Automated Driving Using External Perception

Individual Lab Report - ILR10
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Team E - Outersense

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1 Individual Progress

1.1 Planning subsystem

Over the past week, my focus has been on augmenting the planning subsystem of our self-driving car. This involved implementing a hierarchical multi-layered architecture to enable high-level mission planning integrated with low-level trajectory generation.

The rationale behind this layered approach is to combine the benefits of both deliberative goal-driven planning and reactive local motion planning. The higher layers provide overall route guidance while the lower layers handle real-time safe trajectory generation based on sensor inputs.

Specifically, I worked on the following planning components:

1.1.1 Obstacle and goal publisher

A key component I developed was an obstacle and goal pose publisher module within the planning subsystem. This node listens to the output of the perception system to obtain the latest positions of static obstacles and barriers on the track.

The obstacle positions detected by perception are transformed from the perception coordinate frame to the planning frame and published as PointCloud messages. These static obstacle messages are consumed by the local trajectory planner to avoid collisions during high-speed driving.

Similarly, the current vehicle state from the localization module is transformed to extract the start position for planning. The goal extracted from the mission plan is also converted to the planning frame and published.

The planner subscribes to the obstacle pointcloud and start/goal poses published by this node to have up-to-date information about the track environment for safe trajectory generation.

The node was designed to be modular and flexible, easily allowing alternative perception sources. The output adheres to standard message types for interoperability with different planning algorithms.

Publishing planning-centric data on static obstacles, start and goal enables the planner to generate optimal trajectories that avoid track barriers and complete the loop efficiently.

1.1.2 Testing and Implementation

Extensive real-world testing was undertaken to validate the performance of the hybrid A* planner in actual driving scenarios. The planner was evaluated in closed-loop with lagging pose estimates to mimic real sensor latency. Numerous test runs were conducted under various conditions to verify robustness.

The planner exhibited satisfactory performance in computing safe, optimal trajectories in real-time even with noisy sensor inputs. Additional testing focused on failure modes and error handling. The results provide confidence for deployment under the full range of conditions expected during autonomous driving.

