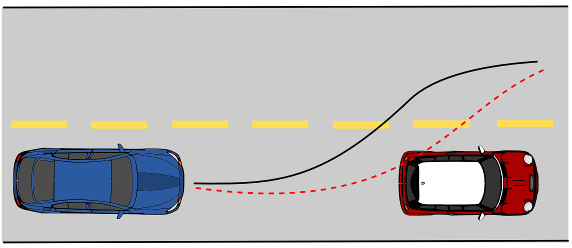
Formally-Guaranteed Safe Motion Planning for an Autonomous Car

Background

Autonomous driving is an important application area, where ensuring safety is a key problem. When facing a safety-critical situation as shown in the figure below, where we want to drive by another vehicle, we have to plan a safe trajectory (shown in black) [1] which avoids the other vehicle. However, due to noisy sensors, external disturbances such as changing road surfaces, and limited inputs, the ego vehicle might deviate from the desired trajectory and drive the red trajectory instead, therefore colliding with the other vehicle. Thus, we need to guarantee that a planned trajectory can be safely driven. However, it is not computationally feasible to verify this online for complex scenarios.

A solution to this problem is presented in [2, 3], where we pre-compute short trajectory pieces, so-called motion primitives, for which we compute verified controllers offline in advance. They are then stored as states in a maneuver automaton, where the transitions indicate which maneuvers can be connected. Consequently, the original trajectory planning problem simplifies to a discrete search using the pre-computed motion primitives to plan a desired trajectory. Therefore, the online computation time for the planning and tracking problem becomes very low, yet we still have guarantees that the planned trajectory can be followed despite all uncertainties, limitations, and disturbances.



When planning trajectories online (black line), one has to ensure that it can be driven by the real vehicle (red line).

Description

The task is to use the previously developed methods and apply them to an autonomous car prototype of BMW. The motion primitives should be computed based on a model derived from real measurements. A planning algorithm should be developed which is applied to a simulation environment and possibly a real vehicle. The thesis therefore contains the following tasks:

- Obtain a simple model plus uncertainties which contains the real vehicle dynamics using conformance testing based on real measurements.
- Compute motion primitives and generate a maneuver automaton for this model.
- Implement a planning algorithm which can plan safe trajectories using the maneuver automaton.
- Test the planning algorithm for simulations and possibly on the BMW car.

References

[1] Benjamin Gutjahr, Christian Pek, Lutz Gröll, and Moritz Werling. Efficient trajectory optimization for vehicles using quadratic programming. *Automatisierungstechnik*, 64(10):786–794, 2016.

[2] Bastian Schürmann and Matthias Althoff. Guaranteeing constraints of disturbed nonlinear systems using set-based optimal control in generator space. In *Proc. of the 20th IFAC World Congress*, pages 12020–12027, 2017.

[3] Bastian Schürmann, Daniel Heß, Jan Eilbrecht, Olaf Stursberg, Frank Köster, and Matthias Althoff. Ensuring drivability of planned motions using formal methods. In *Proc. of the Intelligent Transportation Systems Conference*, 2017.

Technische Universität München

Fakultät für Informatik

Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

Supervisor:
Prof. Dr.-Ing. Matthias Althoff

Advisor:
Bastian Schürmann, M.Sc.,
Christian Pek, M.Sc.

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For more information please contact us:

Phone: +49.89.289.18140

E-Mail:
bastian.schuermann@in.tum.de,
christian.pek@bmw.de

Website:
www6.in.tum.de/people/bastian-schuermann-msc/