Follow the Rules: Efficient Optimization-based Motion Planning for Autonomous Vehicles

Our research vehicle Excellent Driving GARching.

Background

One of the barriers in the development of autonomous vehicles is being held liable when involved in traffic accidents. This issue can be addressed, e.g., by unambiguously formalizing traffic rules in temporal logic [1]. If one can prove, that the autonomous vehicle always complies with the mathematically formalized rules, they cannot be held liable for a collision. A possible way of incorporating these temporal logic rules as constraints in motion planning problems is to formulate the problem as a Mixed-Integer Programming (MIP) problem [2]. However, general MIP problems have an exponential complexity with respect to the number of integer variables and the computational times are extremely unpredictable. To overcome this, complex temporal constraints formalized in signal temporal logic (STL) [3] are handled within the successive convexification framework `SCvx` [4] in [5], which provides both theoretical convergence guarantees and real-time capability.

Description

In this thesis, the suitability of `SCvx` for motion planning of autonomous vehicles subject to STL constraints shall be investigated. First, the `SCvx-STL` definition shall be analyzed based on the STL motion planning benchmarks provided by stlpy[1]. Then, the optimization framework `SCvx`[2] shall be adapted in such a way, that it can handle motion planning problems, instead of aerospace applications. This also includes the linearization of the vehicle dynamics and the discretization of the overall motion planning problem. Finally, the capabilities and drawbacks of `SCvx` in the context of motion planning for autonomous vehicles shall be demonstrated in CommonRoad[3] [6], which is a collection of composable benchmarks for motion planning on roads.

Tasks

- Literature review on STL, optimal control, and successive convexification
- Implementation of the `SCvx-STL` method [5] to solve the benchmarks provided by stlpy
- Adaption of the texttttSCvx optimization framework to solve optimal control problems for autonomous vehicles (including linearization of the vehicle dynamics and discretization of the problem)
- Evaluate the suitability of the `SCvx` optimization framework for motion planning based on CommonRoad scenarios
- Documentation of code and other related materials

[1] https://github.com/vincekurtz/stlpy
[2] https://github.com/EmbersArc/SCvx
[3] https://commonroad.in.tum.de/

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Research project:
KoSi

Type:
Guided Research/Master Thesis

Research area:
Motion Planning, Optimization, Temporal Logic, Traffic Rules

Programming language:
Python

Required skills:
Advanced programming skills, able to work independently

Language:
English

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