

Supervisor's review of the Ph.D. thesis of Denis Efremov

Vehicle-Road Safety and Stability Envelope Definition and Protection

Ph.D. program: Electrical Engineering and Information Technology

Branch of study: Control Engineering and Robotics

Supervisor: Doc. Ing. Tomáš Haniš, Ph.D.

I hereby declare I am well-positioned to provide an evaluation for the doctoral thesis titled "Vehicle-Road Safety and Stability Envelope Definition and Protection," submitted by Denis Efremov in April 2024. I have had the privilege of serving as Denis Efremov's academic advisor throughout the entirety of his doctoral studies.

Firstly, I can confirm that the work submitted adheres to the official guidelines set forth by the Czech Technical University in Prague. It meets the formal requisites delineated by the Dean's Directive of the Faculty of Electrical Engineering (FEE) with respect to the content of the dissertation. Furthermore, I am pleased to affirm that the candidate has satisfactorily met the publication requirements as stipulated by the Code of Doctoral Study at the Faculty of Electrical Engineering.

The research connected to the thesis was supported by and done in close collaboration with Toyota Research on Automated Cars in Europe (TRACE) research group, represented at CTU in Prague – Faculty of Electrical engineering by prof. Matas from the Department of Cybernetics, and Toyota Motors Europe.

The Ph.D. thesis deals with the complex issue of wheeled vehicles active safety. First, the definition of vehicle safety limits is discussed. The vehicle limits could be specified using two different approaches. First, the single vehicle dynamics limits are derived from the traction limits of each wheel. Second, the interaction between vehicle and environment, namely the maneuvers limits are considered. Both approaches are called safety envelopes. The driving envelope constrains the set of vehicle maneuvers based on physical limitations derived from traction limits. The environmental envelope constrains the vehicle based on the road situation respecting road limits, other road users, potholes and other traffic obstacles. Finally, the control architecture is developed using MPC methodology. The envelopes protection algorithms are actively preventing vehicle from leaving the safety of Driving Envelop and Environmental Envelop.

The significance of the thesis is substantiated by the journal publication devoted to driving envelop protection algorithm, which is accepted for publication: D. Efremov, T. Haniš, and M. Klaučo, "Vehicle and Wheels Stability Defined Using Driving Envelope Protection Algorithm," IEEE Transactions on Intelligent Transportation Systems, 2024, doi:10.1109/TITS.2024.3362064 (IF8.5). Furthermore, one additional journal paper dealing with environmental envelop protection algorithm, which is currently in 2nd iteration of review process: D. Efremov, T. Haniš, and M. Klaučo, "Enhanced Vehicle Safety through Low-Level Wheel Positioning Control," submitted and under review in IEEE Transaction on Intelligent Transportation Systems, 2024 (IF 8.5). Both topics were also filed as a patent by Toyota Motors: Chumerin, N., Efremov, D., Klauco, M., and Hanis, T. Method and Apparatus for Driver Assistance of a Moving Vehicle. European Patent with application number EP23182777.5. European Patent Office. Filed on 30 June 2023, and Chumerin, N., Efremov, D., Hanis, T., and Klauco, M. Methods and Systems for Calculating Control Variables of a Vehicle. European Patent with application number EP22207286.0. European Patent Office. Filed on 14

November 2022. Finally, five more papers were published, and presentations were given at multiple conferences.

In summary, I deem the submitted thesis and its associated research work to be successful. I fully endorse it and recommend that it proceed to the defense.



In Prague, April 12, 2024

doc. Ing. Tomáš Haniš, Ph.D.