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Your ref:	Our ref:	Attended by:	Bratislava
		prof. Ing. Michal Kvasnica, Dr.sc.	**Oct 4th, 2024**

Review of PhD Thesis of Ing. Denis Efremov

The proposed PhD thesis of Mr. Efremov is concerned with the design and enforcement of stability envelopes for ground vehicles. The thesis spans 108 pages and is divided into three principal parts. The first part presents the introduction and motivation of the dissertation thesis, and summarizes its main contributions. The reviewer appreciates clear visual depictions that convey the main messages in a clear and understandable fashion. The literature review contained in this part clearly demonstrates the applicant's broad overview of the investigates field. The reviewer wishes to particularly highlight the contribution of Section 1.3, where the thesis describes related existing commercial products to achieve drive safety. In the reviewer's opinion, by this section Mr. Efremov demonstrated that he is not just well versed in theoretical concepts of the discussed topic, but he has a broad overview of how theory can be translated into a successful commercial product.

The second part of the thesis is concerned with the driving envelope. The material of this part has been, to a large extent, subject to a peer review in an accepted IEEE Transactions on Intelligent Transportation Systems contribution. This fact, together with the reviewer's own reading this part, confirms soundness and validity of the proposed methodology and results. The driving envelope is derived using first-principle modeling approaches that consider nonlinear aspects. Subsequently, the driving envelope is defined and consequently linearized. Although not instrumental to the technical derivation, the graphical representation of the driving envelope presented in the thesis aids both the reader and interested customers to get a vital insight and interpretation of the results. Based on the envelopes, the applicant then derives the maximum control invariant set as the set of all control actions that keep the vehicle safe in case of an abnormal situation. This is achieved using a model predictive control strategy. The reviewer considers the technical results correct, and the methodology fully appropriate. Quality and practicality of the approach is sufficiently demonstrated by an experimental case study.

The third part of the thesis discusses the environmental envelope and presents an algorithm for its protection. The envelope serves to keep the vehicle within road limits while avoiding obstacles. To alleviate the computational demands, the author proposes to employ linear and polynomial approximations of the segments of the envelope, which is fully appropriate. Once the envelope is derived, the thesis applies model predictive control to come up with a set of control actions that keep the vehicle within specified boundaries. The thesis presents a detailed derivation of the problem and its

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individual constraints, which enhances the overall of the contribution. The technical results are validated in an experimental case study. The study considers multiple real-life scenarios, such as lane keeping, obstacle avoidance, and obstacle prioritization. The detailed analysis of computational demands confirms practical applicability of the proposed control strategy.

After a thorough reading of the thesis, this reviewer has come to a firm conclusion that the PhD thesis of Mr. Efremov fulfills all conditions for it to be accepted for defense. The thesis undoubtedly contains novel material that contributes to scientific knowledge in the field of analysis and control of dynamical systems. The candidate, through his thesis, and his other scientific publications too, has demonstrated his ability and readiness to conduct independent scientific research. The reviewer wishes to highlight two patent applications that has been submitted in connection with the thesis. These confirm that the applicant is fully prepared to translate theory into practical applications. Therefore, this reviewer provides a **pass** assessment of the PhD thesis of Mr. Efremov.

Questions:

- How would the individual envelopes change when considering front-drive, read-drive, and all-wheel-drive vehicles?
- Do you envision an added value of presenting the graphical representation of the envelopes to the driver in real time? Do you think it can contribute to his/her driving skills?
- In the environment envelope it appears that you only consider stationary obstacles. How would you approach tackling moving obstacles and how would doing so influence complexity of the control problem?
- In your thesis, you compare the development of aerospace and ground vehicles. What specific lessons from aerospace engineering do you believe can be most effectively applied to the advancement of ground vehicle safety and control systems?
- The vehicle-road envelope is divided into driving and environmental envelopes. How do you ensure that the definitions of these envelopes remain adaptable to various vehicle configurations and road conditions, especially in unpredictable environments?
- Given that your algorithms enhance human operations to increase vehicle safety, how do you envision the interaction between human drivers and your proposed systems, particularly in scenarios where human decision-making is critical?
- As the automotive industry evolves towards greater automation, how do you foresee your envelope protection algorithms adapting to fully autonomous vehicles, and what challenges do you anticipate in this transition?

Sincerely,

prof. Ing. Michal Kvasnica, Dr.sc.
Full professor of automation