all other modules. The AI module on the Raspberry Pi uses the camera to detect and recognize objects, while the GPS module adds real-time location for navigation and tracking. Based on this information, the path planner suggests safer routes. Earphones give voice guidance and reminders, and the vibration motor provides tactile alerts when obstacles are close. The RTC-backed reminder scheduler handles timed notifications such as medicine reminders. In an emergency, pressing the button sends a signal to the Raspberry Pi, which forwards an alert and location details to the caretaker app, allowing caregivers to monitor the user and manage reminders remotely.

3.3 ACTIVITY DIAGRAM OF GUIDEWAY

Figure 3: Activity diagram of Guideway

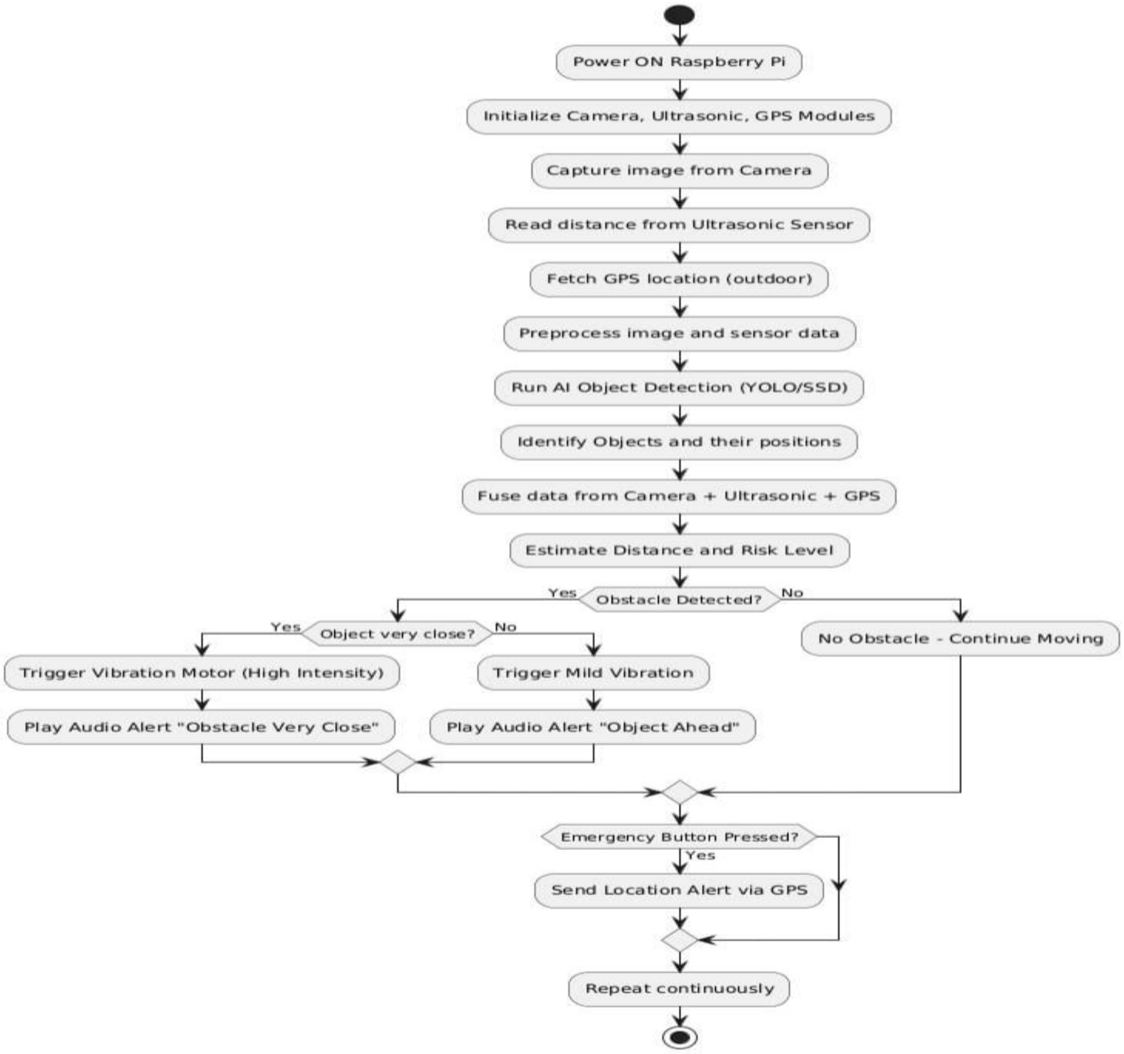


Figure 3 shows how the GuideWay wearable works step by step, from startup to obstacle detection and emergency alerts. When the Raspberry Pi is powered on, it starts all the main modules such as the camera, ultrasonic sensor, and GPS. The system then keeps collecting data: the camera captures live images, the ultrasonic sensor measures how far obstacles are, and the GPS reads the user's current location. Next, the device processes this data. Images and sensor readings are cleaned, and the AI model detects and classifies objects around the user. The system combines camera, distance, and location information to understand what is nearby and where it is. Based on this, the device decides whether there is an obstacle. If an object is detected very close, it triggers strong vibrations and a clear audio warning (for example, "Obstacle very close"). If an object is further ahead, it uses milder vibration and a softer warning (for example, "Object ahead"). If no obstacle is found, it simply keeps monitoring without disturbing the user. In parallel, the device also checks if the emergency button is pressed. If it is, the system immediately sends an alert with the user's GPS location to the caretaker app. All these steps run continuously in a loop so that the user always gets real-time navigation help and safety monitoring while moving.

4. IMPLEMENTATION OF GUIDEWAY

This chapter explains how GuideWay is practically built on the Raspberry Pi, and how hardware, software, and communication modules work together to provide obstacle detection, SOS alerts, and medicine reminders for visually impaired users.

4.1 System Execution Overview

The core of GuideWay is a Python application running on Raspberry Pi OS. When the device powers on, the main script loads the required libraries, configures GPIO pins, and starts parallel threads for three main jobs: object detection and obstacle warning, GPS/SOS handling, and medicine reminders. Using multiple threads ensures that slower tasks like network access or GPS reading do not interrupt real-time obstacle detection. In a continuous loop, the program

