

# An IoT-enabled vision-aid for the blind integrating ultrasonic obstacle detection and GPS-based location tracking

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## ABSTRACT

Visual impairment significantly affects independent mobility and personal safety, creating a need for affordable and reliable assistive navigation technologies. This paper presents the design and implementation of a low-cost wearable Vision-Aid system to support visually impaired individuals during outdoor navigation. The primary objective of the study is to enhance obstacle awareness, location tracking, and emergency communication using accessible embedded technologies. The proposed system integrates ultrasonic sensors for real-time obstacle detection, an Arduino microcontroller for data processing, a global positioning system (GPS) module for location tracking, and a global system for mobile communication (GSM) module for emergency alert transmission. Audio feedback is provided through a voice module to guide the user safely. Experimental evaluations were conducted under various environmental conditions to assess obstacle detection accuracy, response time, and location reliability. The results demonstrate accurate obstacle detection, timely audio alerts, and reliable real-time location sharing with caregivers. The proposed system improves user confidence, mobility, and safety while maintaining low implementation cost. This work highlights the potential of embedded and internet of things (IoT)-based assistive devices to enhance autonomy for visually impaired individuals and provides a foundation for future integration of artificial intelligence (AI)-based object recognition.

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## 1. INTRODUCTION

The project "Vision-Aid for the Blind" is designed to empower visually impaired individuals by enhancing their mobility and independence through the integration of cutting-edge internet of things (IoT) technology. By leveraging real-time location tracking, obstacle detection, and environmental awareness, the system offers an advanced navigation aid that significantly improves safety and ease of movement for visually impaired users. The proposed solution utilizes a combination of hardware and software components to create a cost-effective and accessible assistive device. Key hardware elements include ultrasonic sensors, global positioning system (GPS) module, Arduino Uno microcontroller, and global system for mobile (GSM) module [1]–[5]. GPS module provides real-time location tracking, enabling users to navigate efficiently, and accurately. Speaker system offers voice-based feedback, providing auditory assistance for navigation. Arduino Uno microcontroller acts as the core processing unit, integrating various sensors and modules to ensure seamless operation. GSM module facilitates real-time communication, allowing for emergency alerts

and remote assistance. The software framework is designed to process sensor data and deliver real-time feedback, ensuring that users receive immediate guidance and warnings. By incorporating data logging capabilities, the system can store navigation patterns and sensor readings for future improvements and personalized assistance [6]–[8].

The key features and benefits are enhanced navigation, obstacle detection and avoidance, real time location tracking, emergency communication, data logging and analysis, scalability and customization, and societal and medical impact. The device provides precise guidance through voice feedback, allowing visually impaired individuals to navigate unfamiliar environments with confidence. Ultrasonic sensors detect obstacles in the user's path and provide immediate auditory warnings to prevent accidents. The GPS module continuously updates the user's location, ensuring accurate navigation. The GSM module enables real-time alerts and communication with caregivers or emergency services when needed. The system records data on navigation patterns and obstacles encountered, enabling future optimizations and improvements. Designed with flexibility in mind, the system can be upgraded to include additional functionalities such as artificial intelligence (AI)-based object recognition and smart city integration [9]–[12].

Beyond personal safety and convenience, the "Vision-Aid for the Blind" project has broader implications for healthcare, accessibility, and social inclusion. By improving independent mobility, the device enhances the quality of life for visually impaired individuals, reducing dependency on caregivers and increasing their ability to participate in daily activities. This advancement in assistive technology sets a benchmark for future innovations in healthcare and accessibility solutions [4], [6], [13]–[15]. Vision-Aid is a transformative organization dedicated to empowering blind and visually impaired individuals by providing them with essential tools, resources, and support to live fulfilling lives. Through a wide range of programs, Vision-Aid works to break down barriers faced by visually impaired individuals by focusing on developing and deploying assistive devices that enhance mobility and independence. Providing accessible learning opportunities and skill development programs tailored to visually impaired individuals [12], [13], [16], [17]. Offering job-oriented training to help individuals secure employment and achieve financial independence. Encouraging community engagement and inclusion by fostering awareness and understanding of visual impairments. By collaborating with communities, organizations, and volunteers, Vision-Aid creates an inclusive environment where vision loss does not limit potential. Their mission emphasizes accessibility, education, and awareness to ensure that visually impaired individuals have equal opportunities to achieve personal and professional success [6], [18]–[20].

