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MPC Tuning using Deep Reinforcement Learning and Pareto-Optimal Parameter Sets: A Two-Stage Optimization Approach

One of the key challenges in autonomous vehicle control is ensuring the vehicle follows a desired trajectory while maintaining stability and safety. The use of Model Predictive Control (MPC) has been widely adopted as an effective method for trajectory following. MPC uses a prediction model of the system to optimize control actions over a finite horizon. However, the performance of MPC is highly dependent on the correct choice of the cost function and its parameters used in the optimization problem.

Determining the optimal cost function parameters to optimize different control objectives is a challenging and time-consuming task that requires hand tuning by skilled MPC experts. Furthermore, changes in the operating conditions make it necessary to repeat the tuning process. Consequently, if a system operates in a changing environment, it is desirable to adapt the controller parameters at runtime.

The goal of this thesis is to develop an automated method for online adaption of the MPC cost function. To improve the MPC performance and ensure robust parametrization, a combined framework of Bayesian Optimization (BO) and Reinforcement Learning (RL) is to be used. BO is an optimization method that searches the optimal values of a function by using prior information and a probabilistic model. In the scope of this thesis, it serves to find a preselection of suitable parametrizations in an offline setting. An RL agent is then trained to select the most beneficial parameters at runtime in order to optimize the driving performance.

Tasks to be completed during the thesis:

- Conduct a state-of-the-art review on the use of Bayesian Optimization in MPC
- Formulate the problem of optimizing the parameters of the cost function used in the MPC
- Concept, develop and implement a Bayesian optimization algorithm to tune the MPC parameters
- Concept, develop and implement a Reinforcement Learning algorithm to select beneficial parameters sets at runtime.
- Test and evaluate the performance of the proposed approach in simulation and/or experiment
- Compare the performance of the proposed approach with traditional manual tuning methods
- Write a comprehensive thesis report documenting the research, methodology, implementation, and results

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