Real-time Motion Planning for Autonomous Driving

Technical University of Munich

TUM School of Computation, Information and Technology

Associate Professorship of Cyber-Physical Systems

Background

Despite the recent successes in the development of autonomous vehicles, there are still major challenges like motion planning in complex traffic situations. Usually, the computational effort increases with the complexity of the traffic scenario, which is particularly problematic in safety-critical scenarios in which the vehicle must react in a timely manner. Thus, exploring and validating all maneuver options is typically impossible, which raises the question how to compute feasible maneuvers while respecting real-time constraints.

To address this issue, we proposed to combine set-based reachability analysis with optimal control [2], which formulates the motion planning task as an optimization problem. Using set-based reachability analysis, we can efficiently explore the traffic scenario and identify collision-free states of the vehicle. We then use the reachable sets to formulate the collision-avoidance constraints in the optimal control problem. This approach makes it possible to find driving maneuvers even in small and convoluted solution spaces, which can be crucial in safety-critical scenarios.

Our autonomous research vehicle EDGAR.

Description

The main goal of this thesis is to explore the real-time capability of the approach proposed in [2]. To this end, it should be combined with acados, which is a toolbox for (embedded) optimal control. Since the traffic scenario usually does not change too much between two planning cycles (usually, the motion planner runs at $\approx 10\,\mathrm{Hz}$), the computation times can be reduced by exploiting knowledge from previous planning cycles. Thus, suitable approaches should be developed and implemented in this thesis.

This thesis provides you with the opportunity to get to know a state of the art algorithm for motion planning of autonomous driving and to contribute to our autonomous driving software stack. Moreover, you gain/deepen your knowledge in numerical optimization and optimal control.

Tasks

- Familiarization with CommonRoad and CommonRoad reach.
- Familiarization with optimization-based motion planning using reachable sets [1, 2].
- Combination of the convexification approach in [2] with the acados toolbox[1] [3] to solve the optimal control problem efficiently.
- Development and implementation of replanning strategies to reduce the computational burden.

[1] https://docs.acados.org/index.html

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Research project:
justITSELF, i4driving

Type:
Master's thesis

Research area:
Motion planning, optimal control

Programming language:
Python

Required skills:
Solid Python knowledge.
Background in numerical optimization.

Language:
English, German

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- Evaluation of your algorithm using scenarios from the CommonRoad benchmark suite[2].
- Documentation of your results.

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References

[1] Stefanie Manzinger, Christian Pek, and Matthias Althoff. Using reachable sets for trajectory planning of automated vehicles. *IEEE Transactions on Intelligent Vehicles*, 6(2):232–248, 2021.

[2] Lukas Schäfer, Stefanie Manzinger, and Matthias Althoff. Computation of solution spaces for optimization-based trajectory planning. *IEEE Transactions on Intelligent Vehicles*, 8(1):216–231, 2023.

[3] Robin Verschueren et al. acados—a modular open-source framework for fast embedded optimal control. 14:147–183, 2022.

[2]https://commonroad.in.tum.de/scenarios