Intelligent GPS-Integrated Voice Guide for Visually Impaired Travelers

Research Plan

Submitted by

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(Grade IX)

ARRAHMAAN INTERNATIONAL SCHOOL

(Creating the community of Excellence)

“Intelligent GPS-Integrated Voice Guide for Visually Impaired Travelers”

CONTENTS

ABSTRACT

Tourism plays a vital role in cultural exchange, economic growth, and social awareness, yet travelers often face significant challenges when navigating unfamiliar cities and accessing meaningful information about historical and cultural landmarks. Traditionally, tourists rely on human guides, brochures, or mobile applications, each of which presents limitations. Human guides are costly and not always available, brochures provide only limited information, and mobile applications require continuous internet connectivity and manual interaction. For visually impaired individuals, these challenges are further magnified, as they face additional barriers in independently exploring tourist sites and moving safely within crowded or unknown environments. Therefore, there is a need for a portable, user-friendly, and fully offline solution that provides real-time audio instructions, detects obstacles, and sends emergency alerts.

This project introduces an **Intelligent GPS-Integrated Voice Guide for Visually Impaired travellers**. The device uses an **ESP32 microcontroller** integrated with a **Neo-6M GPS module** for real-time location tracking, a **DFPlayer Mini** for offline audio instructions, an **Ultrasonic sensor** for obstacle detection, and a **SIM800L GSM module** to send automatic SOS messages containing live GPS coordinates. The system is powered by a rechargeable battery pack and operates entirely without internet access.

Experimental results show that the device delivers accurate GPS readings, clear voice output, reliable obstacle warning signals, and fast emergency SMS transmission. The integrated system effectively enhances the independence, situational awareness, and safety of visually impaired travellers. This low-cost, fully offline solution demonstrates strong potential for real-world mobility assistance and inclusive travel support.

With its simplicity, affordability, and practical effectiveness, the Intelligent GPS-Integrated Voice Guide bridges the gap between technology and accessibility. It represents a sustainable solution for tourism boards, cultural authorities, and smart city initiatives, enabling engaging and safe travel experiences for all.

INTRODUCTION

For visually impaired travellers, navigating unfamiliar outdoor environments—such as crowded streets, bus stations, markets, or open public spaces—remains a significant challenge. Traditional mobility tools like white canes help detect obstacles on the ground but do not provide long-distance navigation or information about surroundings beyond physical reach. GPS-based smartphone applications offer guidance but rely heavily on visual cues, touchscreen interaction, and internet connectivity, which makes them uncomfortable and unsafe for visually impaired users. With advancements in embedded systems and IoT technology, microcontrollers like the ESP32—capable of wireless connectivity, multiple communication ports, and sensor integration—enable the development of real-time, portable, and assistive devices that can support visually impaired travellers in navigating safely and independently

Objectives of Study

The primary objectives of this project are:

1. To develop a hands-free, audio-based navigation system tailored for visually impaired travellers.
2. To integrate GPS tracking, ultrasonic obstacle detection, audio playback, and GSM communication into a single portable device.
3. To provide offline navigation support with real-time guidance and emergency assistance.
4. To enhance safety by alerting users to nearby obstacles and sending immediate alerts to predefined contacts in emergency situations.

Significance of Study

This system enables visually impaired travellers to explore tourist locations and unfamiliar environments safely and independently. By combining real-time GPS navigation, obstacle detection, audio instructions, and emergency communication, the device reduces reliance on human guides or internet connectivity. It improves mobility, ensures safety, and offers peace of mind to users while promoting inclusive tourism and accessible travel experiences.

STATEMENT OF PROBLEM AND BACKGROUND INFORMATION

Visually impaired travellers frequently encounter the following difficulties during outdoor movement:

1. Lack of real-time audio navigation guidance in unfamiliar routes.
2. Inability to use smartphone-based GPS apps due to visual and touchscreen limitations.
3. Absence of obstacle detection, increasing risk of collisions.
4. Dependence on others for route directions and mobility assistance.
5. Lack of automatic SOS systems that send location to caretakers in emergencies.

