Smart wheelchair technical report

Abstract

This report presents the development of a smart wheelchair system with autonomous indoor navigation and user-following capabilities. By integrating LiDAR-based mapping and camera-based object detection, the wheelchair can move independently and follow a user with minimal input. The project addresses key challenges such as detecting transparent obstacles, handling dynamic environments, and resolving hardware–software mismatches. A CAD model and simulation have been completed, with basic autonomous functions implemented using ROS2, Rviz, and the A* algorithm. Future work will focus on sensor fusion, improved simulation, and real-world testing using tools like Blender and Intel RealSense.

1. Introduction

1.1 Background

For elderly individuals or those with physical disabilities, independent mobility in daily life can be challenging or even impossible without external assistance. These individuals often struggle to move freely or reach desired destinations without relying on caregivers.

Smart wheelchairs offer a promising solution to this problem by enhancing personal freedom and autonomy. These intelligent systems allow users to navigate their environments safely and comfortably, enabling them to perform daily tasks such as moving around the house, visiting nearby locations, or participating in social events with minimal assistance.

1.2 Motivation

While traditional powered wheelchairs reduce physical effort, they still require manual control and do not provide intelligent functions like autonomous navigation or human-following. This limitation significantly affects users with severe motor impairments.

Introducing smart wheelchairs with built-in autonomy and user-following capabilities can greatly reduce the need for caregiver support and empower users to live more independently. In Singapore, although assistive mobility devices are commonly available, truly autonomous smart wheelchairs are still uncommon and largely confined to research or prototype development stages.

2.Problem Statement

Most existing powered wheelchairs lack autonomous navigation and human-following features. As a result, users who are unable to manually operate a wheelchair remain dependent on others for mobility, restricting their independence and quality of life.

2.1 Project Objectives and Goals

This project aims to design and develop a smart wheelchair equipped with autonomous indoor navigation and human-following functionality. The system will utilize LiDAR for real-time mapping and obstacle detection, alongside a camera system powered by object detection algorithms (such as YOLO) to track and follow the user effectively.

The overarching goal is to reduce reliance on manual input or caregiver intervention, thereby improving mobility, safety, and the overall quality of life for individuals with mobility impairments.

2.2 technical gaps and challenges

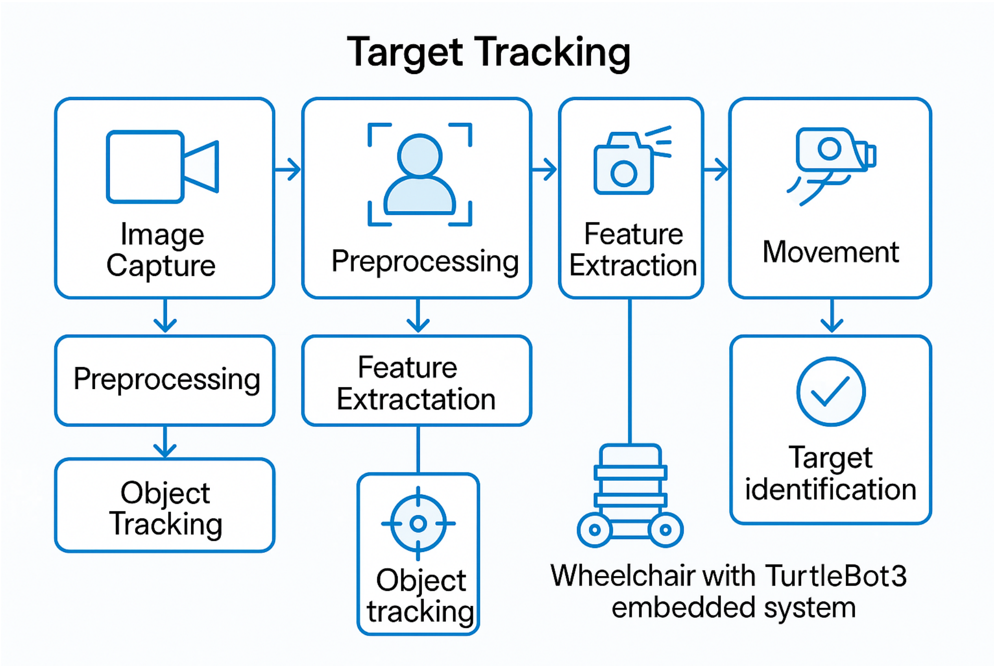
1. One key challenge lies in the **mapping** process. When using LiDAR to detect the environment, certain obstacles—such as transparent glass doors—are difficult to recognize. Additionally, real-time mapping often leaves blind spots, complicating the autonomous navigation process.
2. Another challenge involves the **navigation** logic. In systems like RViz2, real-time navigation often struggles with dynamic environments where obstacles may move or appear unexpectedly. Continuously updating the map while safely rerouting the wheelchair in such scenarios is a complex task.
3. Another major challenge is that we don't quite understand how to set up robots. Since the TurtleBot we used did not match the code loaded on the laptop, we spent a lot of time resetting these.

