Raspberry Pi-Based Assistive Technology for Visually Impaired: Navigation and Emergency Support

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Abstract - *The most significant difficulty for individuals who are visually impaired involves to reach their destination. Although smart helping sticks have been produced, they need to be carried around and have restrictions. The goal of the smart system "Help Me" and navigation aid functions is to greatly improve the ability to move and safety of those with visual impairments. The navigation assistance feature utilizes a GPS-based system and speech-to-text technology to provide real-time audio guidance, making users able to reach their desired destinations efficiently and independently. The "Help Me" feature is designed for emergency situations, where pressing a dedicated button activates an alert system that sends pre-configured messages along with the user's GPS location to designated contacts, ensuring immediate assistance. Together, these features offer a robust and user-friendly solution, improving the overall quality of as well as security for blind people.*

Key Words: Navigation assistance, GPS-based system, speech-to-text technology, real-time audio guidance.

1.INTRODUCTION

For those who are visually impaired, getting about all over may be quite difficult, particularly if it comes to autonomous travel and maintaining personal safety. This project presents cutting-edge solutions with two main elements to address these issues: navigation assistance and an emergency "Help Me" feature. Navigation assistance is important for visually impaired individuals to travel with confidence and ease. The proposed system integrates GPS-based voice navigation with real-time speech recognition to provide seamless guidance. By converting spoken destination requests into actionable directions, the system offers precise, audio-based instructions to help users reach their intended locations. The GPS functionality continuously tracks the user's position, ensuring they receive accurate directions and distance information. This approach not only simplifies the navigation process but also enhances the user's autonomy, allowing them to navigate complex environments and unfamiliar areas with greater ease. In emergencies, immediate assistance is crucial. The "Help Me" feature is developed to offer swift support in critical situations. With a simple press of the emergency button, the system sends out an alert message to pre-configured contacts, including family members and emergency services. Simultaneously, GPS tracking provides real-time location data, enabling responders to pinpoint the user's exact whereabouts. This feature ensures that help is quickly mobilized, offering an added layer of security and peace of mind for visually impaired people who could find themselves in critical situations. Together, these features—navigation assistance and the "Help Me" button form a comprehensive solution that enhances both the freedom and safety of people with vision impairments, enabling them to move about their environment more confidently and with security.

2. LITERATURE REVIEW

Those who are blind or visually handicapped have significant problems while navigating their surroundings. New developments in technology have prompted the creation of a number of systems targeted at improving object detection and navigational skills.

Priya created a smart glasses-based assistive technology for those who are blind. For navigation, it makes use of face and object recognition. With the use of this technology, the user can recognize objects and people in front of them. Only those who have already registered with the system database can be identified by this system [1].

In this work by Israh Akbar, the usage of GPS mobile applications for blind pedestrian navigation was investigated. Improving user confidence in GPS-based applications' accuracy. The study made it easier to analyze and comprehend how blind individuals utilize technology to navigate. The study further aided in highlighting the deficiency of information provided to visually impaired individuals when navigating new surroundings. The fact that every participant mostly relied on the distance measuring units of the applications while being directed by the GPS-based applications further demonstrated the significance of using the right words and units [2].

Sanika Dosi developed a blind-friendly Android app that leverages real-time object recognition through a smartphone camera. By utilizing neural networks, the app can identify objects and provide audio feedback to the user. By enhancing the user's capacity to identify and interact with items in their surroundings, this invention may improve situational awareness and navigation [3].

Ali Khan proposed assistance system that which utilizes ultrasonic sensors to identify obstacles. The wearable jacket has various ultrasonic sensor locations, a vibration device, and a buzzer. User's surroundings are scanned by sensors, which alert them to obstacles along their path by buzzing and vibrating. [4].

S. Duman introduced a portable system utilizing the Raspberry Pi and a camera to measure distances between objects and people. The system employs the YOLO algorithm, a convolutional neural network-based approach for real-time object detection. It provides auditory feedback on distance calculations, offering a significant advantage in spatial awareness and navigation for individuals with low vision [5].

Shahira K C developed a technology that combines YOLO-based object detection with an ultrasonic sensor mounted on an Arduino. This system is designed to help visually impaired individual sense and recognize obstacles in real time while calculating their distance. The incorporation of these technologies enables effective navigation by providing immediate feedback on nearby obstructions [6].