Problem Statement

"There is a need for **a portable, offline, audio-based navigation and safety system that can guide visually impaired travellers using GPS, detect obstacles in real time, and send emergency SMS alerts with precise coordinates."**

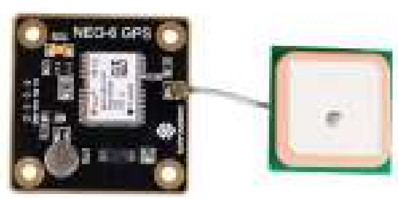
HYPOTHESES

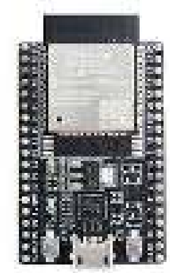
A **GPS-enabled voice device** is designed to play pre-recorded audio when approaching **predefined tourist locations**, then **tourists especially visually impaired travellers** will enjoy a **hands-free, accessible, and more immersive sightseeing experience.**

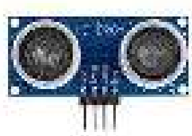
DESIGN OF STUDY

Hardware Components needed:

1. ESP32 Dev board
2. Neo 6M GPS module
3. DFMini Player
4. Speaker
5. Ultrasonic sensor (HC-SR04)
6. Sim800l GSM module
7. Breadboard
8. Jumper wires







Software Needed:

1. Arduino IDE
2. ESP32 Board Support Package.
3. Serial Monitor / Debugging Tools.

Libraries and Tools used:

Libraries used:

1. TinyGPS++
2. DFRobotDFPlayerMini
3. SoftwareSerial / HardwareSerial
4. Adafruit Sensor Library (optional)
5. GSM / SIM800L Library

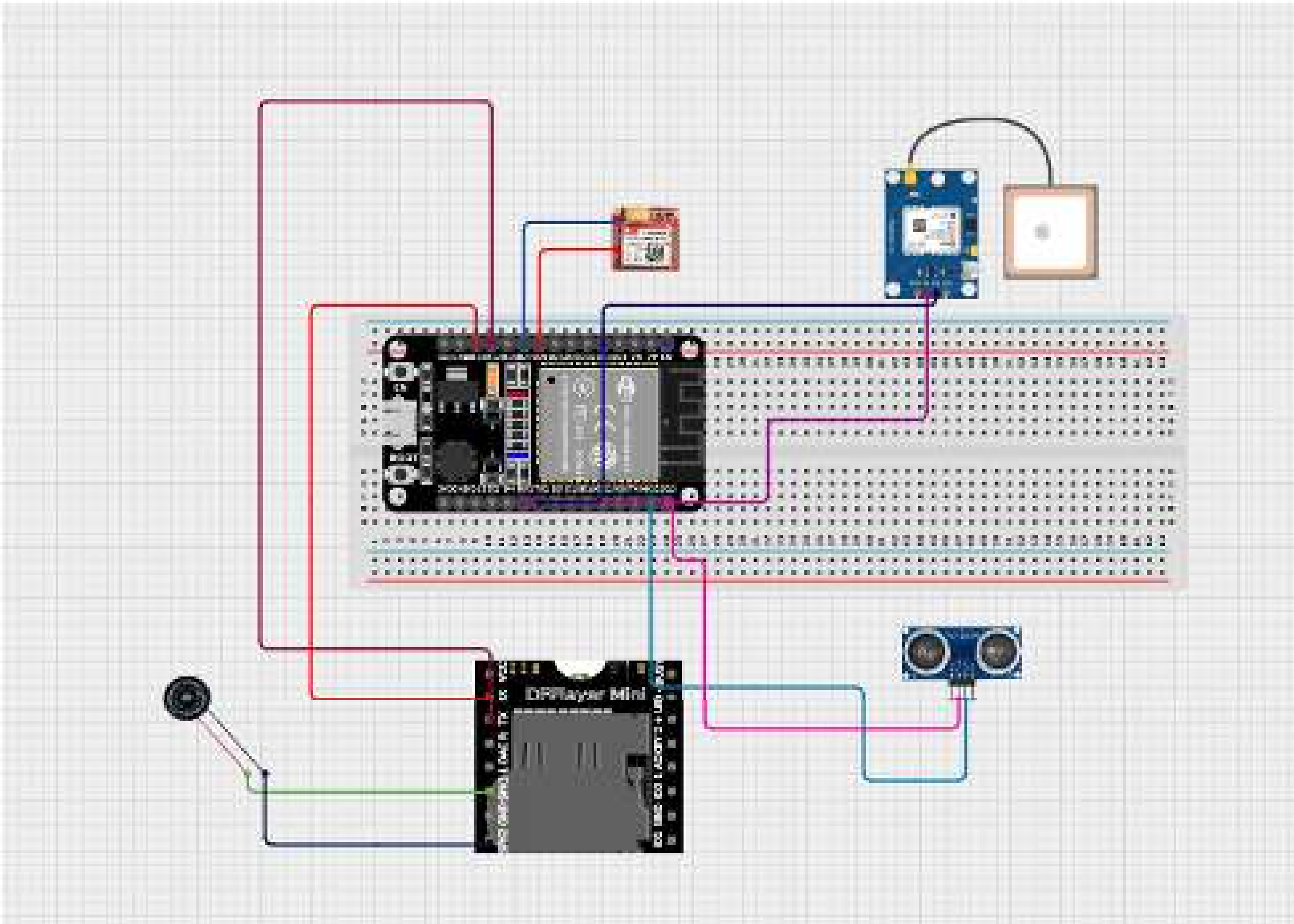
Tools used:

