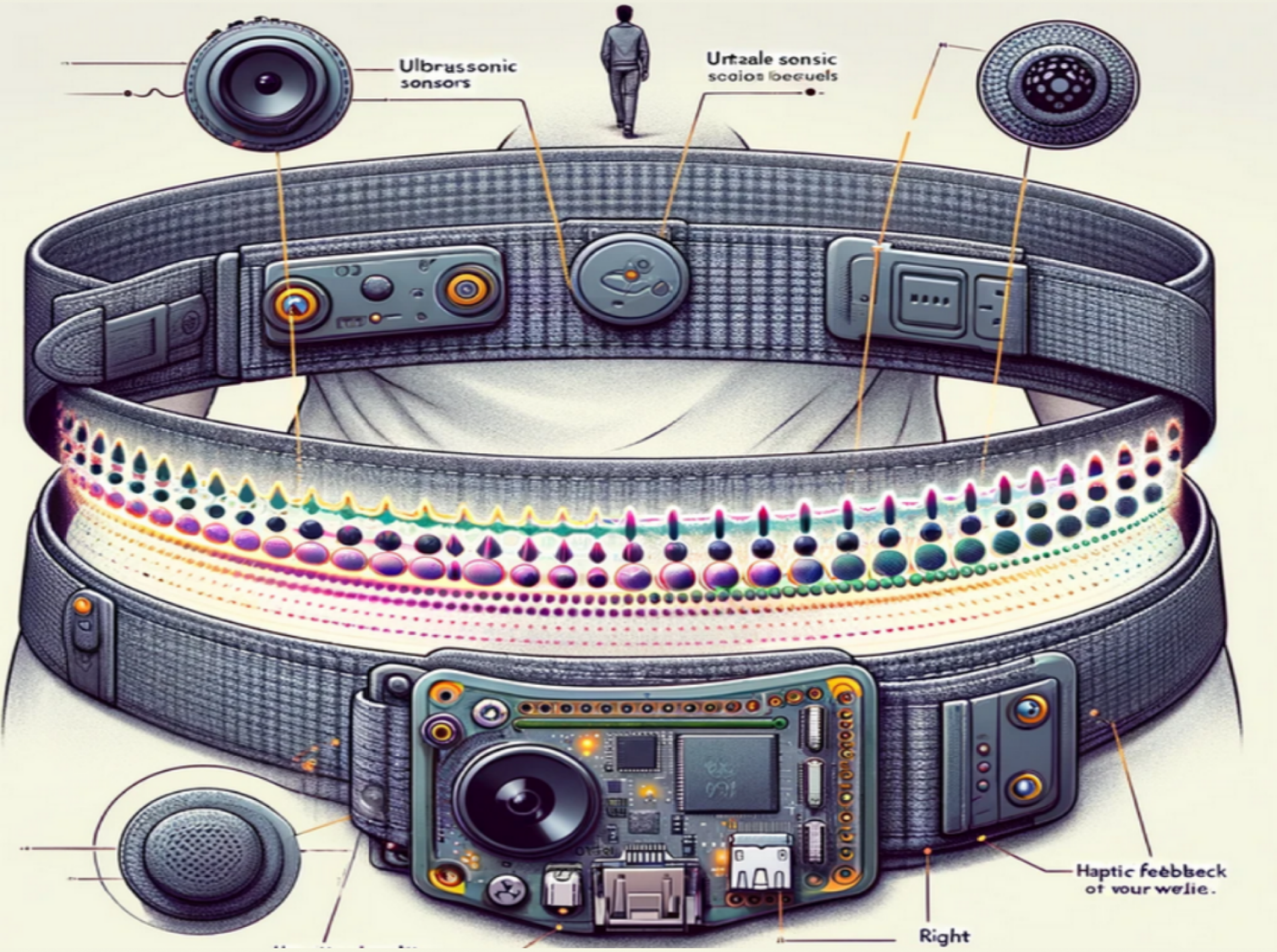
HapNav

Project Abstract

Stage 1 IEEE R10 Robotics Competition 2024

Robotics Club IIT Guwahati



Abstract

The solution presented is an innovative smart belt designed specifically for visually impaired individuals to enhance their ability to navigate various environments safely and independently. This wearable assistive technology integrates advanced components such as ultrasonic sensors, a high-resolution camera, haptic feedback modules, and a Raspberry Pi 4B, all orchestrated to provide real-time guidance and obstacle detection. By leveraging these technologies, the smart belt offers a comprehensive solution that addresses the critical need for enhanced spatial awareness and mobility among the visually impaired, empowering them to navigate both familiar and unfamiliar spaces with greater confidence and ease.

