Racing Line Optimization with Adaptive Grip Estimation

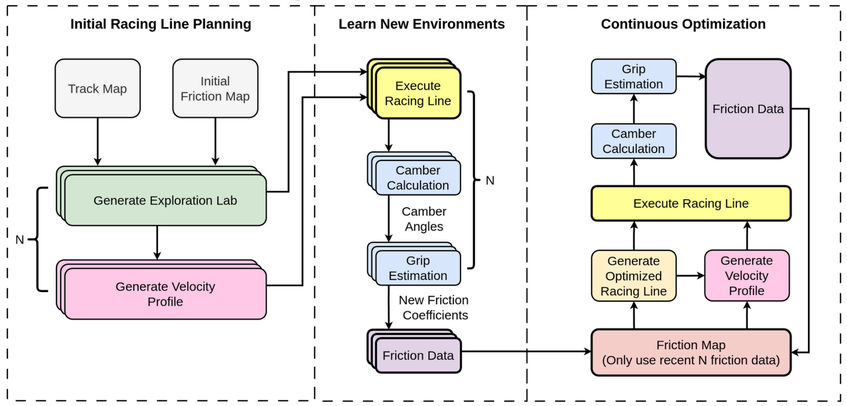
Problem:

Motor racing is a sport highly sensitive to conditions. The limit of the vehicle can vary depending on the weather, track temperature, tire pressure and so on. In order to get to optimal speed, adapting to changing environment is necessary.

Goal:

- Design Racing Line Planning (motion planning) Algorithms for Indy Autonomous Challenge.
- Algorithm should be able to adapt to changing conditions and track.

Algorithm Explanation



Grip estimation / Friction Map Generation

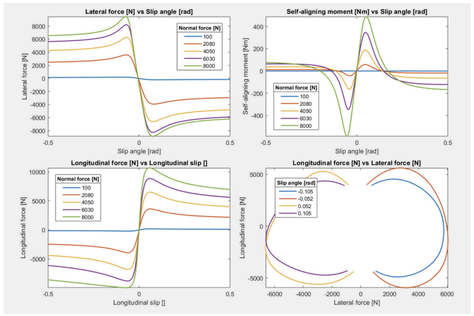
What is Magic formula?

The Magic Formula is a mathematical model used to describe the complex relationship between tire forces (like lateral, longitudinal, or aligning torque) and slip (slip angle or slip ratio) in vehicle dynamics.

Our Methods:

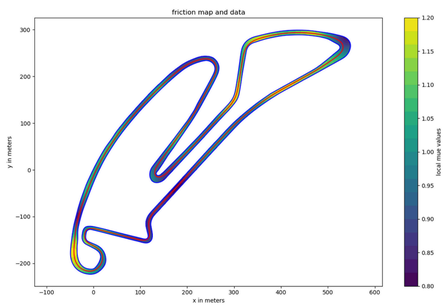
General tire parameters were given by Firestone. We created our tire model based on these parameters.
Tire modeling and grip estimation will be our methods to learn about environments and track conditions.

Grip estimation / Tire modeling



- Based on tire parameters, we were able to create our own tire model with Magic Formula.
- With suspension analysis data, we can calculate camber and slip angle from suspension movement.

Friction Map Generation

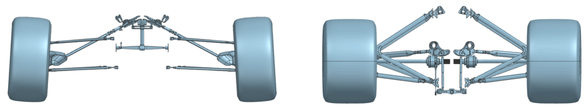


- Using current data to compute friction coefficient.
- Update friction map coefficient to form a complete friction map

Suspension Analysis/ Camber Estimation

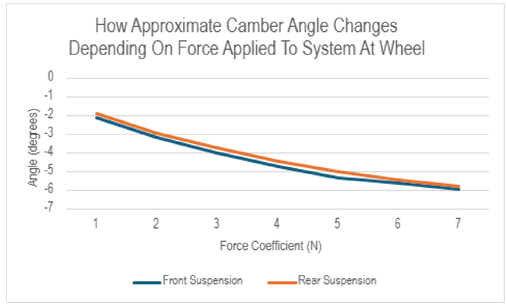
Why is it important to understand camber?

Camber is important to understand because it plays a large role in how much grip our tires will get depending on the circumstances. It helps us know what strategies to use depending on the situation by giving us an idea of how much grip we are going to have.



Camber, as seen from the front of the car

Results:



Our Methods:

-We used NX to create assemblies of the front and rear suspensions
-For reference, an old IAC AV-21 model was used to do the assemblies
-We used those to do simulations to determine how the camber angle will change depending on the force applied

Conclusion:

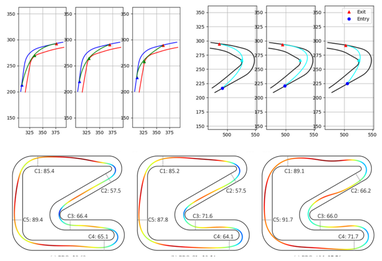
As the chart shows, the camber angle of the front and rear suspension systems increase logarithmically, with the front suspension system always being slightly higher in magnitude than the rear suspension system. The angle values range from about -2 degrees to -6 degrees, which is typical for most motor vehicles. These angles get a good grip on corners and are ideal for drifts but are slightly less efficient on straightaways.

Racing Line Generation

Our Methods:

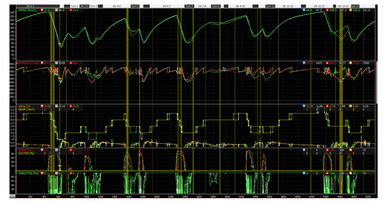
We are planning on using a sampling-based racing line optimization algorithm where we use previous laps' grip estimation to determine the best racing line. This method will lead to robust racing line optimization for changing environments.

Exploration Racing Line Planning



- **Goal:** Generate many different racing lines to provide data to friction map.
- **Key:** Find out which area is important to explore.
- **Algorithm:** First generate possible racing line of each corner by varying corner entry, apex, exit positions. Connect different corners to form full racing line.

Optimization Racing Line Planning (In Progress)



- **Goal:** Find optimal racing line using friction map data. We can estimate maximum speed of the vehicle and optimize from there.
- **Key:** Predicting suspension movement is important as it will change how much grip the car can have.
- **Algorithm:** After each optimized lab, we are updating friction map to adapt changing environments.

Future plans

- Further simulations on suspension to estimate camber on given speed and curvature.
- Finish racing line optimization algorithm and run test on previous data.
- Lastly, test algorithm on simulation.