Lehrstuhl für Fahrzeugtechnik
Fakultät für Maschinenwesen
Technische Universität München

Bachelor's thesis

# Sensitivity Analysis for Tractor-Trailer Dynamics – Prediction Model Quality Assessment

Trucks are one of the main carriers of goods. The trend of autonomous trucks offers many advantages for the freight transport sector including faster transport by avoiding mandatory breaks, solving the driver shortage problem, more traffic safety by anticipatory planning, and environmental benefits [1].

atlas-l4.com

In the Chair of Automotive Technology, we are working with various cooperation partners from industry and other research institutes on the ATLAS-L4 project. Our main goal is to make truck-trailers drive hub-to-hub autonomously (level 4) through highways.
Within the scope of autonomous driving, the longitudinal and lateral motion control of the truck to follow the planned trajectory is a challenging task. One of the common approaches for autonomous trajectory-following is Model Predictive Control (MPC). Hereby, the prediction model of the MPC is one of the elements that strongly affect its performance. In the automotive context [2], it should, on the one hand, precisely model the vehicle dynamics and on the other hand, meet the real-time execution requirements.

To illustrate the control challenges within the ATLAS-L4 Operational Design Domain (ODD), the tractor-trailer system has a limited time window to merge into one highway lane due to the merging lane limits and the presence of other road participants. Disturbances and parameter uncertainties such as crosswind, longitudinal- and lateral road banking, and varying trailer load induce strong system state prediction deviations. Hence, the controller can fail to meet the tight time constraints of the reference trajectory, which can lead to safety-critical situations.

Thus, for a robust control performance, an identification/quantification of parameter uncertainties and disturbances is needed.

This Bachelor's thesis deals with the following research questions:

- Which disturbances and uncertainties occur in a tractor-trailer context in a high-velocity range on a highway?
- Which impact do the model parameter uncertainties and disturbances have on the predicted system state?
- How to model the most relevant uncertainties and disturbances to improve the open-loop prediction quality?

Besides improving the system state prediction, the results of a sensitivity analysis could help to deal with the trade-off between model complexity and real-time execution constraints.

There exist mainly two methods of sensitivity analysis methods: local and global. The first is based on the analysis of partial derivatives of the system state with respect to the parameters. Nolte et al. [3] already conducted a local sensitivity analysis for single- and double-track models of passenger vehicles. Two common global sensitivity analysis methods are the Morris- and the Sobol method [4].

The following work packages are included in the bachelor's thesis to be assigned:

- Familiarization with the fundamentals of the vehicle dynamics of a tractor-trailer system
- Identification of uncertainties and disturbances in the context of tractor-trailers and their effects (e.g. CG displacement)
- Research, selection, and implementation of suitable sensitivity analysis methods for the different uncertainties/disturbances based on chosen truck dynamics models (dynamic nonlinear single-/ double-track models).
- Identification of uncertainties/disturbances that affect the prediction quality (open-loop prediction error) the most.
- Extension of the models by modeling the most relevant uncertainties and disturbances and evaluation of the prediction quality of the extended models
- Writing a thesis report

The thesis should document the individual work steps in a clear form. The candidate undertakes to complete the bachelor's thesis independently and to indicate the scientific resources used.

The submitted thesis remains the property of the chair as an examination document.

[1] Andersson, P., & Ivehammar, P. (2019). Benefits and costs of autonomous trucks and cars. *Journal of Transportation Technologies*, *9*(2).

[2] Kong, J., Pfeiffer, M., Schildbach, G., & Borrelli, F. (2015, June). Kinematic and dynamic vehicle models for autonomous driving control design. In *2015 IEEE intelligent vehicles symposium (IV)* (pp. 1094-1099). IEEE.

[3] Nolte, M., Schubert, R., Reisch, C., & Maurer, M. (2020). Sensitivity Analysis for Vehicle Dynamics Models–An Approach to Model Quality Assessment for Automated Vehicles. In *2020 IEEE Intelligent Vehicles Symposium (IV)* (pp. 1162-1169). IEEE.

[4] Ye, M., & Hill, M. C. (2017). Global sensitivity analysis for uncertain parameters, models, and scenarios. In *Sensitivity analysis in earth observation modelling* (pp. 177-210). Elsevier.

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