Multiple Autonomous Vehicles in Complex Scenarios

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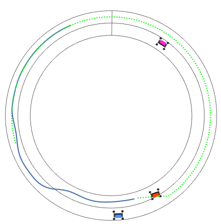
Project Objectives

The goal of this project was to implement an autonomous system, capable of managing complex scenarios involving multiple vehicles. By combining physical cars and simulated cars, a real world scenario could be achieved without the risk of crashes in the process. The physical car managed to drive in the middle of the assigned lane and perform overtakes of slower cars when deemed feasible without a crash. The system could be tested in simulation to facilitate testing. Four modules in particular were implemented: Perception, Planning, Control, and Visualisation. The physical cars can be seen in the left picture. Simulation to the right.

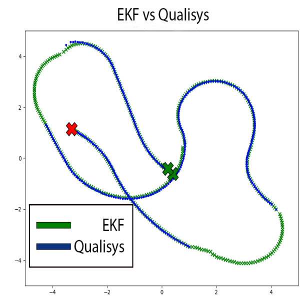


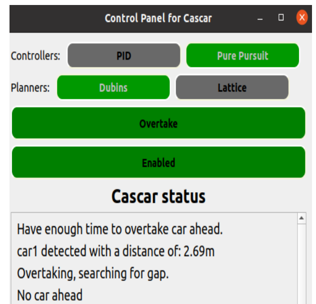
Perception module

The perception module uses an *Extended Kalman Filter* for state estimation. The time update follows the motion model:

$$\dot{\mathbf{x}} = [v\cos(\theta) \quad v\sin(\theta) \quad u+\beta \quad 0 \quad 0] \tag{1}$$
$$\mathbf{x} = [x \quad y \quad \theta \quad v \quad \beta] \tag{2}$$

The states were measured using the localization system Qualisys, wheel speed and 6-DOF IMU. The variable u is the yaw rate measured by the IMU.





A GUI was developed to facilitate initialisation and decisions by the ego vehicle.

Planning module

The planning module primarily consisted of a behavior layer and local path planning layer. Segments of the global map were continuously sent to the regulator. The segments aligned with the middle of the current lane. The behavior layer determined if an overtake was desired and feasible by considering the number of vehicles ahead and also their speed and distance to the ego vehicle. The local path planner computed the path to change lanes.

Controller module

The controller was decoupled into a longitudinal controller and a lateral controller. The lateral controller was a pure pursuit controller due to its simplicity and robustness in this particular scenario. The longitudinal controller was a platooning PD controller.

$$\ddot{x} = -K_p * e - K_d * \dot{e} \tag{3}$$

$\ddot{x}$ denotes the acceleration, e and $\dot{e}$ is the preferred distance error and relative velocity error to the car in front.

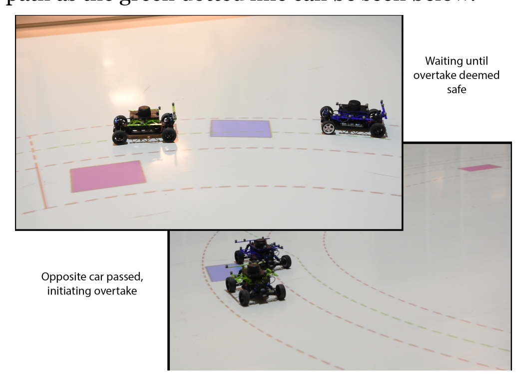
The speed of the physical car was determined by a PWM signal. To control the speed, a model was used to convert the acceleration from the longitudinal controller to the desired throttle using the following model.

$$u_t = \frac{1}{2.4145}(v_{t-1} - 1.8170v_t + 0.8375(v_t + aT)) \tag{4}$$

Where T is time step, a is desired acceleration, v is speed and u is throttle signal. The model was identified by fitting data to an ARX model.

Visualisation module

The environment was projected on the floor. The road, the simulated cars represented as rectangles and the planned path as the green dotted line can be seen below.



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