AI Smart Belt to Guide the Visually Impaired:
Real-Time Indoor Guided-Tour Navigation for the Visually Impaired

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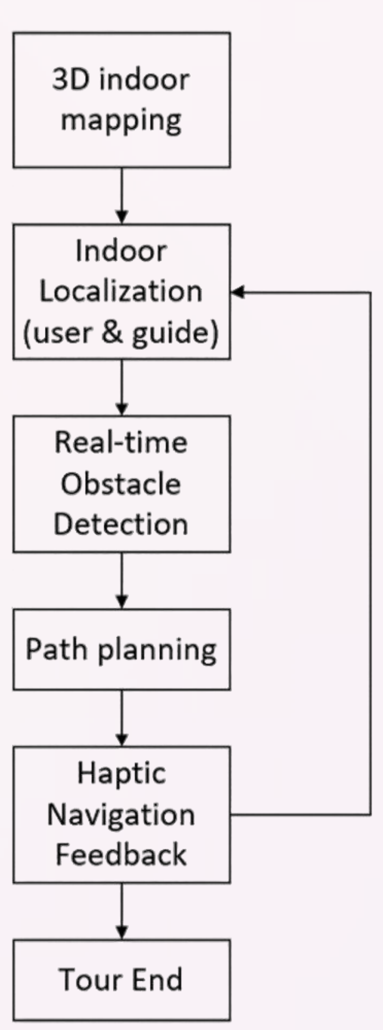
Introduction

Indoor navigation poses a significant challenge for visually impaired individuals, especially in public spaces like museums where GPS signals are unavailable and trained sighted guides remain costly and scarce. With over 2.2 billion people worldwide living with visual impairment, many avoid unfamiliar venues such as galleries simply because navigating these spaces independently feels overwhelming.

This project addresses this gap by developing a wearable smart belt that empowers visually impaired users to follow guided tours independently while safely avoiding obstacles. The system combines LiDAR mapping, RGBD-based obstacle detection, Ultra-Wideband indoor positioning, and real-time path planning to deliver intuitive haptic guidance—all running efficiently on portable, low-power embedded hardware.

Design Overview



Objectives

1. Locating the user's indoor position accurately

2. Managing both static and dynamic obstacles

3. Integration with tour guides

4. Accomplishing all these tasks with limited hardware and computational resources.

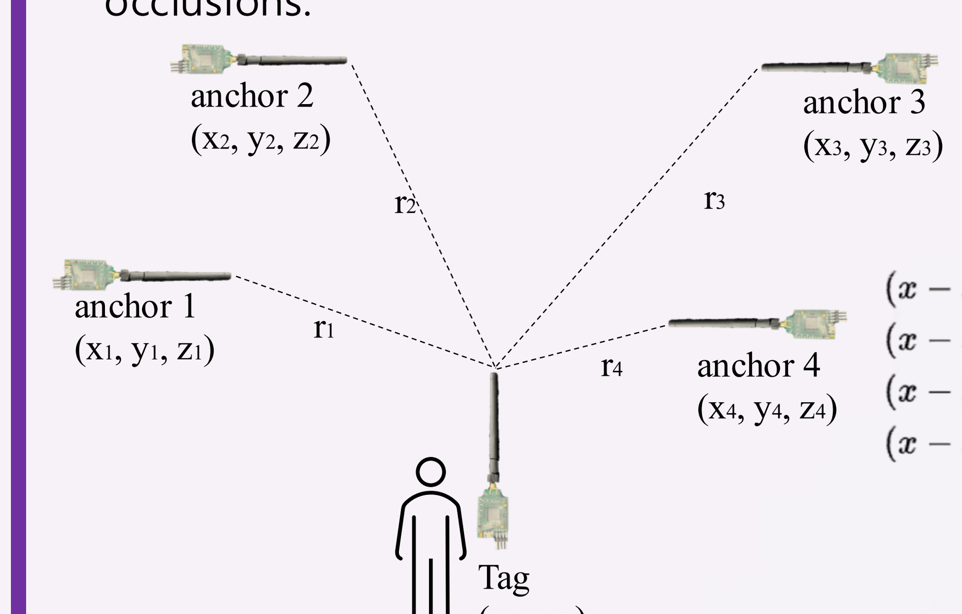
Implementation

3D Indoor Map Scanning

LiDAR scanning on an iPad Pro captures high-resolution point clouds of the indoor environment, which are then converted into 2D occupancy grid maps. This approach achieves accuracy map and reduces processing time from hours (photogrammetry) to under 30 minutes, providing a reliable static map for navigation.

