Habib University
Mobile Robotics - EE/CE 468

Project Proposal

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1 Introduction - Proposal and Viability

1.1 Idea and Motivation

The idea behind our project is to harness the power of autonomous wheeled mobile robots to revolutionize indoor navigation for the visually impaired. Navigating unfamiliar indoor spaces can be an incredibly challenging task for individuals with visual impairments, as they often rely on canes, guide dogs, or verbal directions from others.

Our motivation for this project is to provide a more independent and efficient solution, leveraging advanced robotics to assist visually impaired individuals in finding the shortest and safest path to their destination while avoiding obstacles along the way. In this project, the user will hold the robot, which will not only act as a guide but also serve as a walking cane, ensuring a smooth and reliable journey.

By integrating this user-friendly approach, we aim to enhance their autonomy, improve their quality of life, and offer a newfound sense of freedom in navigating indoor environments. In this project, we will feed the robot with a pre-defined map that includes waypoints, allowing it to navigate and guide visually impaired users efficiently. This approach will ensure accurate and safe guidance, enabling users to explore indoor spaces with increased independence and confidence.

2 Project Description

2.1 Environment and Constraints

In our designed indoor environment for visually impaired navigation, we ensure a structured and uncluttered setting. This environment comprises a single-story layout, completely devoid of stairs or multi-level elements, eliminating potential obstacles for visually impaired individuals. While maintaining a straightforward layout, it is important to note that the environment will be inhabited, with people moving within it. Distinctive landmarks, such as office doors within office spaces, serve as key reference points for users. We'll assume that the robot possesses prior knowledge of these landmarks' locations and coordinates. To aid the robot in identifying and utilizing these landmarks, our system will be equipped with a combination of cameras and infrared sensors. These sensors play a crucial role in distinguishing between people and landmarks, ensuring that the robot accurately identifies and navigates towards the designated points. However, it's essential to note that in real-world environments, the robot's ability to sense and recognize landmarks relies heavily on computer vision technology, enabling it to interpret the surroundings, detect landmarks, and guide users with optimal precision.

2.2 Motion Constraints

- **Wheel Slippage:** Wheel slippage can limit a robot's accuracy, especially on uneven or slippery surfaces, leading to constraints on its motion.
- **Control System Delays:** The responsiveness of a robot's control system can constrain its ability to perform rapid and precise movements.
- **Battery Life:** For battery-powered robots, limited energy storage can impact the duration and range of operation.
- **Wheel Wear and Maintenance:** Over time, wear and tear on the wheels can affect the robot's performance and may require maintenance.
- **Localization and Mapping Accuracy:** The accuracy of the robot's localization and mapping systems can constrain its ability to navigate and make informed decisions.
- **Communication Range:** For remote-controlled or autonomous robots, communication constraints can limit their operational range.
- **Regulatory Constraints:** Legal and safety regulations may impose constraints on the speed and operation of mobile robots, particularly in public spaces.

2.3 Functionality of the Robot

The robot will have the map of the desired location it will be used in. The user will be able to input their desired destination either using voice command or any other means, and the robot will autonomously navigate the shortest path to the destination.

The robot will be equipped with a camera and a LiDAR sensor to detect obstacles in its path as well as recognize the landmarks to estimate its position in the location. The robot will be able to detect static obstacles such as walls, furniture, and other objects, as well as moving obstacles such as people. In the case of moving objects, it will come to a temporary halt until the object/person has passed, and in the case of static obstacles, it will change its direction to find an unobstructed path. The robot will start moving slowly on its planned path. It will have a suitable velocity according to the walking speed of the person. Since it will be held by a visually impaired person, the chances of error being introduced in its position and heading are increased. Hence Kalman filters and relevant error reduction approaches will be used to keep the error in robot minimal and prevent it from completely diverting from its original path.

2.4 Frameworks and Algorithms

In the development of our maze-solving robot designed to assist visually impaired individuals with indoor navigation, we have chosen a robust combination of frameworks and algorithms to ensure its efficiency and reliability. Our primary frameworks are ROS (Robot Operating System) and Gazebo. ROS serves as the core infrastructure for sensor integration, communication, and control, while Gazebo provides a sophisticated simulation environment for testing and fine-tuning our robot's performance. In addition, MATLAB/Simulink will be instrumental in modeling and optimizing our control algorithms.

The algorithms we are employing are diverse and tailored to address different aspects of the robot's functionality. We will utilize control algorithms such as Proportional-Derivative (PD) controllers for precise maneuvering and orientation. For path planning and exploration, we will implement well-established algorithms like Dijkstra's and Breadth-First Search (BFS) to find the optimal routes, and the Pure Pursuit algorithm to guide the robot along these paths. This comprehensive approach ensures that our robot can efficiently explore, navigate, and assist visually impaired individuals, contributing to a safe and effective indoor navigation experience.

3 Hardware

Hardware is tentative and subject to time and budget constraints.

4 Tentative Project Timeline

#	Milestone Description	Tentative Deadline
1	Define the Blocks within a Simulink Model	Week 11
2	Linear Motion	Week 12
3	Shortest Path	Week 13
4	Obstacle Avoiding	Week 14
5	Leading the Person	Week 15

Table 1: Tentative Project Timeline

5 Limitations and Constraints

Robotic systems designed for indoor navigation to assist the visually impaired come with various limitations and constraints, many of which need to be considered during their development and deployment. Here are some of the key limitations and constraints:

1. **Complex Indoor Environments:** Indoor environments can be highly complex and dynamic, with changing layouts, obstacles, and lighting conditions. Robots may struggle to adapt to every possible scenario, making them unreliable in certain situations.

2. **Limited Battery Life:** Most indoor navigation robots are battery-powered. Limited battery life can constrain the robot's operational duration, potentially leading to navigation interruptions.

3. **Cost:** Building and maintaining navigation robots can be expensive, limiting their accessibility to a broader user base.

4. **Maintenance and Repairs:** Robots require regular maintenance and repairs, which can be costly and time-consuming.

5. **Sensory Limitations:** The accuracy and range of sensors can be limited. For example, LiDAR may not detect low obstacles, and ultrasonic sensors may have a limited range.

6. **Safety Concerns:** Safety is a critical concern, especially in crowded indoor environments. Robots must navigate safely, avoiding collisions with people, objects, or other obstacles.

7. **Accessibility:** Ensuring that the robot's user interface and feedback mechanisms are accessible to all visually impaired individuals can be challenging.