Devshree Bharatia proposed an e-stick module integrated with a voice-activated Android application. This solution aims to offer an affordable and a sensible choice for those with visual impairments, preserving the familiar structure of traditional white canes while incorporating modern technology. The system enhances navigation by integrating real-time audio feedback and maintaining the traditional stick's utility [7].

Anish Aralikatti reported on an Android-based mobile application system that utilizes real-time video from a camera for object recognition. The mechanism allows people with vision impairments to navigate their surroundings more safely by identifying adjacent objects and providing feedback to prevent collisions. This approach focuses on enhancing situational awareness and navigation accuracy [8].

Fayaz Shahdib presented a sensor fusion approach combining a camera and an ultrasonic sensor for mobile navigation. This method allows for the detection of obstacles, measurement of distances, and calculation of dimensions with minimal sensor and computing costs. The fusion of these sensors provides an economical solution for improving navigation capabilities [9].

Maisha Mashiata reviewed the most advanced available assistive technology for people with visual impairments, with a focus on features like obstacle detection, portability, and mobile assistance. This paper showcases how various technologies can be integrated to enhance navigation and overall mobility, providing a comprehensive overview of current advancements in the area [10].

A. Peterson examined into how people with impairments may utilize Bluetooth technology to get wireless navigation assistance in places that are available to them, which can let them move around more freely. The study examines how wireless connectivity might improve the mobility and accessibility of individuals with visual impairments, which is crucial for improving their quality of life. [11].

Xinnan Leong proposed a system using a Raspberry Pi, camera module and sonar sensor for real-time object detection and distance estimation. The incorporation of convolutional neural networks with hardware demonstrates successful real-time performance in diverse settings, validating the system's effectiveness for navigation and obstacle avoidance [12].

Lourdes Santhosh S introduced an innovative assistive technology using the YOLO algorithm for real-time wearable glasses with obstacle detection and recognition. The Raspberry Pi CPU is connected to a camera and an earphone by the system, which transforms visual input into audible feedback. This technology performance evaluation shows how it could improve item detection and navigation in practical situations [13].

These all studies include a wide range of technology developments meant to help visually impaired people navigate more easily. These developments improve mobility and safety in daily settings by combining a variety of sensors, algorithms, and user interfaces.

3. METHODOLOGY

Fig.1 shows the block diagram of assistive device for visually impaired individuals using a Raspberry Pi, a comprehensive approach that was implemented. First, a stable 5V 2.5A power supply was established to ensure reliable operation of the Raspberry Pi and its peripherals. A push button was integrated into a GPIO pin to provide "Help Me" feature. A GPS module connected via UART pins enabled real-time location tracking, with software libraries configured for data interpretation. For audio input, a USB microphone was utilized, supported by audio processing software to capture and analyze sounds. Output was managed through a USB or Bluetooth speaker for auditory feedback and notifications. Python scripts were developed to coordinate these components, handling emergency alerts, GPS data processing, audio input management, and spoken responses, thereby creating an operational and responsive assistive device.

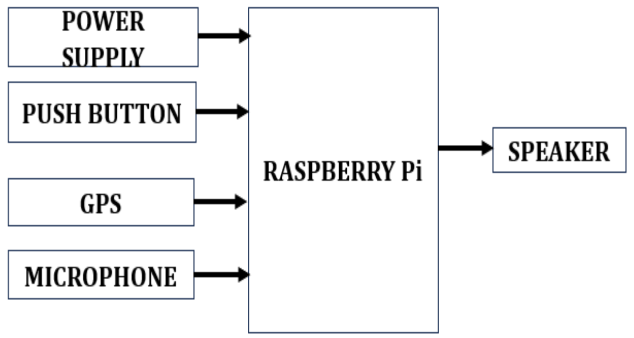

Fig -1: Block diagram of Assistive Device

3.1 Navigation Assistance

The navigation assistance function is a critical component of the project, aimed at giving those who are blind or visually handicapped comprehensive support for reaching their destinations. This functionality is designed to operate seamlessly based on user input and current location. Initially, the user communicates their destination verbally, which is captured by a speech-to-text system integrated into the navigation module. This system converts the verbal input for the text, which is then processed to identify the desired location.