The primary objective of this paper is to address the problem of unsafe and inefficient outdoor navigation faced by visually impaired individuals due to the lack of affordable, real-time assistive systems [21], [22]. The proposed solution aims to design and implement a low-cost, wearable Vision-Aid system that enables reliable obstacle detection, accurate location tracking, and emergency communication using embedded and IoT-based technologies, thereby improving user safety, independence, and mobility [23]–[25].

## 2. RESEARCH METHOD

The method section is divided into the following subsections: library installation and code setup, obstacle sensor block diagram, and circuit design for obstacle detection.

### 2.1. Library installation and code setup

Initially, we begin by writing the code and installing the necessary libraries required to run our project. The ESP8266 wireless fidelity (Wi-Fi) library is essential for enabling Wi-Fi functionality in projects that involve the ESP8266 Wi-Fi module (or microcontroller). This library facilitates connecting ESP8266-based devices to a Wi-Fi network, allowing communication over the internet or a local network.

The software-serial library is used in Arduino projects to enable serial communication on any digital pins, rather than being limited to the default hardware serial pins (TX and RX). This is particularly useful when multiple serial devices are involved or when hardware serial ports are insufficient. The TinyGPS++ library is utilized for decoding and interpreting data from GPS receivers, extracting valuable information such as location, time, speed, and altitude. It is specifically designed to process National Marine Electronics Association (NMEA) sentences, which contain raw data from GPS satellites.

The flowchart in Figure 1 describes the operational sequence of an Arduino Uno–ESP8266-based monitoring and control system that continuously supervises sensor data, manages configuration settings, and controls actuators. The process begins at the Start block, where the system is powered on and all necessary hardware and software resources are initialized. During the initialize system settings stage, the Arduino Uno configures its input/output pins, establishes communication with the ESP8266 module, initializes sensors and actuators, loads previously stored parameters, and prepares the system for normal operation.

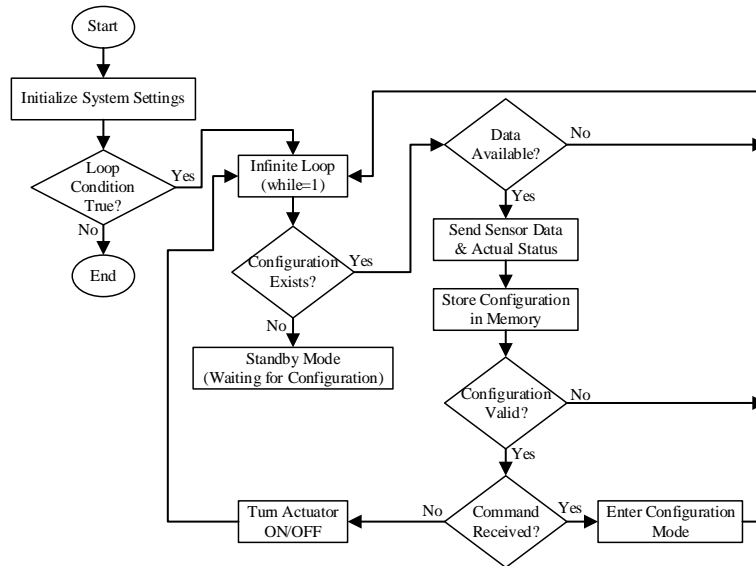


Figure 1. Flow diagram for execution

After initialization, the controller evaluates the loop condition true? decision block. This block determines whether the system should continue execution. If the condition evaluates to false, the program terminates and reaches the end block. However, under normal operating conditions, the condition remains true, and the system enters the infinite loop (while=1). This infinite loop forms the core of the program, ensuring uninterrupted operation and enabling the controller to continuously monitor, process, and respond to incoming information.

