Implementation of a path-planning algorithm for automated vehicles using model predictive control in a simulated environment

Master‘s Thesis of Nina Neubauer

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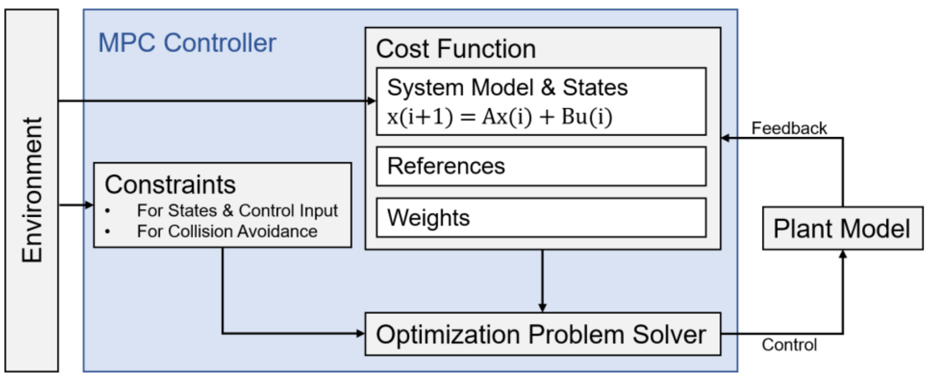


MPC Controller Structure

Automated vehicles are gaining increasing relevance in the scientific community. The driving situation in inner-city areas becomes much more complex and the presence of various road users like motorcyclists, cyclists or pedestrians must be considered. The challenge here is that these road users can make unforeseen movements. Predicting and reacting accordingly is still a challenging task in the development of Advanced Driver Assistance Systems (ADAS) and Autonomous Driving (AD). The development of suitable and accurate controllers for the path planning approach is a cutting-edge field of research that still provides enhancements and development.

In the scope of this thesis, a linear Model Predictive Control (MPC) controller was developed and evaluated for the application in automated vehicles in an urban environment with one moving obstacle. The optimal path is found by minimizing a quadratic cost function while respecting constraints and taking future time steps within a finite time prediction horizon into account.

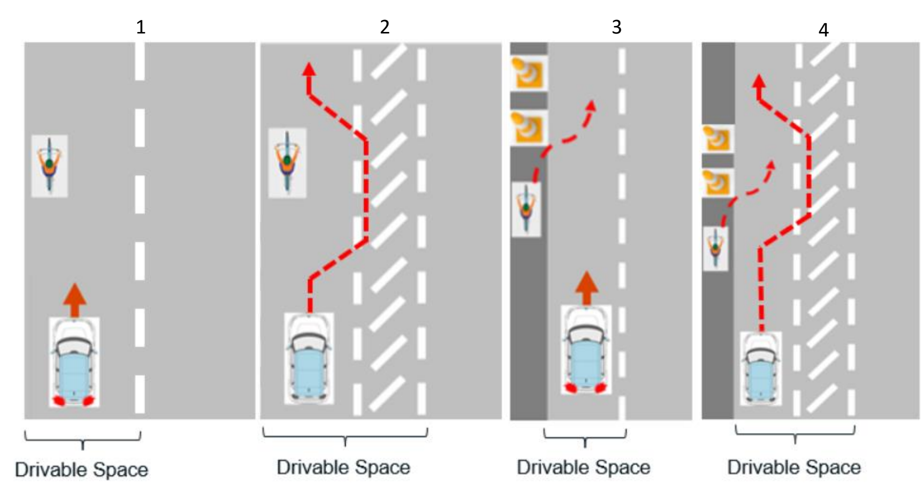
Different state of the art methods for determining the drivable space and performing motion modelling were presented and evaluated.

Based on the founding, the controller is designed while considering the vehicle dynamics and crucial constraints with special attention to safety and comfort for the passengers. The structure of the controller is pictured on the upper left corner.

Reference values where created which can be weighted accordingly to assign each term its influence in the cost function.

After receiving the estimated values, a plant model is simulating how the real vehicle would behave and gives the actual states back to the controller. The simulations where done while the prediction horizon is receding over time.

By integrating the obstacle's states in the model, its motion can be predicted, and a suitable obstacle-free path can be determined.



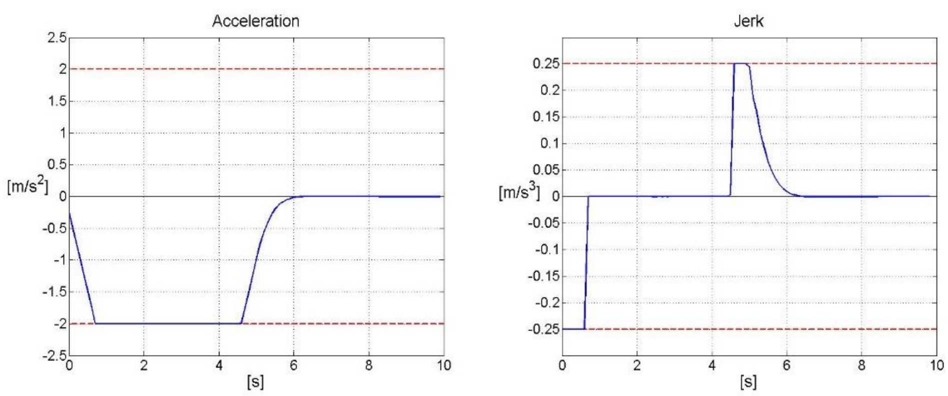
Tested Use Cases in the Simulations

The controller was then tested against four urban driving scenarios on a straight road with different manoeuvres which encompass the interaction with a cyclist. (illustrated on the right side)

Two solvers were tested to solve the optimization problem using quadratic programming.

The diagrams on the bottom left corner show results of the first use case simulations. The MPC controller estimated the values for the acceleration and the jerk in the simulations but is not exceeding the red marked safety constraints at any time.

A final result assessment and interpretation proves the MPC controller’s potential ability for real-world application.



Acceleration and Jerk Values (blue) in the First Use Case and their Constraints (red)