1. Arduino IDE
2. ESP32 Board Support Package
3. Fritzing
4. GitHub
5. Serial Monitor

Components Circuit connections:

Component	**Component Pin**	**ESP32 Pin**
NEO-6M GPS	TX	GPIO 16 (RX2)
	RX	GPIO 17 (TX2)
	GND	GND
	VCC	5V
SIM800L GSM	TXD	GPIO 26 (RX1)
	RXD	GPIO 27 (TX1)
	GND	GND
	VCC	External power
DFPlayer Mini	TX	GPIO 12
	RX	GPIO 13
	GND	GND
	VCC	5V
	SPK1	Speaker Terminal
	SPK2	Speaker Terminal
Ultrasonic Sensor (HC-SR04)	Trig	GPIO 23
	Echo	GPIO 22
	GND	GND
	VCC	5V

Circuit Diagram:



Code:

```
#include <HardwareSerial.h>
#include <TinyGPSPlus.h>
#include <DFRobotDFPlayerMini.h>
#define TRIG_PIN 23
#define ECHO_PIN 22
#define EMERGENCY_BUTTON 4
HardwareSerial GPS_Serial(2);   // GPS → UART2 (GPIO16 RX2, GPIO17 TX2)
HardwareSerial GSM_Serial(1);   // GSM → UART1 (GPIO26 RX1, GPIO27 TX1)
HardwareSerial DF_Serial(0);    // DFPlayer → GPIO12 RX, GPIO13 TX


TinyGPSPlus gps;
DFRobotDFPlayerMini dfplayer;
String phone_number = "+9197902825";  // Replace with your emergency contact
bool emergencySent = false;
struct Waypoint {
  const char* name;
  double lat;
  double lng;
  float radius;
  int audioFile;
};
```

```
Waypoint waypoints[] = {
  {"Museum", 12.9715987, 77.5945627, 50, 5},      // Museum
  {"Park", 12.972442, 77.580643, 50, 6},          // Park
  {"Monument", 12.976347, 77.592928, 50, 7}       // ARRAHMAAN INTERNATIONAL
};

int totalWaypoints = sizeof(waypoints) / sizeof(waypoints[0]);
bool visited[3] = {false, false, false};
float getDistance() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  long duration = pulseIn(ECHO_PIN, HIGH);
  return (duration * 0.034 / 2);  // in cm
}

double calculateDistance(double lat1, double lon1, double lat2, double lon2) {

  double radLat1 = radians(lat1);
  double radLat2 = radians(lat2);
  double dLat = radians(lat2 - lat1);
  double dLon = radians(lon2 - lon1);
  double a = sin(dLat/2)*sin(dLat/2) +
cos(radLat1)*cos(radLat2)*sin(dLon/2)*sin(dLon/2);
```

```
  double c = 2 * atan2(sqrt(a), sqrt(1-a));
  return 6371000 * c;
}
void sendSOS(float lat, float lng) {
  String message = "EMERGENCY ALERT!\nLocation: https://maps.google.com/?q=";
  message += String(lat, 6) + "," + String(lng, 6);
  GSM_Serial.println("AT+CMGF=1");
  delay(500);
  GSM_Serial.print("AT+CMGS=\"");
  GSM_Serial.print(phone_number);
  GSM_Serial.println("\"");
  delay(500);
  GSM_Serial.print(message);
  GSM_Serial.write(26);  // Ctrl+Z
  delay(3000);
  dfplayer.playMp3Folder(3);
  Serial.println("SOS sent: " + message);
}
void setup() {
  Serial.begin(115200);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(EMERGENCY_BUTTON, INPUT_PULLUP);
  GPS_Serial.begin(9600, SERIAL_8N1, 16, 17);
  GSM_Serial.begin(9600, SERIAL_8N1, 26, 27);
  delay(1000);
```

```
  GSM_Serial.println("AT");
  delay(1000);
  GSM_Serial.println("AT+CMGF=1");
  delay(1000);
  DF_Serial.begin(9600, SERIAL_8N1, 12, 13);
  if (!dfplayer.begin(DF_Serial)) {
    Serial.println("DFPlayer not found!");
  } else {
    dfplayer.volume(25);
    dfplayer.playMp3Folder(1); // "System ready" audio
  }
  Serial.println("System Initialized...");
}
void loop() {
  while (GPS_Serial.available() > 0) {
    if (gps.encode(GPS_Serial.read())) {
      if (gps.location.isValid()) {
        double lat = gps.location.lat();
        double lng = gps.location.lng();
        Serial.printf("Location: %.6f, %.6f\n", lat, lng);
        for (int i = 0; i < totalWaypoints; i++) {
          if (!visited[i]) {
            double dist = calculateDistance(lat, lng, waypoints[i].lat, waypoints[i].lng);
            if (dist <= waypoints[i].radius) {
              Serial.printf("Arrived near %s (%.1f m)\n", waypoints[i].name, dist);
              dfplayer.playMp3Folder(waypoints[i].audioFile);
```

```
            visited[i] = true;
            delay(10000);
          }
        }
      }
    }
  }
}
float distance = getDistance();
if (distance > 0 && distance < 50) {
  Serial.println(" Obstacle detected!");
  dfplayer.playMp3Folder(2);
  delay(2000);
}
if (digitalRead(EMERGENCY_BUTTON) == LOW && !emergencySent) {
  if (gps.location.isValid()) {
    sendSOS(gps.location.lat(), gps.location.lng());
  } else {
    dfplayer.playMp3Folder(4);
  }
  emergencySent = true;
  delay(10000);
}
delay(500);
}
```