Within the infinite loop, the first task is to verify whether a valid configuration is available through the configuration exists? decision block. Configuration parameters may include sensor thresholds, actuator control settings, communication parameters, and other operational values required for proper functioning of the system. If no configuration is found, the system enters standby mode (waiting for configuration). In this state, the controller remains idle while continuously waiting for configuration information to be received from a remote user, cloud platform, or mobile application through the ESP8266 module. Once configuration data becomes available, the controller exits standby mode and returns to the infinite loop for further processing.

If a valid configuration already exists, the flow proceeds to the data available? decision block. Here, the controller checks whether new data has been received through the communication interface. This data may include updated sensor readings, actuator status information, or configuration commands transmitted through the ESP8266 module. If no data is available, the system immediately returns to the infinite loop and continues monitoring for incoming information. If data is available, the controller proceeds to the send sensor data and actuator status block, where the latest sensor measurements and actuator operating conditions are transmitted to the connected device, server, or monitoring application. This enables real-time observation of system performance and environmental conditions.

Following data transmission, the controller executes the store configuration in memory block. At this stage, any newly received configuration parameters are stored in non-volatile memory so that they remain available even after power interruptions or system restarts. Storing the configuration ensures that the system can resume operation using the most recent settings without requiring manual reconfiguration.

After storing the configuration, the system evaluates the configuration valid? decision block. The purpose of this step is to verify the correctness and integrity of the received configuration data. The controller checks whether all parameters fall within acceptable ranges and whether the configuration contains all required information. If the configuration is determined to be invalid, the system rejects the configuration and returns directly to the infinite loop, where it waits for new or corrected data. If the configuration is valid, the controller proceeds to the next stage of operation.

The next decision block, command received?, determines whether a specific control command has been received from the user or remote monitoring platform. If a valid command is present, the controller enters the enter configuration mode block. In this mode, users are allowed to modify operating parameters, update threshold values, adjust actuator settings, or perform system reconfiguration tasks. Once these actions are completed, control returns to the infinite loop so that the updated configuration can be applied during subsequent operation.

If no command is received, the decision block directs the flow toward the turn actuator ON/OFF block. Here, the controller executes the actuator control logic based on the current configuration and system conditions.

Depending on sensor values and predefined thresholds, the actuator may be switched ON or OFF to achieve the desired control objective. After the actuator state is updated, the controller again returns to the infinite loop.

Thus, the entire process continuously repeats, cycling through configuration verification, data monitoring, information transmission, memory updating, configuration validation, command processing, and actuator control. This repetitive loop enables the Arduino Uno and ESP8266 system to operate as a reliable real-time monitoring and control platform suitable for applications such as smart agriculture, industrial automation, environmental monitoring, and IoT-based remote control systems.

## 2.2. Obstacle sensor block diagram

Figure 2 represents a vision aid system for the blind using an ultrasonic sensor, Arduino Uno, and an audio output system. Here's a breakdown of the components and their functions:

- a. Ultrasonic sensor: detects obstacles in the surrounding environment by emitting ultrasonic waves and measuring the reflected signals.
- b. Arduino Uno: acts as the central processing unit, receiving data from the ultrasonic sensor and triggering appropriate responses.
- c. ISD1820 (voice recorder module): stores pre-recorded voice messages and plays them back when triggered by the Arduino.
- d. PAM8403 (audio amplifier module): amplifies the audio signal from ISD1820 to ensure clear output through the speaker.
- e. Speaker: provides auditory feedback to the user, alerting them about obstacles.

Working principle: i) the ultrasonic sensor continuously scans for obstacles, ii) if an obstacle is detected within a certain range, the Arduino Uno processes the data, iii) the ISD1820 module plays a corresponding pre-recorded message (e.g., "Obstacle ahead"), iv) the PAM8403 amplifier boosts the audio signal, and v) the speaker delivers the warning to the user.