Once the destination is determined, the GPS (Global Positioning System) module calculates the user's current position and determines the route to the specified destination. GPS is a satellite-based navigation system that is usually used for mapping, navigation, and positioning. It gives time and location information anywhere on or near the Earth's surface. The system then computes essential navigational information, including the distance to the destination and directional guidance. In terms of degrees, instructions are supplied, offering precise and actionable instructions. Let's consider, the system might instruct the blind to "turn left at 45 degrees" or "proceed straight for 200 meters."

Speech-to-text integration guarantees that users may engage with the system in a natural way without having to enter data by hand. This designed system thus offers real-time updates and guidance, making navigation intuitive and accessible. By delivering clear, step-by-step directions and distance information, the navigation assistance function aims to improve the user's autonomy and confidence while traveling.

3.2 Help Me Feature

The "Help Me" feature is an essential safety operation of the assistive device, designed to offer immediate support during emergencies for visually impaired individuals. This feature includes a readily accessible button that the user can activate in emergency situations. When pressed, the button sends an emergency alert through wireless communication channels such as SMS, including the user's current location obtained via the GPS module. To confirm the alert has been sent, the device provides auditory reassure the user. Additionally, the device notifies pre-selected contacts, such as family members or caregivers, to ensure a rapid response. By guaranteeing that the user may promptly and efficiently request assistance, this integrated system improves their safety and freedom in emergency circumstances.

3.3 Assistive Device Workflow for Navigation and Emergency Support

The sequence diagram below in Fig.2 illustrates a comprehensive process integrating navigation assistance and emergency alert features into an aid for those who are blind or visually challenged. This system enhances user security and independent by providing real-time location data, voice navigation, and immediate emergency response capabilities. The diagram is divided into five key components: Push Buttons, Audio Output, Emergency Contact, GPS Module, and Navigation System.

When the user presses a push button, an emergency alert is triggered, sending a alert notification to predefined emergency contacts with a tracking link. The GPS module continuously tracks the user's location, facilitating swift responses from emergency contacts. For navigation assistance, the user can request location data through speech. The device captures the audio input, converts it to text using a speech-to-text system, and processes the request via the navigation system. The GPS module provides current location data, which the navigation system uses to calculate the route and convert it into spoken instructions. The user receives these instructions via the audio output.

This integrated system ensures seamless interaction, real-time updates, and enhanced user safety. The GPS module provides continuous location tracking, crucial for both navigation and emergency situations, while the audio feedback keeps the user informed, enabling easy activation of emergency alerts and navigation assistance without relying on visual feedback.

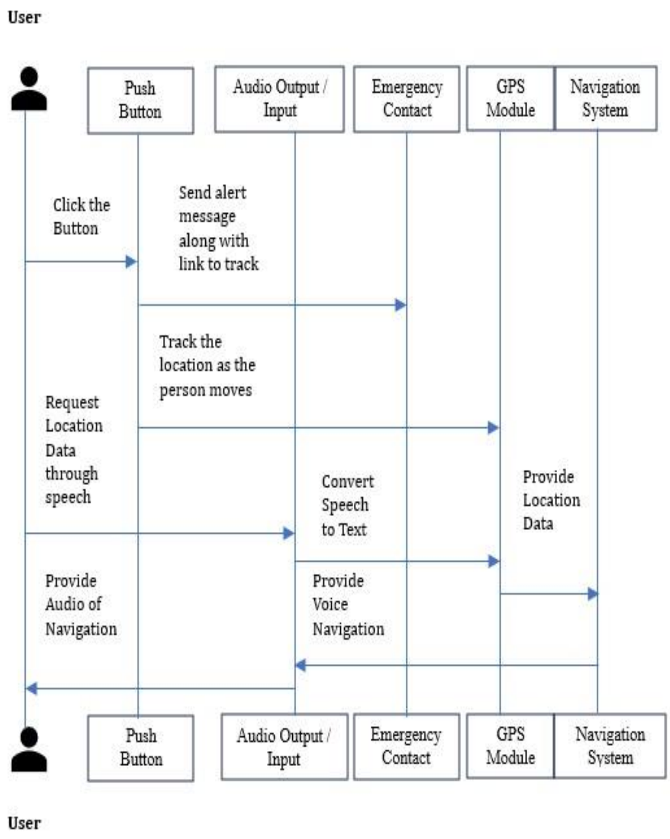

Fig -2: Sequence Diagram

3.4 Implemented Model

According to the project description, the physical prototype of the assistive technology intended for people with visual impairments is shown in the picture below in Fig. 3. The device is housed in a compact rectangular case with a yellow top and black bottom. Through the holes created, the Raspberry Pi is linked to the microphone. The GPS module is intended to fit inside the round hole, which gives it a straight line of view for precise real-time position monitoring. This prototype integrates several crucial components, including the GPS module for location tracking, speech-to-text technology for converting verbal destination inputs, and an audio output system for delivering navigational instructions and emergency alerts. The compact and thoughtful design of the case allows for seamless integration of these technologies, enhancing the mobility and safety of visually impaired users. Additionally, it has a push button that visually challenged people can use in an emergency.

