Lehrstuhl für Regelungstechnik
TUM School of Engineering and Design
Technische Universität München

Semester Thesis / Master's Thesis: Model Predictive Contouring Control for Autonomous Racing

Introduction: Autonomous racing is a growing field of motorsports. Autonomous driving competitions do not only offer an inherent entertainment value but are also an extreme testing environment for developing autonomous driving systems. As part of the TUM Autonomous Motorsports Team, the automotive group at the Institute of Automotive Control develops planning and control algorithms for racing in series, such as the Indy Autonomous Challenge (IAC) and the Abu Dhabi Autonomous Racing League (A2RL).

Problem description: In the control module, a robust Model Predictive Control (MPC) algorithm calculates the optimal control input variables to minimize the deviation of the vehicle state from a reference trajectory generated by the planning module. The planning module determines the reference trajectory with a sampling-based approach. The planner samples a set of trajectory candidates and selects the fastest driveable trajectory as the reference for the control algorithm. The sampling-based approach is simple and suited for planning in multi-vehicle racing. However, the number of sampled candidate trajectories limits the time-optimality of the generated reference trajectory. Thus, there is a potential for improving on-track driving performance by moving from a trajectory-tracking MPC to a Model Predictive Contouring Control (MPCC) formulation. The MPCC is an optimal control formulation that balances tracking accuracy with a time-optimality objective for faster driving.
The goal is to develop an MPCC algorithm for autonomous racing. Considering time-optimality will inevitably lead to greater deviations from the reference trajectory, as the MPCC algorithm sacrifices tracking accuracy for speed. As a result, simplifying assumptions applied in the MPC tracking control algorithm are invalid for the MPCC formulation. In this context, the thesis will involve developing alternative solutions for cost and constraint definition in the control module.

Tasks:

- Literature review in MPC and MPCC algorithms for autonomous driving (particularly racing)
- Implementation of the MPCC in the python prototype control module
- Evaluation and improvement of the algorithm regarding computation time and recursive feasibility
- Implementation of the algorithm in the C++ software stack and final evaluation in driving simulations

Prerequisites:

- Solid background and interest in optimal control theory (particularly MPC)
- Experience in software development with Python and/or C++
- Interest in vehicle technology and autonomous driving systems
- Analytical, problem-solving mindset and a high degree of autonomy.

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