- reads data from the USB camera, ultrasonic sensor, GPS module, emergency button, and online database,
- processes this data using computer-vision and simple signal-processing routines,
- makes decisions based on distance limits, detected object type, time, and user input, and
- sends feedback to the user through audio and vibration while updating the server for the caretaker's mobile app.

4.2 Object Detection and Obstacle Warning

This module detects obstacles in front of the user and announces what they are and how far away they are. A USB camera, accessed via OpenCV, streams live video to the Raspberry Pi; at startup, the program opens the camera, sets resolution and frame rate, then continuously captures frames and forwards them to the detection model in real time. A pre-trained YOLO model from Ultralytics is loaded once and reused for every frame, returning bounding boxes, class labels, and confidence scores. Only high-confidence detections are kept, and labels such as "person", "chair", or "vehicle" are used to generate meaningful spoken messages instead of generic “obstacle” alerts. An HC-SR04 ultrasonic sensor complements YOLO by providing accurate physical distance. The Raspberry Pi triggers the sensor with a short pulse and measures the echo time to compute distance in centimetres, updating this reading in parallel with the camera loop. In each cycle, the system fuses the YOLO result and ultrasonic distance: if at least one object is detected and the distance is below a safety threshold (for example, 75 cm), the most confident object is selected, a sentence like “Person ahead, 60 centimetres” is generated and spoken through earphones, and the vibration motor is driven with a pattern that depends on how close the obstacle is.

4.3 Emergency Alert (SOS)

The SOS module lets the user quickly request help and share their current location. A NEO-6M GPS module sends continuous NMEA data over UART; the Python program listens to this stream, parses it, and stores the latest valid latitude and longitude along with a flag indicating whether the GPS has a stable satellite lock. If fresh data is briefly unavailable, the last valid position is reused so that a usable location is always ready. An emergency push button is wired to a GPIO input and a buzzer to a GPIO output. When the user presses the button, the software immediately detects the change and plays a short beep sequence to confirm that the SOS request has been registered. The Raspberry Pi then sends an HTTP POST to the backend with the user ID, current coordinates, and an emergency flag (for example, emergbit = "YES"). The server updates the corresponding row in the MySQL database. The Android caretaker app periodically polls this backend; when it sees the emergency flag set to “YES”, it raises an SOS notification, shows the coordinates and a map view of the user’s position, and allows the flag to be reset once assistance has been provided.