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Introduction

1.1. Background

Globally, around 2.2 billion people live with some form of vision impairment, according to the World Health Organization (WHO). Of these, 36 million are blind and 217 million have moderate or severe vision impairment. 217 million people experience moderate or severe vision impairment globally (WHO, 2020).

Current Statistics:

- Over 1 billion people experience near vision impairment, making it difficult to read or do close-up work (WHO, 2020).
- Only 25% of children with visual impairments globally have access to basic eye care services (WHO, 2020).
- A 2018 study found that 63% of blind adults reported difficulty using public transportation due to inaccessible infrastructure (APTA, 2018).
- Another study showed that visually impaired individuals take significantly longer to navigate unfamiliar environments compared to sighted individuals (Lo and Giudice, 2014).

1.2. Solution

The solution presented is an innovative smart belt designed specifically for visually impaired individuals to enhance their ability to navigate various environments safely and independently. This wearable assistive technology integrates advanced components such as ultrasonic sensors, a high-resolution camera, haptic feedback modules, and a Raspberry Pi 4B, all orchestrated to provide real-time guidance and obstacle detection. By leveraging these technologies, the smart belt offers a comprehensive solution that addresses the critical need for enhanced spatial awareness and mobility among the visually impaired, empowering them to navigate both familiar and unfamiliar spaces with greater confidence and ease.

1.3. Novelty

- **Multi-Functional Integration:** Unlike conventional aids that focus on singular functionality, this smart belt synergizes ultrasonic sensors, a high-resolution camera, haptic feedback, and a Raspberry Pi 4B. This fusion delivers a comprehensive navigation aid that enhances spatial awareness and obstacle detection in real-time.
- **Real-World Application:** Tailored for practical, everyday use, the belt is designed to support visually impaired individuals in navigating both familiar and unfamiliar environments with ease, promoting greater independence and confidence in daily activities.

- **Affordability and Accessibility:** By leveraging cost-effective and widely available components, the smart belt aims to democratize advanced assistive technology, making it accessible to a broader segment of the visually impaired community.
- **User-Centered Innovation:** Developed with a strong emphasis on user input, the belt's design prioritizes intuitiveness, comfort, and user-friendliness, ensuring that the technology not only meets but anticipates the nuanced needs of its users.

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Methodology

The Raspberry Pi 4B, at the heart of the system, functions as the central processing unit, coordinating between the input (sensors and camera) and output (haptic feedback) modules. It runs a custom-developed software stack that integrates the input data streams, processes them using the aforementioned algorithms, and manages the timely activation of haptic feedback modules based on the processed data. This orchestrated operation not only ensures real-time responsiveness but also maintains a low power footprint, essential for wearable technology. The system translates navigational instructions into intuitive haptic(vibratory) feedback, using the four haptic modules located in the front, back, left, and right positions on the belt. For example, if the user needs to turn right, the right-side haptic module vibrates. If there's an obstacle directly ahead, the front module vibrates. This method of feedback allows the user to understand and react to navigational commands and obstacle warnings without auditory or visual input, which is crucial for visually impaired users.

2.1. Object Avoidance

The obstacle avoidance module of the system leverages the quartet of ultrasonic sensors arrayed at cardinal directions—front, back, left, and right—ensuring a comprehensive 360-degree surveillance for impediments.

- These sensors emit ultrasonic waves, which upon encountering obstacles, reflect back and are captured by the sensors. The time lapse between emission and reception of these waves is meticulously calculated to ascertain the distance of the obstacles.
- Upon detection of an obstacle within a predefined proximity threshold, the system triggers the corresponding haptic feedback module oriented in the direction of the obstacle.
- This tactile feedback is imperative for the user, providing instantaneous and intuitive alerts regarding the presence and direction of potential impediments, thereby facilitating evasive maneuvers.