This system is designed to assist visually impaired individuals by providing real-time voice feedback about their surroundings, enhancing their mobility and safety.

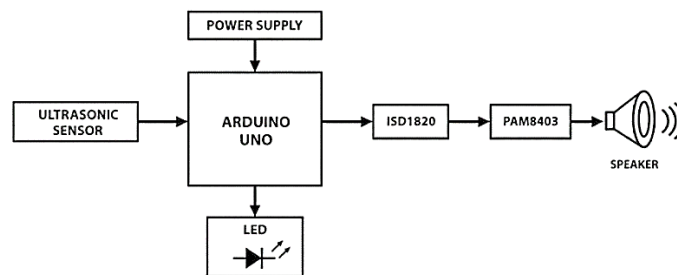


Figure 2. Block diagram for obstacle sensor

## 2.3. Circuit design for obstacle detection

In Figure 3 the Arduino Uno serves as the central microcontroller, controlling interactions between the ISD1820 sound module, HC-SR04 ultrasonic sensor, speaker, and light-emitting diode (LED). It sends a trigger pulse to the HC-SR04 sensor, which emits ultrasonic waves to measure distance. If an obstacle is detected within a predefined threshold, the Arduino triggers the ISD1820 to play a pre-recorded sound through the connected speaker. The ISD1820 can also record sound when prompted. An LED may provide status indication, lighting up during recording or playback. The system operates by integrating sensor-based detection with sound response for automated interaction.

## 2.4. Circuit and connections

The Figure 4 consists of the Arduino Uno, ISD1820 sound module, HC-SR04 ultrasonic sensor, a speaker, and an LED. The Arduino Uno is powered via its voltage common collector (VCC) and ground (GND) pins, which are connected to a 5 V power supply. The HC-SR04 ultrasonic sensor's VCC and GND are connected to the same power source, while its Trig and Echo pins are connected to Arduino's digital pins D2 and D3, respectively. The ISD1820 sound module's VCC and GND are similarly connected to the power supply, with its PLAY and REC pins wired to Arduino's D4 and D5 pins. The speaker is connected to the ISD1820's speaker output pins. The LED, used for status indication, is connected in series with a resistor between a digital output pin of the Arduino and GND. This setup allows for efficient communication between components, ensuring proper functionality of the system.