Fig -3: Implemented Assistive Device

3.5 Advantages and Applications of the Model

Advantages:

- Comprehensive Navigation and Safety: The device combines navigation assistance and emergency support in a single, cohesive system, unlike many existing solutions that address these needs separately. This all-inclusive strategy guarantees that customers will always have assistance for both routine navigation and urgent situations.

- User-Friendly Interaction: By leveraging speech-to-text technology, gadget makes the system accessible and simple to use by enabling people to communicate with it using normal language. This will reduce the learning curve and makes the device more practical for daily use.

- Real-Time Updates and Guidance: The incorporation of GPS technology provides real-time updates and accurate guidance, ensuring users receive the most current and precise information for their navigation needs.

- Enhanced Safety: The "Help Me" feature provides an added layer of security, allows user to send emergency alerts with their GPS location to pre-configured contacts. This ensures rapid assistance in case of emergencies, enhancing the overall safety of visually challenged people.

Applications:

- Enables independent activities and everyday connects with exact location monitoring.

- Transforms spoken destination queries into text that may be interacted with intuitively.

- Increases safety by providing the location in an emergency to contacts.

• Provides Real time assistance to the visually impaired to the required destination through audio feedback.

4. RESULTS AND DISCUSSION

The proposed system introduces several advancements compared to previous works aimed at assisting visually impaired individuals. Unlike existing solutions, which typically focus on specific aspects of navigation or emergency support, the presented system integrates both functionalities into a single, cohesive device.

This assistive device offers a comprehensive GPS-based navigation feature combined with speech-to-text technology. This allowing people to interact with the system using natural language to set destinations and receive real-time, step-by-step audio guidance. In contrast, previous works such as Sanika Dosi Android app and Anish Aralikatti mobile application focus primarily on object recognition and situational awareness rather than full route navigation. While systems like those designed by S. Duman and Xinnan Leong use cameras and sensors for obstacle detection and distance estimation, they don't rely on user input to deliver comprehensive, spoken navigational directions.

The "Help Me" feature of the proposed system provides immediate emergency support by sending alerts with GPS location data to pre-configured contacts. This functionality addresses a critical need for quick assistance, which isn't a focus in many existing systems. For instance, while Devshree Bharatia e-stick integrates real-time audio feedback for navigation, it lacks an emergency alert system. Similarly, systems like those presented by Fayaz Shahdib and Shahira K C focus on obstacle detection but do not include dedicated emergency features.

The proposed system leverages a combination of GPS, speech-to-text, and audio output technologies integrated into a Raspberry Pi platform, offering a holistic approach to both navigation and emergency support. Previous works, such as Lourdes Santhosh S's wearable spectacles and Maisha Mashiata review of assistive devices, showcase various technological advancements but generally address either navigation. The incorporation of these features in the proposed system ensures that users benefit from both real-time navigation assistance and immediate emergency support within a single device.

The "Help Me" feature provides an essential safety mechanism for visually challenged users, allowing them to quickly seek assistance in emergencies. When the emergency button is clicked, the system captures the user's current GPS location and sends it to pre-configured contacts.