2.1.1. Working of Ultrasonic Sensors

Ultrasonic sensors operate on the principle of echolocation, similar to bats. Each sensor emits ultrasonic sound waves at frequencies beyond the audible range for humans. When these waves encounter an obstacle, they are reflected back and captured by the sensor's receiver. The sensor calculates the time interval between the emission and reception of these waves (Time of Flight - ToF) and, utilizing the speed of sound in air (343 meters per second at room temperature), computes the distance to the obstacle:

$$Distance = \frac{\text{Speed of Sound} \times \text{Time of Flight}}{2}$$

This distance measurement allows the system to determine if an obstacle is within a critical range, triggering the appropriate haptic feedback to alert the user.

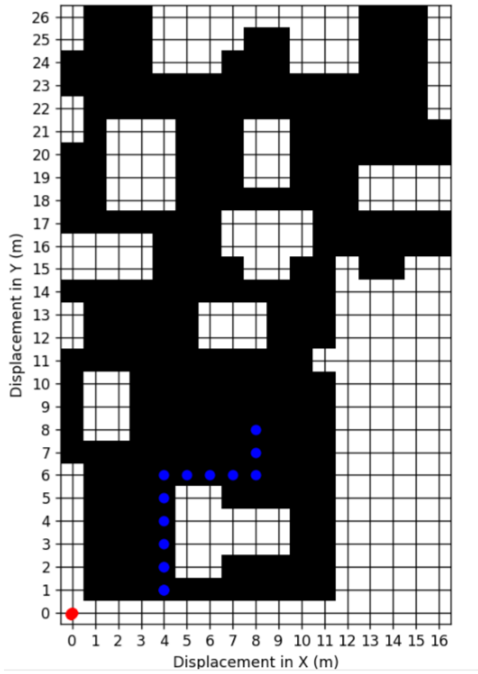

Figure 2.1: Deploying A* on Robotics Club Room Map

2.2. Path Planning

The path planning functionality is bifurcated into two distinct yet complementary segments - navigation within a known environment and dynamic object detection.

2.2.1. Navigation in Known Environments

For navigation within pre-mapped environs, the system employs the A* (A-Star) algorithm, renowned for its efficiency and accuracy in finding the shortest path between two points. The algorithm initializes at the user's current location, designated as point A, and dynamically updates the user's position through the integration of a GY-521 sensor. This sensor meticulously tracks the user's motion, providing real-time updates to the system. The environment is pre-loaded with a set of designated destinations, and upon selection by the user, the A* algorithm delineates an optimal route, marked by sequential checkpoints. As the user progresses, the system conveys directional instructions through selective activation of the haptic feedback modules, corresponding to the intended direction of movement, thereby guiding the user along the computed path.

2.2.2. GY-521 Motion Sensor

The GY-521 module features an MPU-6050 sensor, which is a combination of a 3-axis gyroscope and a 3-axis accelerometer. The accelerometer measures linear acceleration, while the gyroscope measures angular velocity. By integrating these measurements over time, the system can track changes in the user's orientation and movement. This data is crucial for updating the user's current position in the A* algorithm's path planning and for ensuring accurate navigation guidance.

2.2.3. A* Algorithm

The A* algorithm (2.1) is a heuristic-based pathfinding algorithm renowned for its efficiency and accuracy in finding the shortest path between two points. It combines features of Dijkstra's algorithm and the Greedy Best-First-Search, considering both the distance already traveled (the "g" cost) and an estimated distance to the goal (the "h" cost, heuristic). The algorithm maintains a priority queue of paths based on their "f" cost (f = g + h), where paths with lower f values are given higher priority. By exploring paths in this manner, A* efficiently finds the optimal route to the destination.