2.3 Works that already have been done.

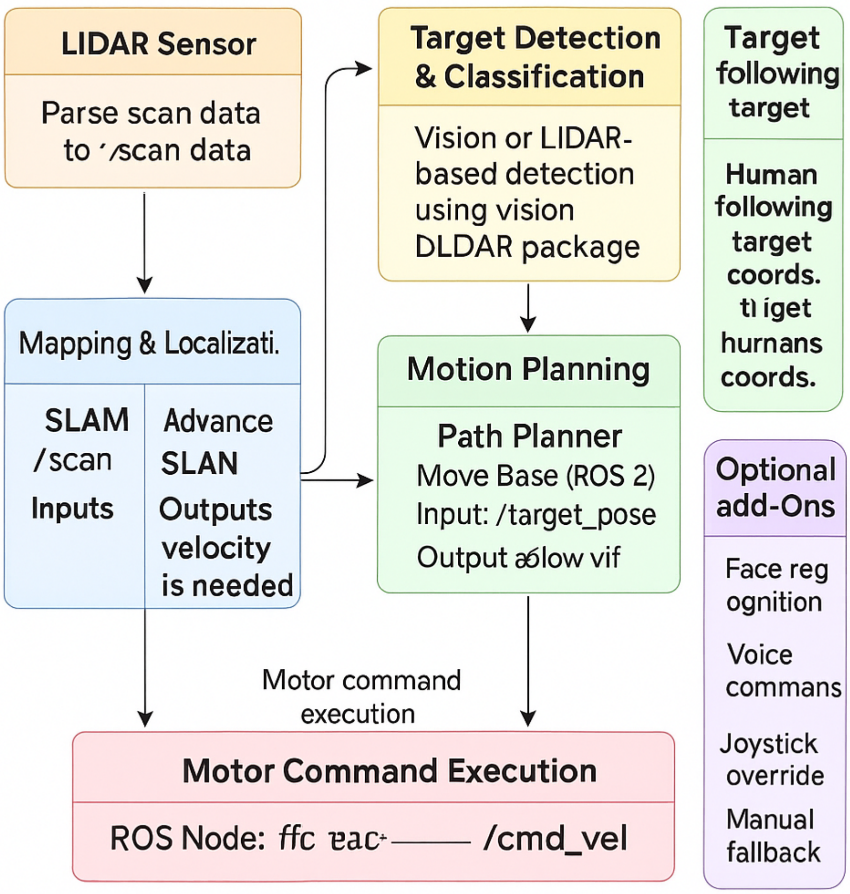
1. A complete CAD model of the smart wheelchair has been developed, along with a simulation of its automatic navigation and obstacle avoidance behaviour.
2. Code for autonomous mapping in a closed indoor space has been implemented and tested. This code has been successfully run on the simulation.

2.4 System Design

1.Block diagram for Target Tracking



2.Block diagram for Robot Interface



3. Proposed Approach

To further enhance the smart wheelchair system, the following steps are proposed:

1. **Improve Simulation Accuracy—**Enhance the simulation environment to more closely replicate real-world conditions and eliminate unrealistic behaviours like object penetration.
2. **Sensor Fusion for Navigation and Tracking—**Integrate camera data with LiDAR to improve obstacle detection accuracy and enable robust people-following functionality.
3. **Algorithm Visualization with Blender—**Use Blender to visually simulate the wheelchair's navigation path using the A* search algorithm, aiding in debugging and demonstrating the system's capabilities. On top of this, we also plan to use the Intel RealSense depth camera for more efficient Rviz visualizations.
4. **Demonstration using Dyson Lab Modelling—**We also plan to model the Dyson Lab and improve the robot animation using Blender as well.

4.References

1. Thale, S. P., Prabhu, M. M., Thakur, P. V., & Kadam, P. (2019). ROS based SLAM implementation for Autonomous navigation using TurtleBot. In International Conference on Advances in Computing, Communications and Informatics (ICACCI). This paper describes using TurtleBot in Gazebo, using Gmapping for SLAM and visualizing map and navigation states in Rviz people.eecs.berkeley.edu+15researchgate.net+15docs.m2stud.io+15.
2. Rajesh K. M., Manoharan, S. K., & Anilkumar, A. V. (2024). Autonomous Navigation Through GMapping-Based SLAM: A Comprehensive Evaluation. Humanitarian Technology (HuT) Labs, Amrita Vishwa Vidyapeetham. Provides an in-depth performance analysis of GMapping-based SLAM including mapping visualization likely in Rviz researchgate.net.
3. Nguyen, T. Q., & Vela, P. A. (2024). A concurrent learning approach to monocular vision range regulation of leader/follower systems. Autonomous Robots.
4. Mathis, A., et al. (2021). Image-Based Trajectory Tracking through Unknown Environments without Absolute Positioning. arXiv preprint arXiv:2103.00055.
5. Mansur, I. B. (2025, January 30). SLAM and Nav2 for Custom Robots in ROS2. Medium.