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

Master's Thesis:
Warm Start Strategies 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. In standard driving conditions the calculation of this Optimal Control Problem (OCP) is numerically stable and reliable. However, when the vehicle is at the limit and wheel slips are very high, it is more difficult to obtain a consistent output from the MPC solver. In this driving regime, the model is not very responsive at side slip angles due to the small gradients in the tire slip-force curve (paceijka curve). Close to the peak of the tire curve, there are also non-convexities, as the same lateral acceleration values can be achieved with different levels of side slip. Thus, the numerical solution of the OCP becomes difficult, and the solutions can jump. To make the solutions more consistent, it is critical to start the optimization with a good initial guess, also known as warm start. In the current implementation the controller switches between the previous MPC solution and the planner reference as a warm start depending on the solver state.
The goal of the thesis is to develop an improved warm start strategy for the MPC algorithm. In this context, the thesis should explore alternative approaches for generating a warm start and how to switch between them.

Tasks:

- Literature review in control algorithms for autonomous racing and warm start strategies for MPC
- Selection/conceptualization of an appropriate warm start strategy
- Implementation and development of the algorithm
- Evaluation of the developed approach in extreme driving scenarios

Prerequisites:

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

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