Indoor localization

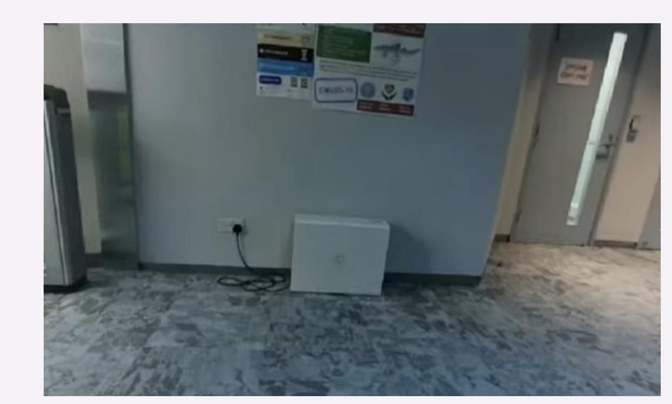
UWB Multilateration combined with IMU sensor fusion achieves sub-meter positioning accuracy. A particle filter integrates UWB distance measurements, accelerometer data, and map constraints to provide stable real-time pose estimates robust to signal noise and temporary occlusions.



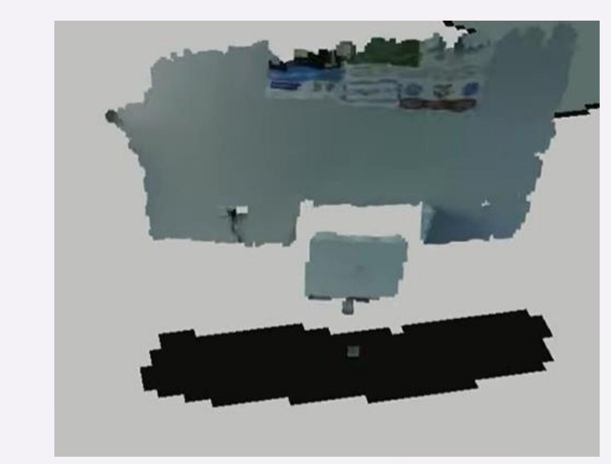
$$(x-x_1)^2+(y-y_1)^2+(z-z_1)^2=r_1^2$$
$$(x-x_2)^2+(y-y_2)^2+(z-z_2)^2=r_2^2$$
$$(x-x_3)^2+(y-y_3)^2+(z-z_3)^2=r_3^2$$
$$(x-x_4)^2+(y-y_4)^2+(z-z_4)^2=r_4^2$$

Real time Obstacle avoidance

An RGBD camera generates aligned depth maps and pseudo point clouds at over 5 fps, detecting both static obstacles and dynamic pedestrians. Distance estimation remains within 3cm accuracy at ranges up to 2 meters, with end-to-end latency below 150ms—sufficient for walking-speed navigation.



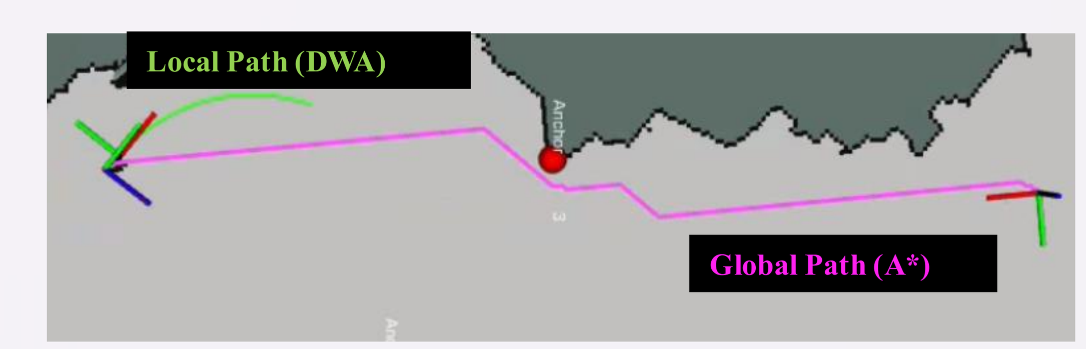
Colour Image



Point Cloud

Path Planning

The A* algorithm computes optimal global paths on the occupancy grid, while the Dynamic Window Approach handles local obstacle avoidance in real-time. The system dynamically fuses static map data with detected obstacles, enabling collision-free navigation around both fixed exhibits and moving pedestrians.



Conclusion

This system integrates LiDAR mapping, RGBD obstacle detection, UWB localization, and dynamic path planning for reliable indoor navigation for visually impaired users. Testing demonstrates sufficient real-world accuracy and responsiveness. Future improvements include upgrading to the RGK X5 board for enhanced processing, adding vibrational motors for intuitive haptic feedback, and expanded testing across varied environments