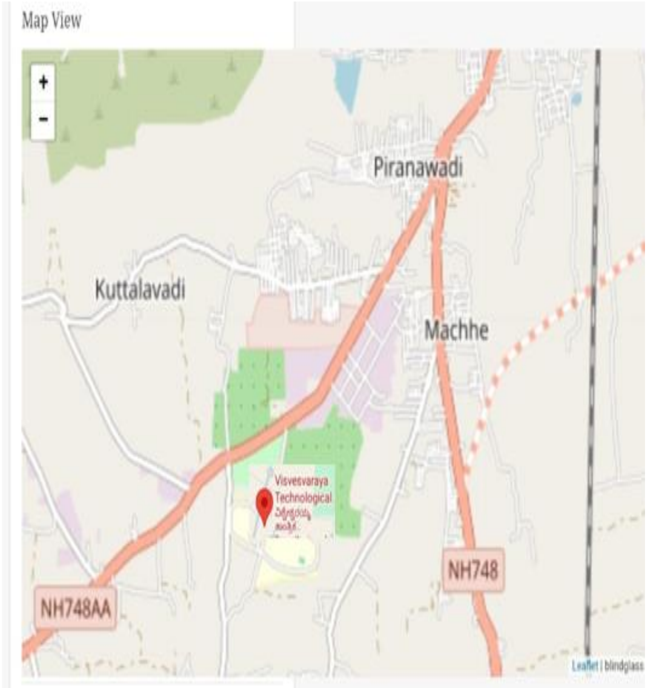

Fig -4: Result for Help Me feature GPS Location

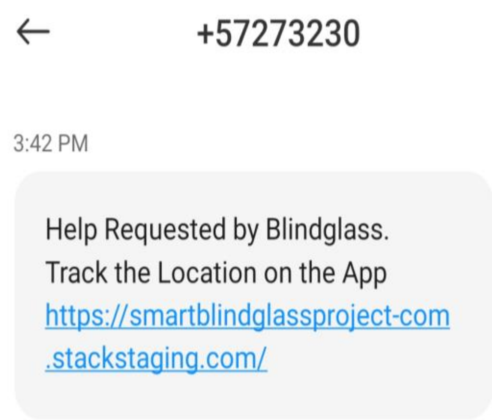

Fig -5: Alert Message to the Emergency contact

As shown in Fig.4, this feature enables the emergency contact person to track the exact location of the blind individual in actual time. Additionally, as illustrated in Fig.5, an alert message containing a link to the GPS location is delivered to the emergency contact, ensuring they have precise and immediate information to respond effectively. This integration of GPS tracking and instant alert messaging significantly enhances the user's safety by facilitating swift and accurate assistance from family members.

The table-1 The outcomes of many test scenarios intended to verify the assistive device's functionality for people with visual impairments are shown below. Every test case corresponds to a distinct system feature.

Table -1: Outcomes for the Test Cases

Test Case ID	Description of Test Case	Expected Outcome	Actual Outcome	Status
1	Convert speech to text	Convert speech to text	Pass	Pass
2	Get location data from the GPS module.	GPS module gives position information.	Pass	Pass
3	Provide location data to navigation system	Navigation system receives and processes location data	Pass	Pass
4	Deliver audio feedback to user	Audio output delivers feedback to user	Pass	Pass
5	Help Me Button pressed then alert message to be sent	Alert message is sent to Emergency contact	Pass	Pass

Test Case TC01 confirmed that the speech-to-text functionality is working correctly, as it successfully converted spoken words into text. Test Case TC02 verified that the GPS module correctly provided position information, which was crucial for location tracking. Following this, Test Case TC03 ensured that the navigation system accurately received and processed the location data from the GPS module. Lastly, Test Case TC04 tested the audio feedback mechanism, confirming that it delivered the intended audio output to the user effectively. All test cases passed successfully, indicating that the device's core features speech-to-text conversion, GPS data retrieval, navigation data processing, and audio feedback are functioning as designed. This outcome shows that the entire system is operating effectively and fulfilling its intended needs.

5. CONCLUSION AND FUTURE WORK

In this paper, introduced an advanced assistive device that enhances the mobility and safety of visually impaired individuals through integrated navigation and emergency support. The system combines GPS-based navigation with speech-to-text technology for real-time audio guidance, helping users reach their destinations independently. The "Help Me" feature adds additional safety by sending alerts with GPS location to pre-configured contacts during emergencies. Results confirm that the system meets its design goals, with successful validation of key functionalities like speech-to-text conversion, GPS data retrieval, navigation processing, and audio feedback. Unlike existing solutions that focus on individual aspects, this device provides a unified solution for navigation and emergency support.

This research advances assistive technology by offering a comprehensive, user-friendly solution that improves both autonomy and security. Future work can refine the system further and explore additional features based on user feedback and technological advancements.

Future enhancements could include integrating obstacle detection sensors and machine learning algorithms for improved accuracy. The device can also add text reading feature. These all features can be operated separately using different buttons as per the requirement. The incorporation of a GSM module could enable direct communication with emergency services. Additionally, developing a mobile application for remote device management and updates would enhance user convenience.

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