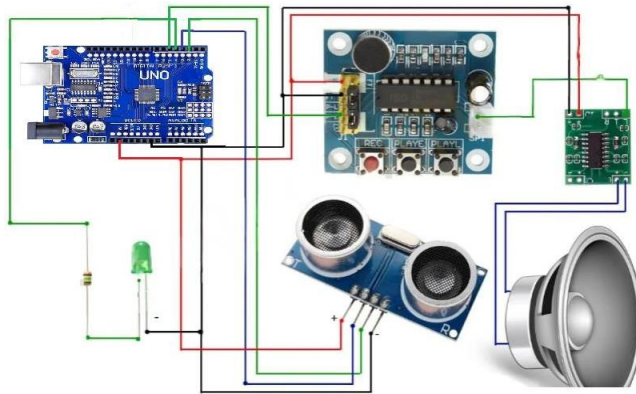


Figure 3. Circuit of obstacle sensor

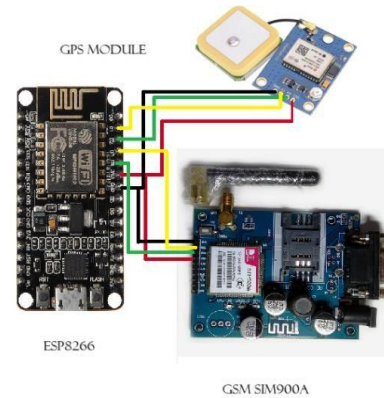


Figure 4. GPS location detection

In Figure 5 caretaker can locate a blind person using GPS location detection by leveraging mobile apps, wearables, or other GPS-enabled devices that continuously track the person's location and share it with their family. This technology enables real-time tracking, providing peace of mind to caregivers or caretaker, while promoting independence for the blind person. Test individual modules for functionality (GPS accuracy, GSM communication, and webcam clarity). Conduct field tests in various environments to ensure system reliability. Validate audio feedback timing and accuracy. Combine all components into a compact, wearable format. Perform usability testing with target users to refine audio feedback, system ergonomics, and response times. GPS location detection using the ESP8266 is a useful application in many IoT projects, providing real-time location data through satellite signals. To implement GPS location detection with the ESP8266, the most common method involves using a GPS receiver module like the NEO-6M, which is capable of receiving signals from GPS satellites and calculating the latitude, longitude, and other relevant data. The ESP8266, a Wi-Fi enabled microcontroller, can be used to interface with the GPS module, read the GPS data, and send it to remote servers or IoT platforms over the internet. The GPS receiver module typically communicates with the ESP8266 using serial communication universal asynchronous receiver-transmitter (UART) over pins such as RX and TX. Once connected, the GPS module outputs the location data in a standard NMEA format, which includes sentences that contain details about the current time, latitude, longitude, altitude, speed, and more. The ESP8266 reads these sentences and parses the data to extract the relevant location information, specifically the latitude and longitude coordinates. With this data, the ESP8266 can display the GPS coordinates on a local display, send them to a remote database, or even integrate with a mapping service like Google Maps to show the location on a map.

As the GPS module relies on satellite signals, the device may require a clear view of the sky to get an accurate location fix, and in indoor environments, the accuracy may be limited. Nevertheless, GPS location detection with the ESP8266 is a reliable and scalable solution for creating a variety of location-based services and IoT applications.

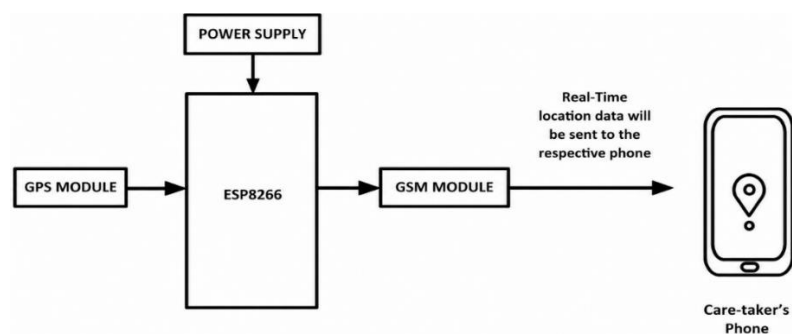


Figure 5. Block diagram for GPS location detection

### 3. RESULTS AND DISCUSSION

In Figure 6 GPS location detection technology offers significant benefits for enhancing the safety and independence of blind individuals. By using GPS-enabled devices, family members can track the

location of their blind loved ones in real-time. This can be especially useful in ensuring the person’s safety, helping them navigate unfamiliar environments, and providing peace of mind for their caregivers or family members. This discussion will focus on various methods by which family members can use GPS technology to locate a blind person, as well as the results and effectiveness of such systems. Enhanced independence: GPS technology enables blind individuals to navigate independently, without constant assistance from others. With real-time tracking, they can explore new areas or travel alone with the assurance that their family can monitor their location for safety. Peace of mind for caretaker: GPS tracking provides significant peace of mind for family members. Knowing that they can track the blind person’s location at any given time reduces anxiety and enhances their ability to respond quickly in case of an emergency. It allows for a higher level of comfort for both the blind individual and their family members.

Safety and emergency response: in emergency situations (e.g., if the person is lost, disoriented, or in danger), the ability to instantly locate the blind person is critical. Features like save our souls (SOS) buttons and geofencing provide proactive safety measures, alerting family members to take action when needed. Additionally, real-time location tracking helps ensure a rapid and informed response.