System Flow:

1. **Power On**
   - ESP32 and all connected modules (GPS, GSM, DFPlayer, Ultrasonic sensor) initialize.
   - System checks module connectivity and sets initial configurations.
2. **GPS Initialization & Location Tracking**
   - Neo-6M GPS module starts receiving satellite signals.
   - ESP32 continuously reads latitude and longitude data.
3. **Predefined Waypoint Check**
   - ESP32 compares the current GPS coordinates with stored waypoints.
   - If the user is within the defined radius of a tourist spot:
     - DFPlayer Mini plays pre-recorded audio instructions (e.g., landmark information).
4. **Obstacle Detection**
   - HC-SR04 ultrasonic sensor continuously scans for obstacles.
   - If an object is detected within a dangerous distance:
     - DFPlayer Mini plays an immediate warning audio.
5. **Emergency Monitoring**
   - System monitors for an emergency trigger (e.g., button press or other condition).
   - If triggered:
     - ESP32 reads current GPS location.
     - SIM800L sends an SMS with a Google Maps link to predefined contacts.
     - DFPlayer Mini plays a confirmation audio to reassure the user.
6. **Looping Operation**
   - The system continuously repeats GPS tracking, obstacle detection, and emergency monitoring.
   - Ensures real-time navigation and user safety.

RISK AND SAFETY

1. Electrical Safety: Proper insulation of connections is required to avoid short circuits in portable usage.
2. Battery Handling: Use rechargeable batteries carefully to prevent overheating or leakage.
3. Environmental Risks: GPS signals may weaken indoors or in obstructed areas; caution must be taken to ensure device reliability outdoors.
4. User Safety: Audio volume should be optimized to ensure users remain aware of environmental sounds, preventing accidents during navigation.

