# Automated Driving Using External Perception

Individual Lab Report - ILR08
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Team E - Outersense

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# 1 Individual Progress

## 1.1 Gazebo Simulation

The Gazebo simulation platform has been an essential tool in the project's development and testing phases. Gazebo, renowned for its realism and versatility, provides an accurate environment for simulating robotic applications, making it a prime choice for our endeavors.

- **Environment Setup**: The simulation environment was carefully crafted to reflect real-world driving conditions. This involved designing a track layout, incorporating relevant landmarks, and ensuring that lighting and surface conditions matched real-world scenarios. Such precision ensures that the simulation's outcomes closely mirror real-world results.
- **Vehicle Integration and Ackermann Constraints**: A pivotal accomplishment was the integration of a car model into the Gazebo environment. Beyond just a visual representation, the car was replaicated with dimensions and Ackermann constraints replicating the capabilities of an actual vehicle. We paid special attention to the Ackermann steering constraints, adjusting the vehicle's dimensions and other parameters to ensure accurate representation and behavior. The car was also designed to interpret and execute custom commands, bridging the gap between the planning subsystem and the simulation.
- **Testing and Validation**: With the car model in place, Gazebo became the primary platform for testing. Outputs from the planning subsystem were introduced into the simulation, enabling observation of the vehicle's behavior in a controlled setting. This iterative process was vital for pinpointing potential issues and addressing them preemptively.
- **Realism and Challenges**: Gazebo's strength lies in its ability to emulate real-world physics. While this realism is advantageous, it also presents challenges. Fine-tuning various parameters, from tire friction to sensor noise, was essential to ensure the simulated vehicle's behavior matched its real-world counterpart.

In summary, the Gazebo simulation platform has proven indispensable. It offers a risk-free environment for rigorous testing, and the insights derived from numerous simulation runs have been crucial in refining both the planning and simulation subsystems.

## 1.2 Planning subsystem

Building on insights from previous reports, the planning subsystem underwent significant enhancements. A comprehensive literature review was initiated, focusing on a spectrum of planning algorithms. Central to this exploration was the MotionPlanner repository by Engin Bozkurt.