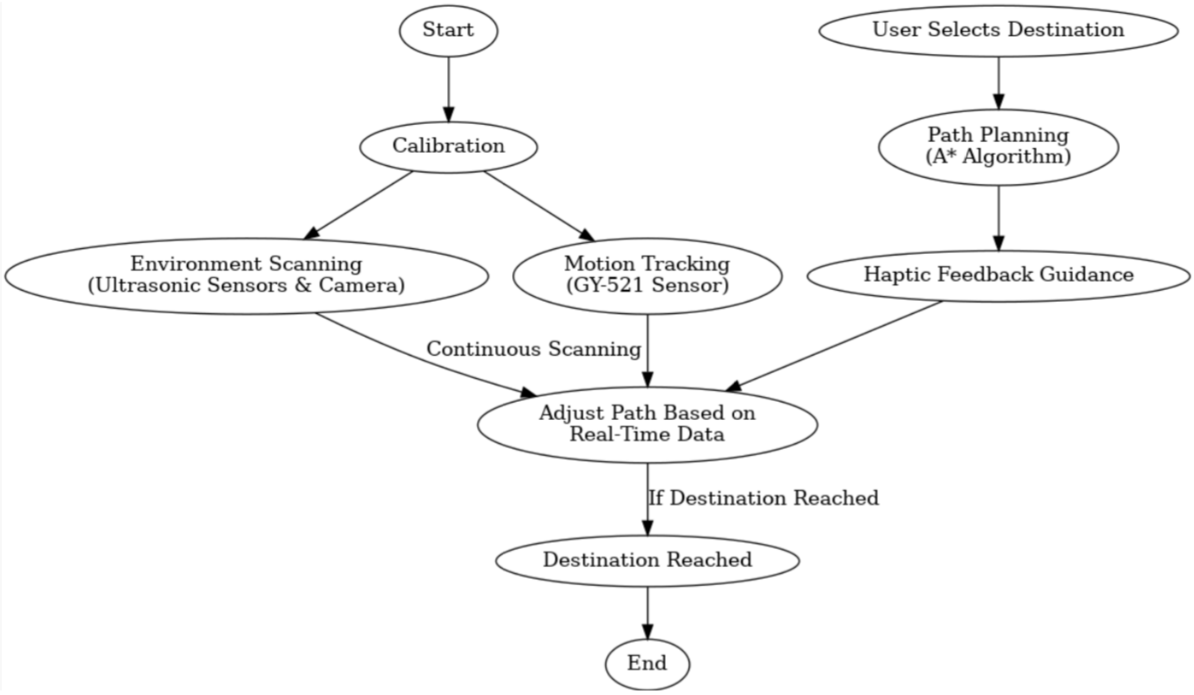

Figure 2.2: System Architecture

2.2.4. Dynamic Object Detection

To address the challenges posed by unforeseen obstacles within known environments, the system incorporates an object detection module powered by the YOLOv4-tiny algorithm. This convolutional neural network is adept at recognizing and classifying a variety of objects such as humans, furniture, and even currency. The integration of a high-resolution camera facilitates the real-time capture and analysis of the surrounding environment, enabling the detection of dynamic obstacles. Upon identification, the system processes the spatial orientation of these objects and activates the appropriate haptic feedback module to alert the user, thereby enhancing situational awareness and ensuring seamless navigation through complex environments.

2.2.5. YOLOv4-tiny for Object Detection

YOLO (You Only Look Once) v4-tiny is a scaled-down version of the YOLOv4 algorithm, designed for real-time object detection with reduced computational requirements. It employs a single convolutional neural network (CNN) that divides the input image into a grid and predicts bounding boxes and class probabilities for each grid cell simultaneously. This approach enables the detection of multiple objects in real time, including static and dynamic obstacles, as well as specific items like currency, enhancing the situational awareness of the user.

The smart belt is designed with modularity and scalability in mind, allowing for the integration of additional sensors or improved algorithms in the future. For instance, future iterations could incorporate machine learning models to predict and adapt to the user's behavior and preferences, enhancing the personalization of navigation assistance.

The system's software architecture is designed for low latency and high reliability, with real-time operating system (RTOS) characteristics to ensure that sensor data is processed and acted upon promptly.This is crucial for the safety and effectiveness of the assistive device in various environments.

3

Impact and Application

3.1. Community Use

3.1.1. Day to Day Working

- **Safety and Confidence:** The project provides blind individuals with a reliable tool for navigating their surroundings safely and confidently 3.1. By alerting them to obstacles and hazards in real-time, it helps prevent accidents and instills a sense of security as they move through different environments.
- **Greater Independence:** The electronic belt enhances the independence of blind individuals by reducing their reliance on assistance from others. With the ability to navigate more effectively and make informed decisions about their movements, they can engage in daily activities such as shopping, commuting, and socializing with greater freedom and autonomy.
- **Improved Quality of Life:** By facilitating easier navigation and reducing the stress and anxiety associated with mobility challenges, This project contributes to an improved quality of life for blind individuals. It enables them to focus on their goals, interests, and relationships without the limitations imposed by their visual impairment.
- **Increased Inclusivity:** By providing blind individuals with a tool that enhances their mobility and independence, the project contributes to a more inclusive society. It promotes equal access to public spaces, transportation, and various amenities, thereby reducing barriers and fostering a more inclusive environment for individuals with visual impairments.

