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

SA/MA

Estimating Parameters for Autonomous Vehicle Dynamics using Unscented Kalman Filter and Heuristics of Differential Evolution Algorithms

(this subject can also be researched in a semester + master thesis combination)

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. If the parameters are not accurately estimated, the MPC predictions would lead to suboptimal control performance.

The current approach uses a nonlinear dynamic single track model with a Pacejka tire model. Most vehicle dynamics parameters, such as the total mass of the vehicle (m), the moment of inertia (Iz) and the distance from the center of gravity (CG) of the vehicle to the front and rear axles (lf and lr), are difficult to obtain directly. These parameters are typically estimated using various techniques, such as road testing or computational simulation. However, the accuracy of these estimates can be limited by factors such as measurement noise and model uncertainty.

Objectives: The objective of this thesis is to develop a new approach for accurately estimating the vehicle parameters of a nonlinear dynamic single track model for MPC predictions as follows:

1. Estimate the vehicle parameters (lf, lr, m, Iz) and/or tire model parameters (Pacejka's Magic Formula parameters) using Unscented Kalman Filter (UKF) as a baseline.
2. Develop a new approach for estimating the vehicle parameters through heuristics of Differential Evolution Algorithms (DEAs) and Genetic Algorithms (Gas).
3. Compare the performance of the UKF and the new approach in estimating the vehicle parameters and to analyze the results.

Methods: The methods to be used in this thesis are:

1. Unscented Kalman Filter (UKF): UKF is a statistical technique for estimating the state of a dynamic system from noisy measurements. Here it will be used to estimate the parameters instead of the full state.
2. Differential Evolution Algorithms (DEAs) and Genetic Algorithms (GAs) are optimization techniques that use heuristics inspired by biological evolution to find the optimal solution to a problem. In this thesis, DEAs and GAs will be used to develop a new approach for estimating the vehicle parameters. The heuristics will be used to search the parameter space to find the optimal solution.

Eligibility: This thesis is suitable ideally for students with a background in control systems, autonomous vehicles, and estimation techniques. Knowledge of Model Predictive Control (MPC) and Unscented Kalman Filter (UKF) is desirable but not required.

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In terms of programming skills, proficiency in Python is required and knowledge of C++ is desirable. The candidate should have strong programming skills and be able to implement the algorithms and simulations required for the thesis.

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