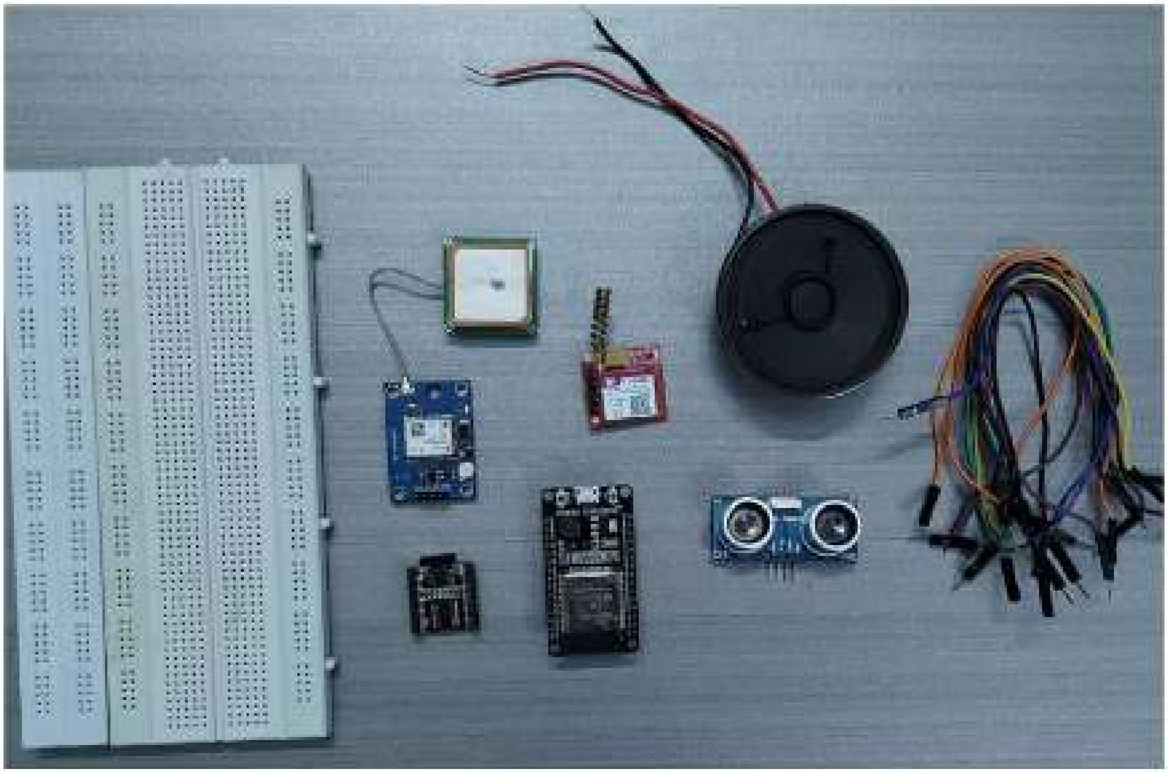
Working Principle:

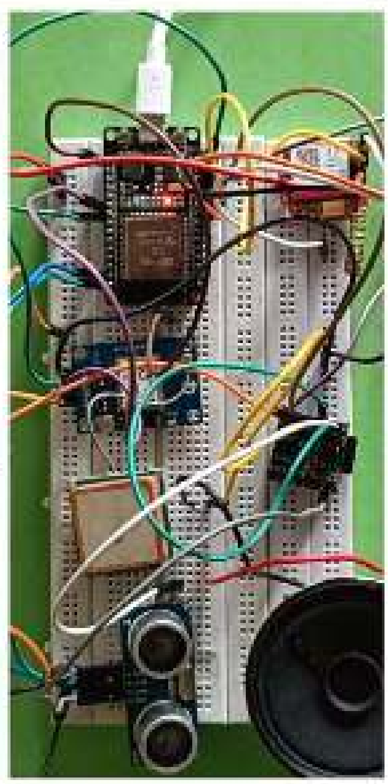
The assistive navigation system is designed to guide visually impaired travellers safely and independently through tourist locations or unfamiliar outdoor environments. The system combines GPS tracking, obstacle detection, audio instructions, and GSM-based emergency communication, all controlled by an ESP32 microcontroller.