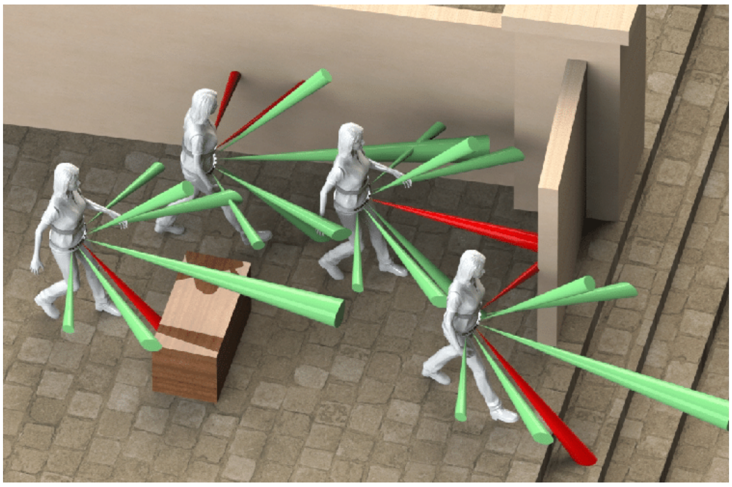

Figure 3.1: Navigation in Outside World

3.1.2. Outside World

- **Navigation Assistance:** The electronic belt can assist blind individuals in navigating various environments in their daily lives, such as streets, sidewalks, public transportation, and indoor spaces like malls or office buildings. It provides real-time feedback about obstacles and hazards, enabling them to move safely and independently.
- **Outdoor Activities:** Blind individuals can use the electronic belt during outdoor activities such as walking, jogging, or hiking to navigate trails, parks, or other recreational areas with confidence. The belt helps them detect obstacles and terrain changes, allowing for a more enjoyable and accessible outdoor experience.
- **Shopping and Errands:** When running errands or shopping, blind individuals can rely on the electronic belt to navigate through stores, locate items on shelves, and maneuver around crowded aisles. It facilitates independent shopping experiences and reduces reliance on assistance from store personnel or companions.
- **Public Transportation:** The belt can assist blind individuals in using public transportation systems, including buses, trains, and subway stations. It helps them navigate transit hubs, find boarding platforms or stops, and avoid obstacles while moving through crowded stations or terminals.

3.2. Commercial Use

3.2.1. Application in Hospital

- **Patient Navigation:** In hospital settings, the electronic belt can serve as a navigation aid for blind patients, helping them move safely and independently within the facility. It assists them in finding their way to various departments, clinics, or hospital rooms without relying on hospital staff or volunteers for guidance.
- **Medical Appointments:** Blind patients can use the electronic belt to navigate to and from medical appointments within the hospital or clinic, ensuring they arrive on time and without difficulty. It helps reduce stress and anxiety associated with navigating unfamiliar healthcare environments.
- **Emergency Situations:** During emergencies or evacuations, the electronic belt can provide vital assistance to blind patients by guiding them to emergency exits, evacuation routes, or designated safe areas within the hospital. It enhances their ability to respond effectively to emergency situations and evacuate the premises safely.
- **Rehabilitation Support:** For blind individuals undergoing rehabilitation or therapy in hospital settings, the electronic belt can be incorporated into mobility training programs to improve orientation and mobility skills. It provides real-time feedback and reinforcement during therapy sessions, helping patients build confidence and independence in navigating their surroundings.

3.3. Market analysis

The visually impaired assistive technologies market is projected to grow at a CAGR of 9.5% despite a slight setback from the COVID-19 pandemic. Lockdowns initially disrupted access to essential services for visually impaired individuals, but teleconsultations and virtual education helped mitigate the impact. As restrictions ease and institutions reopen, the market is expected to stabilize. The market's growth is further fueled by the high global prevalence of visual impairment, particularly among the aging population. Innovative solutions like OrCam's latest software aim to enhance accessibility, though high product costs remain a challenge to market expansion.

Table 3.1: Market Competitors

Company	Product	Problems
Wayband	wrist-wearable navigation device	no obstacle detection
WeWalk	Cane Attachment	expensive and complicated

3.4. Conclusion

In summary, the smart belt for visually impaired individuals stands as a testament to the innovative application of advanced algorithms and sensor technologies, offering a comprehensive solution that not only mitigates the challenges posed by navigation but also empowers users with greater autonomy and confidence in their daily lives.