MASTER

ADAS steering control and tire-road friction estimation using steering torque modelling

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Award date:
2023

MASTER THESIS

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14-02-2023

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CONFIDENTIAL

Automotive Technology
Master's thesis (45 EC)

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DC 2023.022

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February 2023

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I have read the TU/e Code of Scientific Conduct[i].

I hereby declare that my Master's thesis has been carried out in accordance with the rules of the TU/e Code of Scientific Conduct

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February 21, 2020

Abstract

In this thesis a steering angle controller for the Lightyear Validation Prototype is developed. Before a controller can be developed the steering system has to be identified for which frequency response measurements (FRF) with a lifted vehicle have been performed. An overview of the applied FRF-methods and results is provided. Measurements to obtain the static friction and jacking torque are also described. Subsequently a mechanical model of the steering system is shaped to match the plant estimate of the FRF-measurements and is suited to include torques as a result of static friction, jacking and tire forces. The model therefore acts as a plant model for the controller development.

The main disturbance which needs to be opposed by the steering actuator to rotate the vehicle's front wheels is caused by the tires. Therefore a two-track vehicle model which employs a contact patch slip tire adapted to the use of the Magic Formula has been set up to accurately determine the torque as a result of tire forces acting on the steering column. A non-rolling tire model is also incorporated to improve the model performance at standstill and low velocities. The chosen vehicle and tire models are explained and defended before the model outputs are compared with measurement data of the Lightyear Validation Prototype. Parameter fitting is employed to increase the resemblance between the model and the measurements. Hence it demonstrates the designed vehicle model is able to match the measurements and therefore can act as a ground truth model for controller design.

The loop shaping control method is employed to develop a feedback controller. The controller achieves the set requirements and objectives which followed out of a literature review and hardware limitations. The feedforward controller is tackled by using a single track vehicle model. It employs the Magic Formula tire model for which scaling factors are optimized to fit the outputs of the single track vehicle model to the those of the high-fidelity two-track model. The controller is implemented in a simulation model which demonstrates it is able to achieve good tracking performance. Furthermore it demonstrates the inclusion of feedforward control can substantially increase the tracking performance. Finally controller simulation results are compared with Validation Prototype measurement data of the baseline controller for a selection of driving cycles.

A parameter which has great influence on the vehicle performance and cannot cost-effectively be measured is the tire-road friction coefficient. By estimating this parameter the feedforward output can be improved. This thesis presents a concept where the torque on the steering column as a result of the tire forces is employed in a vehicle state estimator to determine the tire-road friction coefficient. The Extended Kalman Filter (EKF) is chosen as estimation method and employs the same single track vehicle model as the feedforward controller. The two-track model is used as the ground-truth to generate the measured outputs. The filter is, in simulation, able to determine the tire-road friction coefficient using the assumption that the single track vehicle model which includes a non linear tire model is valid.

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