4.4 Medicine Reminder Module

This module provides spoken reminders so the user does not miss scheduled medication. The caretaker uses the Android app to enter the medicine name and the desired time in HH:MM format; these details, along with the user ID, are stored in a dedicated table on the backend. On the Raspberry Pi, a separate reminder thread runs alongside other modules and, at regular intervals, requests the current reminder settings from the server and parses the time and medicine fields. In each polling cycle, the thread reads the system clock, converts it to HH:MM, and compares it with the configured reminder time. When they match and that reminder has not yet been issued, the system plays a spoken message such as “Time to take medicine” through the earphones.

4.5 User Feedback Interfaces

GuideWay uses both audio and vibration so that messages remain clear in different environments. All voice messages, obstacle warnings, SOS confirmations, and medicine reminders—are generated by a lightweight text-to-speech engine on the Raspberry Pi and sent to earphones to ensure privacy and good audibility. A small vibration motor, controlled by a GPIO pin through a driver circuit, provides tactile feedback with different patterns: for example, continuous vibration for very close obstacles and short pulses to acknowledge an SOS button press.

4.6 Thread Management and Startup Configuration

To keep the system responsive, the implementation uses a multithreaded design. The main thread handles startup and the core object-detection loop, while additional threads take care of GPS and SOS monitoring, reminder polling, and background communication. Shared data structures and simple synchronization are used so that threads can safely exchange information without blocking the real-time navigation tasks.

5. TESTING AND RESULTS

This chapter summarizes how the GuideWay prototype was tested to verify obstacle detection, SOS alerts, and medicine reminders. The hardware and the full system were evaluated in indoor conditions to check wiring, sensor calibration, GPIO operation, feature behavior, and end-to-end workflows such as approaching obstacles, pressing the SOS button, and receiving scheduled reminders. Measured results showed object detection accuracy around 93%, GPS error under 5 m, reminder timing within about 2 seconds, and SOS alerts reaching the caretaker app in about 1.8 seconds.

Figure 4: Complete project toolkit

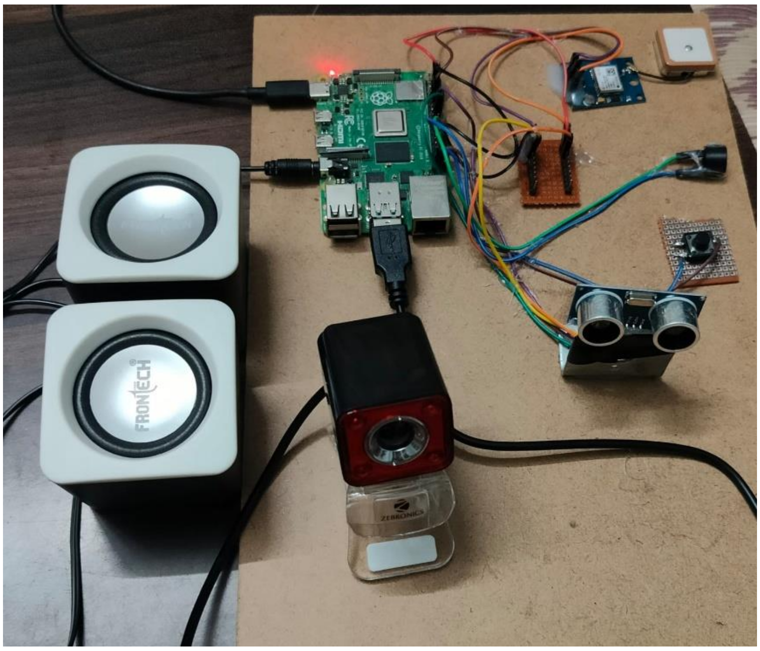
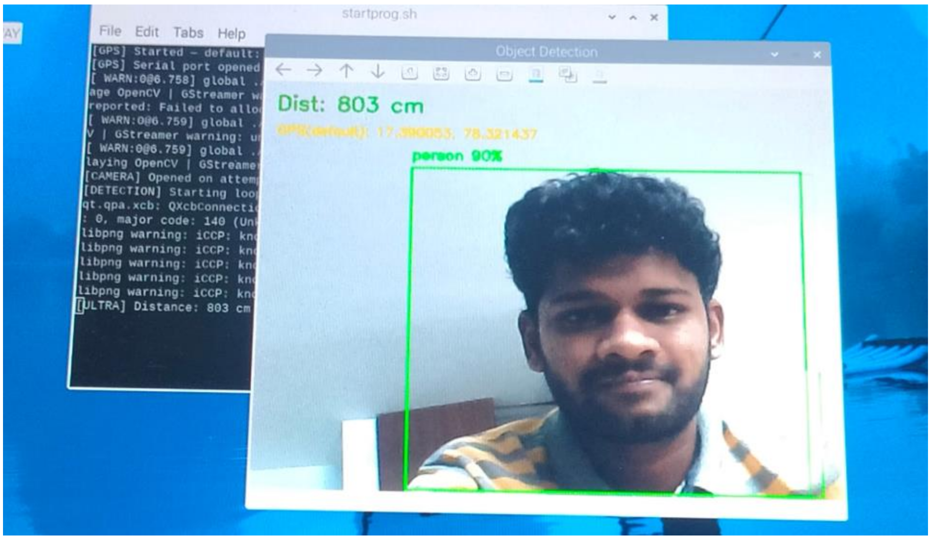


