Autonomous Systems Project
Project: Autonomous Small Car using Raspberry Pi
Team Number: 20

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Milestone Completion Summary

Milestone 1: Initialization and Basic Setup

This milestone involved setting up the foundational environment for the project. We installed Ubuntu 20.04 and ROS Noetic, configured as a dual boot on our laptops, and installed ROS on Raspberry Pi. We configured ROS workspaces to enable package management and node execution. We selected the Ackermann-like car model for the Gazebo simulation due to its compatibility with ROS Noetic and realistic car dynamics. During the setup, we faced issues with ROS dependencies, which we resolved by using 'rosdep' to install missing packages. We also created a basic ROS package for testing node communication, implementing a simple publisher-subscriber model to verify data transmission.

Milestone 2: Teleoperation and Open Loop Control

In this milestone, we focused on manual control through teleoperation using ROS nodes. We developed a Teleoperation ROS node that mapped keyboard inputs to car movements, using 'geometry_msgs/Twist' messages to control speed and steering. The node subscribed to keyboard events and published velocity commands to the car model. We also created an Open Loop Response (OLR) node for basic motion testing, which published fixed PWM signals to the motor. One major challenge was maintaining real-time control via the Raspberry Pi, which we addressed by optimizing the data transmission rate. We tested the teleoperation node in both simulation and hardware, validating the car's response to directional commands.

Milestone 3: Closed-Loop Control (Speed and Steering)

This milestone marked the transition to autonomous control. We implemented a PID controller for longitudinal speed regulation and a Stanley controller for lateral path tracking. The PID controller continuously adjusted the motor PWM to maintain the target speed, while the Stanley controller calculated the steering angle to minimize cross-track error (CTE). We tuned the PID gains using the Ziegler-Nichols method, balancing stability and responsiveness. Initially, oscillations occurred at high speeds, but fine-tuning reduced them. Data from wheel encoders and the IMU were filtered using a Kalman Filter to reduce sensor noise, significantly enhancing accuracy. Testing on a straight track and curves confirmed improved stability and precision in speed control.

Milestone 4: Planning and Simulation on Racing Track

The objective was to implement path planning and obstacle avoidance. We utilized the A* algorithm for global path planning and a Dynamic Window Approach (DWA) for local obstacle avoidance. The A* algorithm calculated the optimal path based on track waypoints, while the DWA adjusted the speed and steering in real-time to avoid collisions. To enhance obstacle detection, we fused data from LiDAR and ultrasonic sensors, feeding the fused data to the DWA node. Initial tests revealed false positives in obstacle detection, which were minimized by calibrating the sensor thresholds. The planning node also integrated a cost map for terrain evaluation, allowing smooth navigation on uneven track surfaces.

Milestone 5: System Integration and Testing

This milestone focused on integrating all individual components into a unified system. We created a master launch file to execute the localization, control, and planning nodes simultaneously. One of the critical technical challenges was synchronizing real-time data from different sensors. To manage this, we implemented a ROS topic synchronization mechanism to ensure that data from the IMU, encoders, and LiDAR were processed in the correct order. Additionally, we created an error monitoring node that logged deviations from the desired path and speed. Final tests on the racing track demonstrated that the car could autonomously navigate complex paths while maintaining stability, even in the presence of moving obstacles.

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