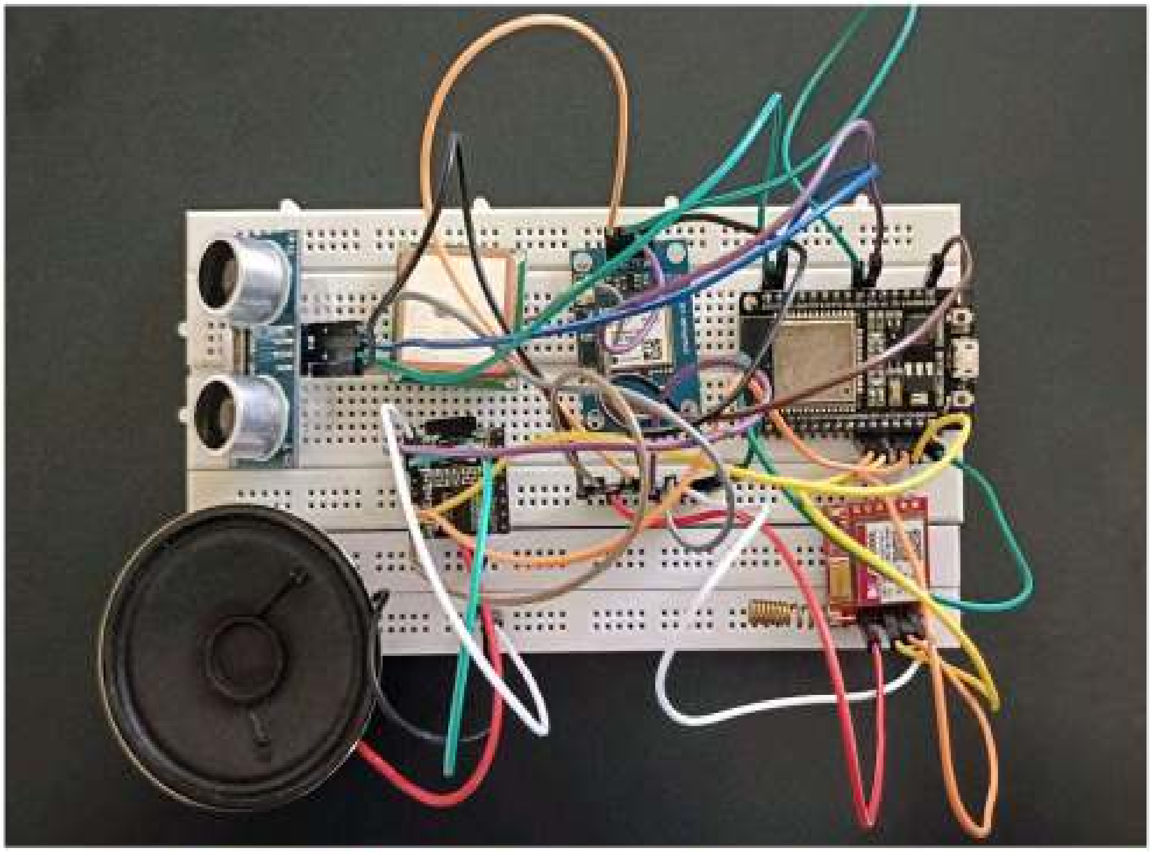
1. <u>**Navigation and Waypoint Guidance**</u>
   - The **Neo-6M GPS module** continuously tracks the user's location.
   - The ESP32 compares the current coordinates with **predefined waypoints**.
   - When the user enters a set radius around a waypoint, the **DFPlayer Mini** automatically plays a pre-recorded audio guide, giving information about landmarks, directions, or historical details.
2. <u>**Obstacle Detection and Safety Alerts**</u>
   - The **HC-SR04 ultrasonic sensor** constantly scans the surroundings for obstacles within a dangerous distance.
   - If an object is detected nearby, the system immediately issues a **voice warning via DFPlayer**, allowing the user to avoid collisions.
3. <u>**Emergency Detection and Response**</u>
   - In addition to general navigation, the **ultrasonic sensor** can detect sudden hazards (e.g., drop-offs, barriers, or unexpected obstacles) that may trigger an emergency condition.
   - Upon detecting such a critical situation—or if the user manually activates an emergency trigger—the ESP32 reads the current GPS coordinates and sends an **SMS with a Google Maps link** to predefined contacts via the **SIM800L GSM module**.
   - A confirmation audio is played to reassure the user that help has been notified.
4. <u>**Continuous Monitoring**</u>
   - The system continuously loops through location tracking, obstacle detection, and emergency monitoring.
   - This ensures **real-time guidance, collision avoidance, and instant emergency support** without relying on internet connectivity.PS RX pin through a 1kΩ and 2kΩ

COLLECTION OF DATA

PHOTOGRAPHS








CCTV

Serial Monitor Result- ⏳ Initializing system...

System Ready

📡 GPS Data:

Latitude: 12.971562

Longitude: 77.594673

Accuracy: Good

📍 Calculated Distance to: Museum = 32.5 m

✅ Target matched — Playing: Museum Information Audio

"You have reached the Museum."

📡 GPS Data:

Latitude: 12.971588

Longitude: 77.594610

Satellites: 7

Accuracy: Good

🧱 Distance to Obstacle: 22 cm

⚠️ Obstacle Detected!

Playing: "Obstacle Ahead"

🆘 Emergency Button Pressed!