Figure 4 shows the complete GuideWay prototype assembled on a single baseboard. On the left, the two external speakers are used during development to play text-to-speech messages for obstacle alerts, SOS confirmations, and medicine reminders; in the wearable version these are replaced by earphones for private audio guidance. In the centre, the Raspberry Pi 4 Model B acts as the main controller, running the Python application, reading sensor inputs through its GPIO pins, and handling USB connections for the camera and network. Towards the top-right, the small blue board with its antenna is the NEO-6M GPS module, which streams live latitude and longitude data for SOS alerts and outdoor tracking. Next to it is a small prototyping board that carries the emergency push button and buzzer; pressing this button triggers the SOS workflow in software while the buzzer gives the user an immediate confirmation beep. On the right side, the HC-SR04 ultrasonic sensor is mounted on a separate breakout board and faces forward to measure the distance to obstacles in front of the user. At the bottom, the USB camera is positioned to capture real-time video of the scene, which is then processed by the YOLO model on the Raspberry Pi for object detection and classification.

Figure 5: Person detection with GPS coordinates



```
[GPS] Started - default:
[GPS] Serial port opened
[ WARN:0@6.758] global .
age OpenCV | GStreamer w
reported: Failed to allo
[ WARN:0@6.759] global .
V | GStreamer warning: u
[ WARN:0@6.759] global .
laying OpenCV | GStreame
[CAMERA] Opened on attem
[DETECTION] Starting loo
qt.qpa.xcb: QXcbConnecti
: 0, major code: 140 (Un
libpng warning: iCCP: kn
libpng warning: iCCP: kn
libpng warning: iCCP: kn
libpng warning: iCCP: kn
libpng warning: iCCP: kn
[ULTRA] Distance: 803 cm
```

Figure 5 demonstrates the system detecting a person (90% confidence) at 80.3 cm distance. The display of object detection results operation of camera processing.

Figure 6: Real-time object detection of water bottle

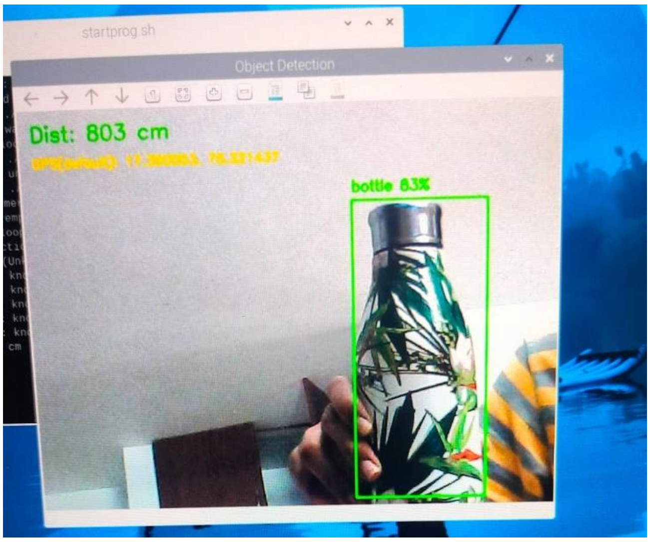


Figure 6 shows the YOLO model successfully detecting a water bottle with 83% confidence in VNC viewer. The green bounding box and distance overlay confirm accurate object identification and proximity measurement during testing.