Non-intrusive and easy to use: wearable devices and smartphone apps are often discreet and easy for blind individuals to use. Features like voice control, screen readers, and simple interfaces make it easier for blind users to interact with the tracking systems, ensuring they can independently maintain communication with caretaker.

In Figure 7 the caretaker has to register the number by messaging R to the number that is used in GSM module from the mobile phone to laptop and the message will be received in serial port and the message will be processed and message will be sent back as, number is registered. In Figure 8 the person can register multiple number by sending a message like R1=+91xxxxxxxx it will register same as it registered first number. To know how much number or which number is registered we should message as, LIST we will get the list of numbers that are registered which is shown in Figure 9.

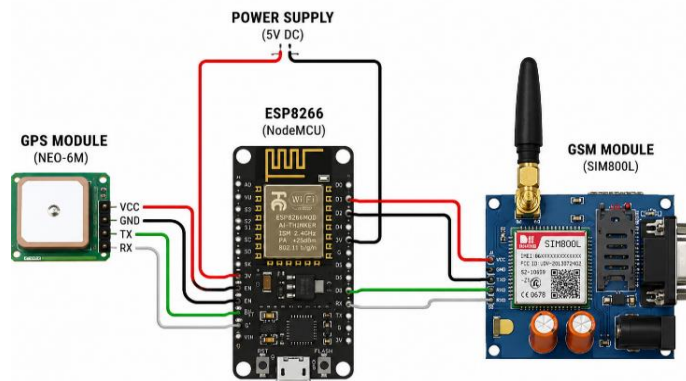


Figure 6. Circuit of GPS location detection

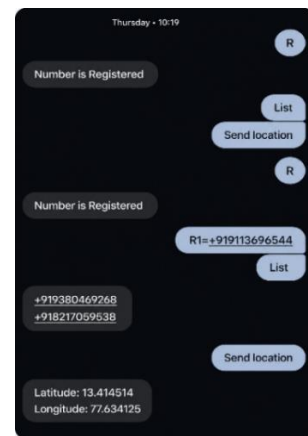


Figure 7. Message sent from mobile phone

```
AT Command Sent...
SMS Received: R
Processing Request...
Response: Number is Registered Successfully
```

Figure 8. Message received by serial port

```
Command Received: LIST
Registered Numbers:
1. +91XXXXXXXXXX
2. +91YYYYYYYYYY
```

Figure 9. Message received by serial port

To get location we have to send message from the mobile phone as, send location. Which is shown in Figure 10. The message will be received by the laptop and the message will be processed and the exact location will be sent back to the person, who asked for the location of the blind person as shown in Figure 11.

In Figure 12 at first we will record the voice in the ISD1820 voice module. We could hear the recorded voice by pressing play button. The program is compiled and uploaded to the Arduino Uno. The Arduino Uno is then connected to ultrasonic sensor which detects the obstacle when the obstacle reaches certain distance which is mentioned in program. When the obstacle is detected the speaker will make the sound which was recorded.

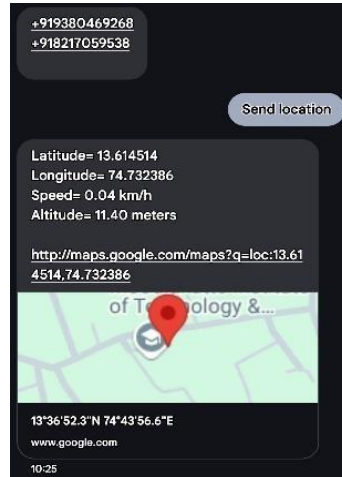


Figure 10. Message sent from mobile phone

```

Command Received: SEND LOCATION
Latitude : 13.3498 N
Longitude: 74.7936 E
Google Maps Link Generated

```

Figure 11. Message received by serial port

We combined both obstacle sensor and gps location detector. When the ultrasonic sensor detects the obstacle in certain distance and makes the sound that has been already recorded in ISD1820 voice module. When the caretaker want the location of the person, he/she would send the message to the number that has already been registered. The caretaker will message as “Send location” and the caretaker will get the location of a person as shown in Figure 13.

