Autonomous Mobile Robot with LiDAR Mapping

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Abstract

Autonomous mobile robots are increasingly used in indoor environments such as research laboratories, service robotics, and logistics systems. A key challenge for such robots is the ability to perceive unknown environments, detect obstacles, and navigate safely without human intervention.

This paper presents the design and implementation of an autonomous mobile robot based on classical robotics approaches using LiDAR-based perception and the Robot Operating System (ROS). The system is built on a UGV02 tracked mobile platform and uses an RPLidar A1 sensor for real-time environment scanning and mapping. Simultaneous Localization and Mapping (SLAM) is employed to construct an occupancy grid map of an unknown indoor environment while estimating the robot's position.

The proposed system demonstrates reliable obstacle detection, real-time map generation, and autonomous navigation. Experimental results show that the robot is able to distinguish free space, obstacles, and unknown areas with sufficient accuracy for indoor navigation tasks. The project emphasizes system integration, modular software design, and robustness rather than machine learning-based approaches.

Keywords

Autonomous Mobile Robot, LiDAR, ROS, SLAM, Obstacle Avoidance, Indoor Mapping

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1 Introduction

Autonomous mobile robots play an increasingly important role in modern applications such as indoor logistics, service robotics, and research environments. A key requirement for such systems is the ability to perceive the environment, detect obstacles, and navigate safely without human intervention.

The goal of this project was to design and implement an autonomous mobile robot capable of building a map of an unknown indoor environment using LiDAR-based perception and ROS. Instead of focusing on machine learning approaches, the project emphasizes classical robotics methods, system integration, and reliable real-time operation.

The robot is based on the UGV02 tracked mobile platform and uses a Jetson Xavier Nano Developer Kit as its onboard computer. Environment perception is achieved using an RPLidar A1 sensor, enabling real-time mapping and obstacle detection.

2 Background and Theory

2.1 Robot Operating System (ROS)

The Robot Operating System (ROS) is a widely used framework in robotics that provides tools and libraries for building complex robot software systems. It is based on a modular architecture where individual components, called nodes, communicate with each other using a publish–subscribe mechanism.

This communication model allows sensor processing, mapping, and control logic to be developed independently while still working together as a single system.

2.2 LiDAR-Based Perception

LiDAR (Light Detection and Ranging) sensors measure distances by emitting laser beams and calculating the time it takes for the reflected light to return. A 2D LiDAR sensor provides a planar scan of the environment, which is especially suitable for indoor navigation.

Compared to camera-based perception, LiDAR is independent of lighting conditions and provides accurate distance measurements, making it reliable for obstacle detection and mapping tasks.

2.3 SLAM and Occupancy Grid Mapping

Simultaneous Localization and Mapping (SLAM) refers to the problem of building a map of an unknown environment while simultaneously estimating the robot's position within that map.

In this project, an occupancy grid representation is used, where the environment is divided into discrete cells representing free space, obstacles, or unknown areas. As the robot moves and collects LiDAR data, the map is continuously updated in real time.

3 System Architecture

3.1 Hardware Architecture

The hardware setup of the robot consists of the following main components:

- UGV02 tracked robot platform providing stable indoor movement
- Jetson Xavier Nano Developer Kit serving as the onboard computer
- RPLidar A1 for distance measurement and environment scanning
- Motor controller and motors responsible for robot movement
- Onboard battery system supplying power to all components

All components are mounted on the robot platform and connected via wired and wireless interfaces.

3.2 Software Architecture

The software architecture is built entirely on ROS and follows a modular design. The main components include a LiDAR node publishing laser scan data, a mapping node generating an occupancy grid map, a control and navigation node performing obstacle detection and decision-making, and visualization tools using RViz.

This architecture allows a clear separation of sensing, mapping, and control, which simplifies debugging and future system extensions.

4 Implementation

4.1 Sensor Data Flow

The LiDAR sensor continuously publishes laser scan data to the ROS topic `/scan`. This data stream is consumed by both the mapping component and the obstacle detection logic.

4.2 Mapping Process

A SLAM-based approach is used to build the environment map while the robot moves. As new LiDAR scans arrive, they are integrated into the map, gradually forming a consistent representation of the indoor environment.

4.3 Obstacle Detection and Control Logic

Obstacle detection is performed directly using LiDAR scan data. Based on predefined safety thresholds, the robot decides whether to move forward, turn to avoid an obstacle, or stop in emergency situations.

4.4 Operating Modes

The robot supports three operating modes: STOP, MAP, and AUTO. This separation proved useful during development and testing.

5 Results

The implemented system demonstrates stable LiDAR data acquisition, real-time SLAM-based map generation, reliable obstacle detection, and autonomous navigation in indoor environments.

6 Challenges and Limitations

Several challenges were encountered during the project, including limited battery life, a constrained indoor test environment, and the complexity of ROS configuration and hardware integration.

7 Conclusion and Future Work

This project demonstrates that a reliable autonomous mobile robot can be built using classical robotics techniques and careful system integration. Future work includes improved power management, additional sensors, and more advanced navigation strategies.

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