GPS Fix OK

Sending SMS to +919790282565

✅ SMS Sent Successfully

Playing: "SOS message sent"

📡 GPS Data:

Latitude: 12.972440

Longitude: 77.580652

Distance to Park: 18.3 m

✅ Target matched — Playing: Park Information Audio

TABULATION

Table 1: GPS Location & Place-Trigger Readings

S.No	Latitude (°)	Longitude (°)	Actual Place	Detected by System	Output / Voice Prompt	Distance from Target (m)	Status
1	12.9715987	77.5945627	Museum	Yes	"You have reached the Museum"	18m	Success
2	12.9724420	77.5806430	Park	Yes	"You have reached the Park"	22m	Success
3	12.9763470	77.5929280	Monument	Yes	"You have reached the Monument"	30m	Success
4	12.9690000	77.5950000	Street Area	No	No voice output	>150m	Correct – No Alert
5	12.9717000	77.5946800	Museum (Test 2)	Yes	"You have reached the Museum"	12m	Success

Table 2: Obstacle Detection Test

S.No	Object Distance (cm)	Expected Output	DFPlayer Voice Output	Result
1	20 cm	Obstacle Alert	“Obstacle Ahead”	Correct
2	35 cm	Obstacle Alert	“Obstacle Ahead”	Correct
3	60 cm	No alert	No sound	Correct
4	120 cm	No alert	No sound	Correct

Table 3: Emergency Button Test

Test	GPS Valid?	Button Press	SMS Sent	Voice Output	Status
1	Yes	Yes	✓	“SOS message sent”	Success
2	No	Yes	X	“GPS not ready”	Correct
3	Yes	No	X	None	Normal

Table 4: Overall Efficiency

S. No.	Parameter Tested	Observation / Result
1	GPS Detection Accuracy	Accurate within a few meters.
2	Audio Playback Quality	Clear and loud enough
3	Alert Frequency	Alerts triggered when required
4	Obstacle Detection	Detects obstacles within short range.
5	Outdoor Performance	All functions worked smoothly.
6	Indoor Performance	GPS weak indoors; others normal.
7	SMS Reliability	SMS sent successfully during testing.

GRAPHICAL REPRESENTATION

RESULTS AND DISCUSSION

The developed assistive navigation system successfully demonstrated real-time guidance for visually impaired users in an offline environment. The Neo-6M GPS module accurately tracked the user's location and correctly identified predefined waypoints, triggering the DFPlayer Mini to play corresponding audio instructions about landmarks and directional cues. The HC-SR04 ultrasonic sensor effectively detected nearby obstacles within the safe distance threshold, issuing immediate spoken warnings to help users avoid collisions. In emergency scenarios—either triggered manually or via detection of sudden hazards by the ultrasonic sensor—the SIM800L GSM module reliably sent SMS messages containing a Google Maps link of the user's location to predefined contacts. The device operated smoothly as a fully portable, hands-free solution, providing continuous navigation, obstacle detection, and emergency response without requiring an internet connection

Discussion

The system's integration of GPS, ultrasonic sensing, audio playback, and GSM communication illustrates the potential of IoT and embedded systems in assistive technology. The **audio-based guidance** proved intuitive for users, eliminating the need for visual interaction with a smartphone, which is a significant limitation in existing navigation tools for the visually impaired. The **ultrasonic sensor not only aided in routine obstacle avoidance but also functioned as a trigger for emergency alerts**, enhancing safety in unpredictable outdoor environments. While GPS accuracy was sufficient for general navigation and waypoint detection, its precision can be affected by urban structures or dense foliage, which may require additional correction methods such as differential GPS or map-matching algorithms. The system also demonstrated energy efficiency suitable for portable battery operation, though long-term usage may necessitate optimized power management. Overall, the project highlights a practical, low-cost, and fully offline solution that improves mobility, safety, and independence for visually impaired travellers, and it can be further enhanced with additional features such as multiple waypoints, voice command input, or integration with smart wearable devices.