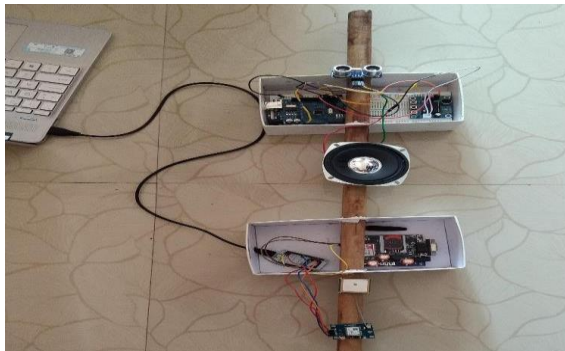


Figure 12. Circuit of obstacle detection

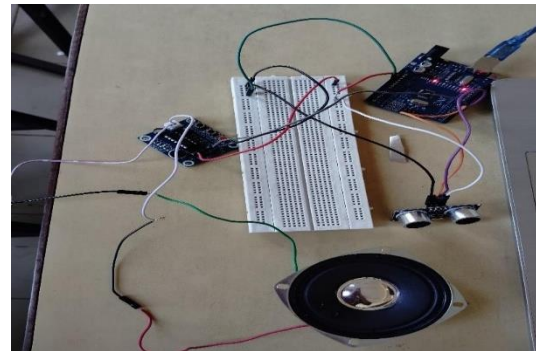


Figure 13. Combining both obstacle sensor and GPS location detection

### 3.1. Limitations and future work

Despite the promising performance of the proposed Vision-Aid system, several limitations must be acknowledged. First, battery life poses a practical constraint, as continuous operation of ultrasonic sensors, GPS modules, and GSM communication increases power consumption. Extended usage may require frequent recharging, which could limit long-term outdoor deployment. Future designs will focus on low-power optimization techniques and energy-efficient hardware components.

Environmental conditions also affect system performance. In noisy surroundings, audio feedback may be less effective, while rainy or highly reflective environments can degrade ultrasonic sensor accuracy due to signal scattering and interference. Additionally, the presence of multiple ultrasonic sources nearby

may introduce cross-sensor interference, leading to false obstacle detection. Incorporating sensor fusion techniques and adaptive filtering algorithms could mitigate these issues.

Data security and user privacy are critical concerns when handling GPS-based location data and GSM communication. Although the current prototype transmits essential information only to registered contacts, it does not implement advanced encryption or authentication mechanisms. Future enhancements will include secure communication protocols, data encryption, and access control to protect sensitive user information. Future studies will address these aspects to enhance the reliability and real-world applicability of the proposed system.

**4. CONCLUSION**

In conclusion, Vision-Aid's innovative approach to assistive technology, particularly its comprehensive navigation support for the blind, and represents a significant advancement. By prioritizing obstacle detection, user-friendly design, and real-time guidance, Vision-Aid empowers visually impaired individuals to navigate their environments with greater confidence and independence. The emphasis on cost-effectiveness and accessibility ensures that these crucial tools are available to a wider population. Furthermore, the focus on scalability and future enhancements, coupled with the high accuracy and versatility of the technology, positions Vision-Aid as a leader in the field. Continued development and refinement of these navigation tools promise to further transform the lives of blind and visually impaired individuals, fostering greater inclusion and independence. GPS location detection technology offers a powerful tool for families to track the location of blind individuals in real-time. Through wearable GPS devices, smartphones, and communication apps, blind people can receive real-time location assistance while providing their family members with peace of mind. These systems enhance the blind person's independence, ensure their safety, and enable rapid response in emergencies. However, it is essential to address concerns such as privacy, GPS accuracy, battery life, and potential reliance on technology. Overall, when used thoughtfully, GPS location detection is an invaluable resource for supporting the mobility and safety of blind individuals.

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**ditng

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

**CONFLICT OF INTEREST STATEMENT**

Authors state no conflict of interest.

**DATA AVAILABILITY**




Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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