Figure 7: SOS alert screen in caretaker app

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MEDICINE SLOT 1 TIME **19:58**

SOS : YES

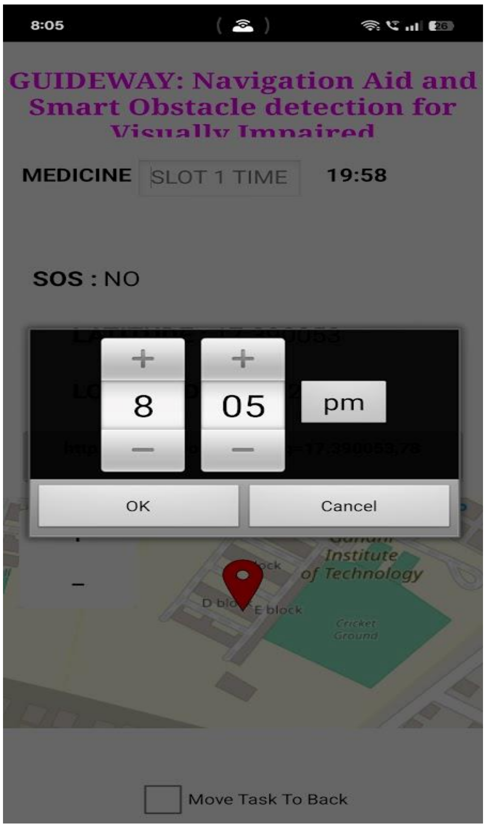
LATITUDE : 17.390053

LONGITUDE : 78.321437

http://maps.google.com/?q=17.390053,78.321437

Figure 7 shows the caretaker application after the SOS button is pressed on the wearable device. The app displays the live latitude and longitude received from the Raspberry Pi, along with a Google Maps link and marker pointing to the user's location. During this test, the phone also produced a voice alert and vibration, confirming reliable emergency notification.

Figure 8: Setting a medicine reminder



8:05

GUIDEWAY: Navigation Aid and Smart Obstacle detection for Visually Impaired

MEDICINE SLOT 1 TIME **19:58**

SOS : NO

Figure 8 illustrates how the caretaker configures a medicine reminder in the Android application. The time picker dialog is used to select the reminder time for Slot 1, which is then stored in the backend database. The Raspberry Pi later reads this value to trigger spoken “time to take medicine” alerts at the scheduled time.

6. CONCLUSION

The GuideWay system was built as an affordable, wearable aid to make every day navigation safer for visually impaired users. By combining a Raspberry Pi with a USB camera, ultrasonic sensor, GPS module, and audio–vibration feedback, the prototype gives real-time awareness of nearby obstacles and the surrounding environment. Using YOLO for object detection together with ultrasonic distance measurement allows the device to announce both what an object is and roughly how far away it is, which is more informative than simple beeps or vibrations. The system also adds a practical safety layer through the SOS feature: when the emergency button is pressed, the user’s current GPS coordinates are sent to a server and shown in the caretaker’s mobile app with a map link so they can quickly locate the user.

The medicine reminder function, set through the Android app and played as spoken alerts on the Raspberry Pi, further supports independent living by helping the user take medication on time. Tests on Raspberry Pi 4 showed that GuideWay can run in real time with good detection accuracy and acceptable delay for both reminders and SOS notifications. The prototype confirmed that object detection, distance sensing, GPS tracking, emergency alerts, and reminders work together smoothly on a single platform. Overall, GuideWay meets its main goal of improving safety, situational awareness, and autonomy for visually impaired users in indoor and limited outdoor settings.

7. FUTURE SCOPE

Although the prototype reaches its core objectives, several improvements are possible. For depth perception, the current design uses only one forward-facing ultrasonic sensor; future versions could add stereo or depth cameras and multiple ultrasonic units to widen the field of view and give more reliable 3-D information, supported by more advanced sensor-fusion algorithms. The hardware can also be moved from the test baseboard into a fully wearable form, such as a belt, chest harness, or smart-glasses style frame. Custom PCBs, compact enclosures, and better battery management would make the device lighter, more discreet, and more comfortable for full-day use. On the software side, the mobile and backend components can be extended with multi-user support, history of routes and alerts, and cloud storage of logs. Replacing periodic polling with push notifications, integrating richer turn-by-turn navigation, and adding secure authentication and encrypted communication would make the system more scalable, user-friendly, and robust.

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