Professorship Autonomous Vehicle Systems
Department of Mobility Systems Engineering
TUM School of Engineering and Design

SA/MA

Learning-Based Model Predictive Control for Autonomous Vehicle Trajectory Following using Gaussian Process Regression

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 accuracy of the prediction model used. The current approach uses a nonlinear dynamic single track model with a Pacejka tire model. But it still can't perfectly model the reality and has structural and parametric uncertainties.

One possible approach to tackle these challenges is to split the prediction model into a nominal model and a learning-based residual model. The nominal model represents the basic physics of the system, while the residual model captures the effects of the model-mismatch and unmodeled dynamics. The goal of this thesis is to improve the performance of the model predictive controller by Gaussian Process Regression (GPR). Combining these two approaches can offer a powerful solution to automatically adapt the prediction model online, handle uncertainty and disturbances that might appear while driving, and improve the closed-loop performance.

Tasks to be completed during the thesis:

- Conduct a state-of-the-art review on the use of GPR in MPC
- Formulate the problem of enhancing the prediction model used in the MPC by using a GPR model
- Concept, develop and implement an open-source available GPR algorithm to learn from model-mismatch and unmodeled dynamics
- Test and evaluate the performance of the proposed approach in simulation and/or experiment
- Compare the performance of the proposed approach with traditional model predictive control methods
- Write a comprehensive thesis report documenting the research, methodology, implementation, and results.

[1] Kabzan, Juraj, et al. "Learning-based model predictive control for autonomous racing." *IEEE Robotics and Automation Letters* 4.4 (2019): 3363-3370.

[2] Brüdigam, Tim, et al. "Gaussian process-based stochastic model predictive control for overtaking in autonomous racing." *arXiv preprint arXiv:2105.12236* (2021).

Prof. Dr.-Ing. Johannes Betz

Supervisor: Baha Zarrouki, M. Sc.

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