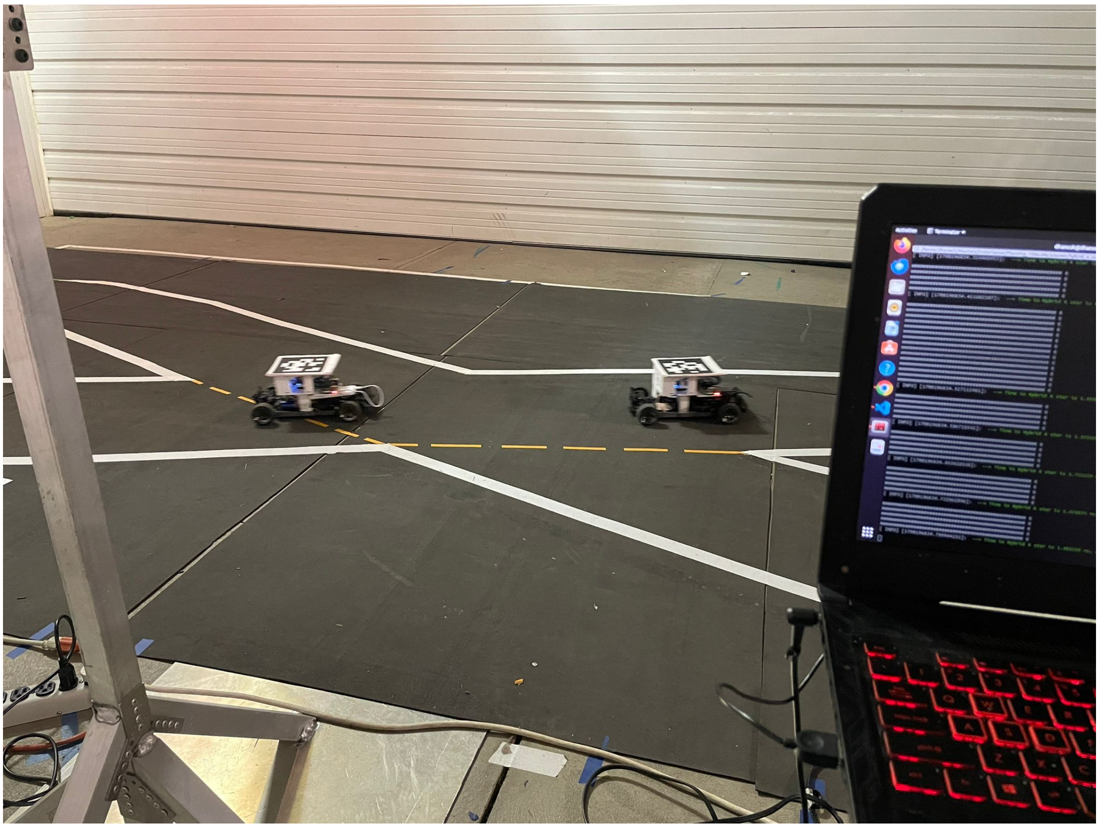

Figure 1: Planning diagram

1.2 Hardware Build

1.2.1 RC Car Build

As a risk mitigation measure prior to the final demonstration, an additional RC car was built from spare components to serve as a backup vehicle. This required 3D printing several custom mounts and parts. The car was then assembled and electronics like the onboard computer and motor controller were installed and configured.

Test runs verified that the control software and algorithms execute properly on the new car. This provides a readily available contingency solution in case of any issues with the main vehicles.

1.2.2 Obstacle Build

Physical obstacles were constructed to specification for deployment on the track during testing and demonstrations. The obstacles provide a means to evaluate the planner's ability to generate trajectories that steer clear of blocking objects.

The obstacles were designed to be highly visible and padded for safety. Their placements on track can be adjusted to vary difficulty and test different maneuvering scenarios. Construction of these obstacles concludes another facets of preparations leading up to the final system showcase.

2 Challenges

2.1 Planning Subsystem

A persistent issue was the occasional flickering of obstacles when perception failed temporarily. This caused erratic re-planning behavior. To mitigate this, I implemented a module to latch onto last known obstacle poses during perception losses. By retaining obstacles for a defined duration, flickering and unnecessary re-planning is avoided, enabling smooth trajectories. This was a difficult node to write because there were many edge cases that had to be resolved.

2.2 Hardware Challenges

On the hardware front, part procurement delays posed challenges in completing the RC car build. With only one 3D printer available and high demand from other teams, getting print jobs completed was time-consuming. The limited stock of certain components also led to waits. Overcoming these hurdles required adjustments to the build schedule and careful coordination among team members.

3 Teamwork

Our team's collaborative effort was pivotal in advancing our project. Each team member brought unique skills and insights, contributing significantly to our collective success.

Ronit: Ronit's primary focus was on enhancing the perception subsystem. His efforts in evolving beyond ArUco markers for detection significantly bolstered the system's robustness. His role was also crucial in the integration and testing phases, ensuring seamless system functionality.

Dhanesh: Dhanesh, with his expertise in planning, was instrumental in developing the custom vehicle model and map representation essential for the hybrid A* planner. Our collaboration was key in refining and optimizing the planner's performance.

Shreyas: Shreyas dedicated his efforts to perfecting the state estimation module. His work in fine-tuning the VESC IMU parameters resulted in highly accurate odometry. His contributions were also vital in vehicle integration and extensive field testing.

Atharv: Atharv's role involved enhancing the longitudinal control system. He adapted the PID cruise controller to ensure safe vehicle distancing, providing a critical control perspective during the planner integration.

Our effective teamwork allowed us to integrate our diverse skills, addressing the multifaceted challenges of this complex project efficiently.

4 Future Work

4.1 Personal

My upcoming focus areas include:

1. Addressing the planner's speed issue to achieve the necessary planning rate.

2. Advancing the planner to effectively handle static obstacles and navigate around them.
3. Conducting extensive tests on the planner and fine-tuning its parameters for enhanced performance.
4. Ensuring smoother integration of the planner with other subsystems, including perception and control.

4.2 Team

Our team's future objectives encompass:

1. Achieving a seamless integration of all subsystems, including perception, planning, and control, for a closed-loop operation.
2. Fine-tuning the state estimation module to deliver more accurate and reliable odometry data.
3. Refining the VESC parameters and its control mechanisms on the actual vehicle.
4. Conducting comprehensive tests on the integrated system to identify and resolve any emerging issues.
5. Continuously improving each subsystem to enhance the overall performance of the project.

Through our concerted efforts and systematic approach, we aim to synergistically combine our individual strengths, propelling our integrated autonomous car platform to new heights of innovation and efficiency.