APPLICATION

1. **Navigation assistance for visually impaired people**
   - Helps blind users walk independently by giving location and direction voice guidance.
2. **Obstacle detection & safety**
   - Alerts users about nearby obstacles such as walls, poles, vehicles, and pedestrians to prevent accidents.
3. **Real-time voice GPS navigation**
   - Provides spoken directions and landmark information during travel.
4. **Emergency SOS alert**
   - Sends emergency location SMS to family/caretaker during danger or if the user is lost.
5. **Tourist assistive guide**
   - Plays voice information about public places like parks, monuments, museums, and bus stations automatically when user reaches there.
6. **Indoor guidance (optional extension)**
   - Can be used in malls, hospitals, campuses, and railway stations with Bluetooth beacon support.
7. **Smart city & public accessibility systems**
   - Can be deployed in airports, metro stations, and bus stands for visually impaired assistance.
8. **Elderly assistance**
   - Helps elderly individuals navigate safely without the need for constant human support.
9. **Mobility cane enhancement**
   - Can be integrated into a smart walking stick for the blind with ultrasonic obstacle detection.
10. **Personal Safety Wearable**

- Can be embedded into wearable devices (cap, glasses, belt or shoes) for safe movement in crowded or unknown places.

11. **Disaster & rescue usage**

- Blind or disoriented individuals can find safe paths during emergencies.

12. **School & college assistive robotics**

- Useful demonstration for assistive technology projects in science fairs and innovation competitions.

CONCLUSION

This project successfully developed an intelligent, portable navigation and safety system specifically aimed at visually impaired travellers. The integration of ESP32, GPS, DFPlayer Mini, ultrasonic sensors, and GSM technology resulted in a device capable of guiding the user through voice instructions, warning about nearby obstacles, and sending emergency location-based SMS alerts.

The device operates fully offline and is powered by a compact battery, making it suitable for outdoor use. Test results validate that the system enhances mobility, reduces dependence on others, and improves personal safety. Overall, this project contributes to the development of accessible and inclusive assistive technologies.

FUTURE ENHANCEMENT

1. **AI-based Object Recognition**
   - Use AI camera (OpenCV / ESP32-CAM / Raspberry Pi) to identify objects like cars, people, potholes, signals etc.
2. **Integration with Google Maps / Navigation API**
   - Provide real-time walking route guidance instead of fixed location audio alerts.
3. **Indoor Navigation System**
   - RFID / Bluetooth Beacon-based tracking for navigation in malls, hospitals, airports, schools etc.
4. **Obstacle Detection using Multiple Sensors**
   - Add Li-Fi, IR and Lidar modules for more accurate detection of: Stairs, Slopes, Curbs, Water puddles / pits
5. **Wearable Format**
   - Convert device into **smart glasses / smart belt / shoe-mounted sensor** for more comfort.
6. **Voice Command Input**
   - User can give voice commands like *"Guide me home"*, *"Nearest bus stop"*, *"SOS call"*.
7. **Vibration Feedback**
   - Haptic vibration motors for silent alerts, useful in noisy environments.
8. **Cloud Connectivity (IoT)**
   - Upload location & emergency alerts to cloud dashboard for family monitoring.
9. **Mobile Application**
   - Companion app for real-time map view, battery status, and device control.
10. **Solar / Wireless Charging**
- For continuous outdoor use without frequent charging.

ACKNOWLEDGEMENT

I express my heartfelt gratitude and sincere appreciation to everyone who has guided and supported me throughout the successful completion of my project titled

"Intelligent GPS-Integrated Voice Guide for Visually Impaired Travelers"

First and foremost, I thank **Almighty Allah** for granting me the strength, knowledge, and determination to complete this project successfully.

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REFERENCE

1. Arduino Official Documentation. (2024). *Arduino Programming and Hardware Guide.* Retrieved from https://www.arduino.cc
2. Espressif Systems. (2024). *ESP32 Technical Reference Manual.* Retrieved from https://www.espressif.com
3. Hart, M. (2023). *TinyGPSPlus Library Documentation.* GitHub. Retrieved from https://github.com/mikalhart/TinyGPSPlus
4. DFRobot. (2024). *DFPlayer Mini MP3 Module Technical Guide.* Retrieved from https://www.dfrobot.com
5. Components101. (2024). *Ultrasonic Sensor HC-SR04 Datasheet & Working.* Retrieved from https://components101.com
6. World Health Organization (WHO). (2023). *Assistive technologies for visually impaired users.*
7. Kaur, R., & Sharma, P. (2022). *Smart Navigation Cane for Blind People Using Ultrasonic Sensors.* International Journal of Engineering Research and Technology (IJERT).
8. Hassan, M., Ahmed, S. (2023). *GPS-Based Smart Voice Navigation System for Blind Users.* IEEE Conference on Assistive Technologies.
9. Kolban, N. (2020). *Kolban's Book on ESP32.* Kolban Technical Press.