DEGREE PROJECT PROPOSAL

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1 THESIS TITLE

Trajectory Optimization for Vehicle Platoons Using Learning-based Model Predictive Control

2 BACKGROUND

The project lies within the research areas of intelligent transport systems (ITS), multi-agent systems, and learning-based control. For several years now, the ITS community has been actively researching the use of platooning for optimizing the fuel economy for heavy-duty vehicles. Platooning refers to a fleet of vehicles that are driving close together as a single unit. Achieving a fuel-optimal, robust and safe trajectory for each vehicle in the platoon poses a control challenge. Current research papers, [1],[2],[3], [4] and [5], provide multiple approaches to solve the platooning problem. For example, by utilizing estimation methods of the road slope and vehicle mass. In a recent paper [6], the authors show that a learning-based control scheme yields promising results for decentralized control of nonlinear multi-agent systems. This thesis project aims to implement a learning approach to the problem of platooning, by utilizing data from previous or simulated optimal trajectories.

At the Integrated Transport Research Lab (ITRL) at KTH, where the project is conducted, platooning is an area of active research with stakeholders ranging from researchers to large companies and external organizations. The findings from this project will provide important insight for the ongoing research. Mainly, this project will reveal how a learning-based approach might extend to the application of platooning.

3 RESEARCH QUESTION

The project aims to answer the following two questions:

- What is the drawback of the platooning methods that are proposed in [1],[2],[3], [4] and [5]?
- How can data be utilized for fuel-efficient and safe control of heavy-duty vehicles in a platoon

4 HYPOTHESIS

Multi-agent Learning Model Predictive Control (LMPC) applied to platooning will provide better fuel-efficiency than current methods, while guaranteeing safety.

5 RESEARCH METHOD

The first research question will be answered by a thorough study of the related literature, [1],[2],[3], [4] and [5].

The second, and main, research question will be answered through a three-step, iterative procedure. Firstly, the control strategy based on LMPC is developed theoretically and implemented through software. Secondly, a simulation environment will be developed to collect the necessary data and find the answer for how one might utilize the data and measure the performance. Lastly, the findings from the simulation phase are employed on the Small VEhicles for Autonomy (SVEA) platform, to perform hardware experiments to validate the performance of the devised control scheme.

6 BACKGROUND OF THE STUDENT

The student has taken all the modeling and control courses that are necessary to understand and synthesize the relevant research papers. Furthermore, through a previous internship at ITRL, the student is familiar with the software and hardware research platforms that are necessary for the project.

7 SUGGESTED EXAMINER AT KTH

- Jonas Mårtensson — jonas1@kth.se (has been contacted and confirmed as examiner)

8 SUGGESTED SUPERVISORS AT KTH

- Yvonne Stürz — stuerz@kth.se (has been contacted and confirmed as supervisor)

- Frank Jiang — frankji@kth.se (has been contacted and confirmed as supervisor)

9 RESOURCES

Besides access to all the relevant research papers (see References), the student is provided with the code for the main paper of the project. Furthermore, the SVEA simulation and platooning platforms, provided by ITRL, will be used for the major parts of the project.

10 ELIGIBILITY

Office of Student Affairs confirmed the eligibility of the student.

11 STUDY PLANNING

The student is only taking the course **DD2352 - Algorithms and Complexity** alongside the thesis. The course will be completed on the 3rd of June, once the student writes the exam. The course is not strictly necessary for the student's graduation, it is taken as an extra course. The thesis will continue afterward and will, hence, be the very last element of the student's education.

References

[1] V. Turri, B. Besselink, and K. H. Johansson. Cooperative look-ahead control for fuel-efficient and safe heavy-duty vehicle platooning. *IEEE Transactions on Control Systems Technology*, 25(1):12–28, 2017.

[2] Valerio Turri, Bart Besselink, Jonas Martensson, and Karl H. Johansson. Fuel-efficient heavy-duty vehicle platooning by look-ahead control. *53rd IEEE Conference on Decision and Control*, 2014.

[3] Gustav Ling, Klas Lindsten, Oskar Ljungqvist, Johan Löfberg, Christoffer Norén, and Christian Larsson. Fuel-efficient model predictive control for heavy duty vehicle platooning using neural networks. 01 2018.

[4] Kuo-Yun Liang, Sebastian Van De Hoef, Håkan Terelius, Valerio Turri, Bart Besselink, Jonas Mårtensson, and Karl H. Johansson. Networked control challenges in collaborative road freight transport. *European Journal of Control*, 30:2–14, 2016.

[5] Gyujin Na, Gyunghoon Park, Valerio Turri, Karl H. Johansson, Hyungbo Shim, and Yongsoon Eun. Disturbance observer approach for fuel-efficient heavy-duty vehicle platooning. *Vehicle System Dynamics*, 58(5):748–767, 2019.

[6] Yvonne R. Stürz, Edward L. Zhu, Ugo Rosolia, Karl H. Johansson, and Francesco Borrelli. Distributed learning model predictive control for linear systems, 2020.