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

Semester-/Master's Thesis:
Automated Tuning for Model Predictive Control in Autonomous Racing

Introduction: Autonomous racing is a growing field of motorsports. Autonomous driving competitions 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 Chair 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 (i.e., steering, throttle, brake) to minimize a cost function subject to a given dynamic model and constraints. The control performance of an MPC is highly dependent on the tuning of its cost and slack weights. This makes comparisons of different approaches and features difficult. Manual tuning can also be quite time consuming.
The goal of the thesis is to develop an algorithm for offline parameter tuning of MPC algorithms. In this context following questions will need to be addressed: What is the most effective parameter optimization technique (e.g.: monte carlo method, genetic algorithms) to reach the desired performance level with few simulations? What are suitable metrics to judge controller performance? Can a faster, simplified simulation be used in advance to filter out certain weight parameter combinations that result in unstable driving conditions? How does the tuning optimized for one track perform on another track and how robust is it to model error?

Tasks:

- Literature review in parameter optimization and MPC for autonomous driving (particularly racing)
- Adaption of the simple Python simulation for rapid prototyping of the optimization algorithms
- Implementation of a Monte Carlo method for parameter sampling as a baseline approach
- Selection and implementation of an alternative parameter optimization algorithm
- Integration, testing, analysis, and comparison of the developed optimization algorithms (Monte Carlo method and alternative) in the existing automated C++ controller simulation pipeline

Prerequisites:

- Interest in optimal control theory (particularly MPC) and optimization algorithms
- 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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