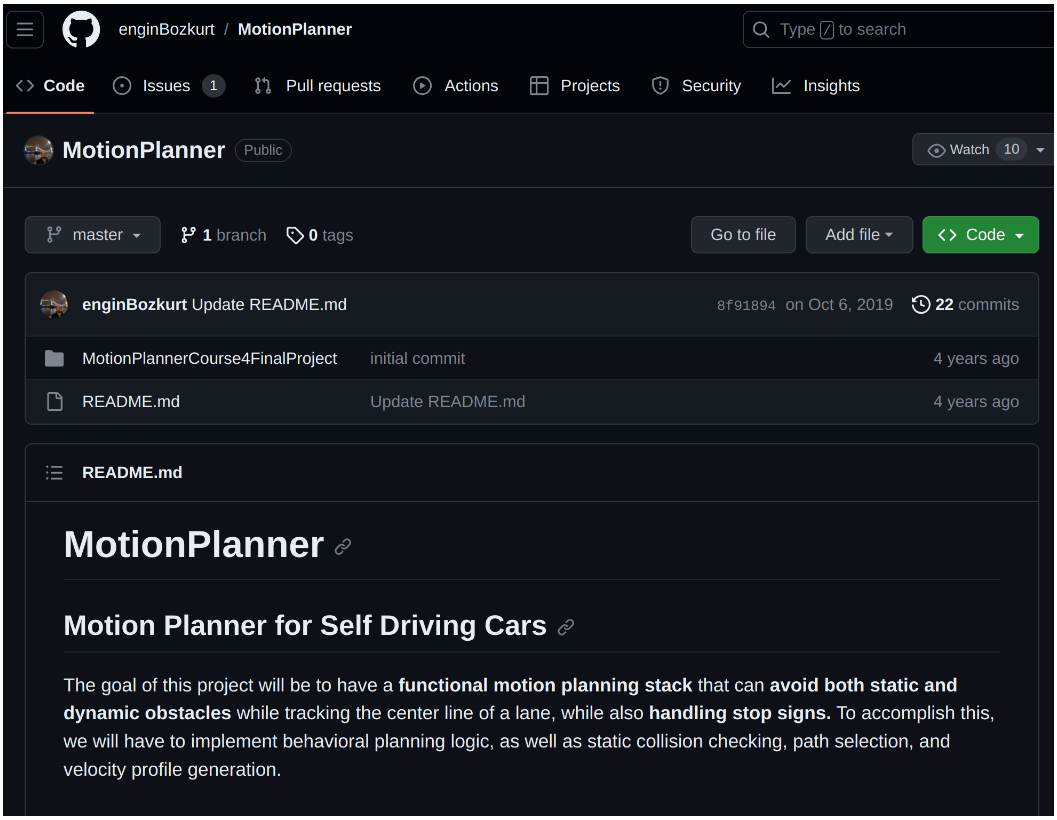


**Figure 1: Planning repo**

### 1.2.1 MotionPlanner Repository

The MotionPlanner repository, curated by Engin Bozkurt, is a standout resource in the domain of motion planning for several reasons:

- **Diverse Algorithms**: The repository is a comprehensive collection of motion planning algorithms. It starts with foundational grid-based methods, which are essential for understanding basic pathfinding. As one delves deeper, the repository introduces more advanced sampling-based techniques like Rapidly-exploring Random Trees (RRT) and optimization-based strategies. This diverse range ensures that users get a panoramic view of the various planning strategies available in the field.
- **Practical Implementations**: Beyond theoretical explanations, what makes this repository a goldmine is the practical code implementations that accompany each algorithm. These implementations are not just functional but are also optimized for performance, ensuring that users can integrate them into their projects with minimal modifications.
- **Clear Explanations**: Each algorithm is accompanied by a clear and concise explanation. This documentation elucidates the underlying logic, the scenarios where the algorithm is most effective, and potential pitfalls or challenges one might encounter. For newcomers and experts alike, this clarity is invaluable.
- **Visual Demonstrations**: To aid understanding, the repository goes a step further by providing visual demonstrations. These visuals, often in the form of graphs or animations, help in grasping the nuances of each algorithm, making the learning process more intuitive.

Given the comprehensive nature of the MotionPlanner repository, a detailed analysis was essential. After reviewing multiple algorithms and weighing their pros and cons in the context of the project's requirements, a decision was made to implement a straightforward planner. This planner's primary function is to follow the center lane, ensuring that the vehicle remains on course and avoids obstacles.

The MotionPlanner repository's insights proved to be a cornerstone for the planning subsystem. It not only provided the necessary algorithms but also shaped the thought process, guiding the design, selection, and implementation phases.

## 1.3 Challenges Faced

Both simulation and planning tasks, while crucial to the project, come with their own set of potential challenges. Understanding these challenges can aid in preemptive problem-solving and smoother project progression.

**Simulation Challenges:**

- **Hardware-Software Mismatch**: Simulations often run on idealized assumptions. Translating these results to real-world hardware can sometimes lead to discrepancies due to hardware limitations or unforeseen real-world conditions.
- **Realism**: Ensuring the simulation environment accurately represents real-world conditions, from road friction to other lighting challenges are important to model. Any oversight can lead to skewed results.
- **Computational Overhead**: High-fidelity simulations, while accurate, can be computationally intensive. This can lead to longer simulation times and may require powerful hardware.

**Planning Challenges:**

- **Dynamic Environments**: Planning in dynamic environments, where obstacles move unpredictably, can be challenging. The planner needs to be robust enough to handle sudden changes in the environment.
- **Optimality vs. Real-time Constraints**: Striking a balance between finding the optimal path and ensuring real-time performance can be a challenge. Highly optimal paths might take longer to compute, which may not be feasible in real-time scenarios.
- **Integration with Other Systems**: Ensuring the planner's outputs are compatible with other systems, like control and perception, is crucial. Any misalignment can lead to undesired behaviors.
- **Safety Considerations**: The planner must prioritize safety, ensuring that the vehicle doesn't undertake risky maneuvers, even if they appear optimal.

Recognizing these challenges early on can lead to better strategies and solutions, ensuring the project's success in both simulation and planning tasks.

## 2 Teamwork

In terms of teamwork, we are flexible and collaborate seamlessly to swiftly address high-priority tasks.

The success of this project is attributed to the collective efforts of the team. Each member brought their expertise to the table, ensuring a holistic approach to problem-solving.

**Ronit:** Ronit primarily focused on the perception subsystem. His contributions include the implementation of multi-object tracking using Aruco markers. He ensured that the perception system was scalable, accommodating more than two infrared sensors. Together, we engaged in discussions and brainstorming sessions regarding the planning subsystem, ensuring that the perception and planning subsystems were well-integrated.

**Dhanesh:** Dhanesh's expertise lies in the mechanical domain. He was instrumental in designing and setting up the track, ensuring it met the project's requirements. In addition to his mechanical contributions, Dhanesh also delved into planning research. Our collaboration was pivotal in identifying the appropriate repositories and resources for the planning subsystem.

**Shreyas:** Shreyas made significant strides in improving the vehicle's localization. He worked on implementing an IMU and odometry-based Unscented Kalman Filter (UKF), which resulted in enhanced pose estimates. Notably, he addressed and resolved the heading problem, ensuring accurate orientation data. Our collaborative efforts extended to planning research, where we jointly explored various algorithms and strategies.

**Atharv:** Atharv's contributions were multifaceted. He worked on scaling the system to accommodate multiple cars, ensuring seamless interactions between them. Additionally, he focused on adaptive cruise control, implementing a PID controller to maintain safe distances between vehicles. Our collaboration centered around the planning subsystem, specifically discussing the necessary inputs the control system would require from the planner.

# 3 Future work

## 3.1 Personal

In the upcoming phases of the project, my primary focus will be on the following areas:

1. **Gazebo Environment Improvement**: I aim to enhance the current Gazebo environment by introducing modular functionality. This will involve adding a ground plane that replicates our track and incorporating obstacles to simulate real-world driving challenges.

2. **Planning Subsystem Enhancement**: My efforts will also be directed towards developing a robust framework for the planning subsystem. The primary objective will be to design algorithms that enable the car to consistently follow a center lane.

3. **Comprehensive Planning**: Delving deeper into planning, I intend to work on both the behavioral and mission planner aspects. The goal is to ensure a holistic approach to vehicle navigation, considering both immediate and long-term objectives.

4. **Real-world Testing**: Ensuring that the planning algorithms work seamlessly on the actual vehicle will be a priority. This involves rigorous testing and fine-tuning to guarantee safe and efficient navigation in real-world scenarios.

## 3.2 Team

For the team's future endeavors, we have set the following milestones:

1. **Multi-Vehicle Navigation**: Our objective is to autonomously navigate two vehicles on a track overseen by three infrastructure sensors.

2. **Prototype Global Planner**: We aim to implement a prototype global planner that consistently steers the vehicle to the center of the lane.

3. **Data Association Approaches**: Instead of solely relying on unique fiducial markers, we plan to experiment with two distinct approaches for data association.

4. **Safe Distance Maintenance**: Ensuring that controlled vehicles maintain a safe distance from each other will be a priority, preventing any potential collisions.

5. **Collision Avoidance with Static Obstacles**: The vehicles will be equipped with algorithms that allow them to halt or maneuver to avoid collisions with static obstacles, ensuring they remain within their designated lanes.