Implementation and Testing of a Cooperative, Partially Automated Driving Function in a Real Vehicle Considering Influences of Road Traffic

Master‘s Thesis of Lukas Leonard Köning

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Introduction

While the development of level 3 Advanced Driver Assistance Systems (ADAS) continues and receives wide attention, level 2 ADAS are also being developed further. The focus of research and development efforts is especially on improving individual functionalities and the expenditure of the Operational Design Domain. The goal of this thesis was to implement and test a fully shared control, partially automated driving function in a real vehicle regarding driving safety, braking behavior, customer value, driver's attentiveness, driver's workload, the influence of the Human Machine Interface (HMI) on the perception of the function, and the impact on surrounding traffic. The results from the preceding driving simulator study were compared to the findings in this thesis. These findings were then discussed in a broader, traffic-related context.

State of Technology

Cooperativity can be defined as the actions or processes of cooperation toward a common goal between at least one human and one machine [1]. If the cooperative task is to cooperatively control a technical system like a vehicle, it is also called "shared control" [1]. The literature of this thesis revealed seven attributes that a cooperative driving function should fulfill. A cooperative function should:

- **Allocation**: allow dynamic allocation of tasks between driver and system.
- **Capabilities**: possess sufficient capabilities to fulfill the intended task.
- **Communication**: include an effective, intuitive, concise, clear, and adequate communication design.
- **Traceability**: allow the driver to trace and predict its abilities and intents.
- **Arbitration**: possess a defined way to coordinate different intentions of the driver and the system.
- **Adaptivity**: be able to adapt to the driver to balance flexibility and stability.
- **Cooperative Design**: be designed so that all relevant layers of cooperation, namely intention recognition, mode of cooperation, allocation, interface, and contact, are adequately defined.

This thesis build upon the results of the driving simulator study of Illgner et al. [2] that introduced and tested the fully shared control, partially automated driving function for the first time.

Methodology

A real vehicle study with 50 participants was conducted in an urban setting in Munich, Germany. The chosen route included different aspects of urban driving. Each participant experienced the state-of-the-art ADAS setup and the novel fully shared control ADAS setup, allowing for between-subject and within-subject analyses of the collected data. Figure 1 shows the design of the study. During the study subjective data from questionnaires and objective data in form of vehicle data was collected and later analyzed to retrieve the results.

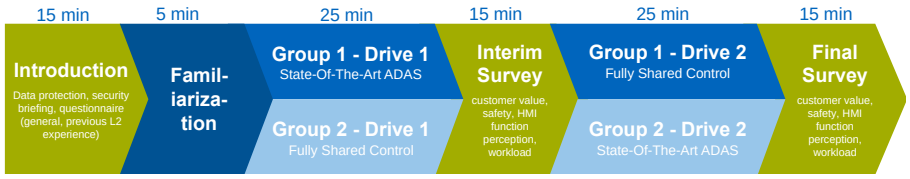

Figure 1: Design of the real vehicle study.

Results

The results of the real vehicle study revealed a higher customer value, a higher ADAS usage rate, more frequent and more anticipatory brake interventions, a higher perceived safety, and a more balanced workload of the fully shared control ADAS setup. Furthermore, no differences in attentiveness and safety, evaluated by the Time-To-Collision, were shown. The possible impacts of the fully shared control concept on the driver and the surrounding traffic are visualized in Figure 2 and Figure 3. Another notable finding was the possible increase in driver engagement that could lead to a reduction of driver inattentiveness and could allow for more level 2 ADAS functionalities.

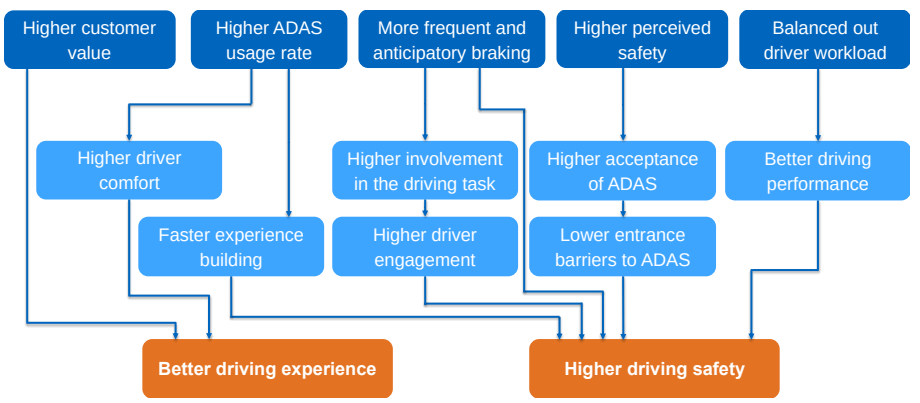

Figure 2: Impact of fully shared control on the driver.

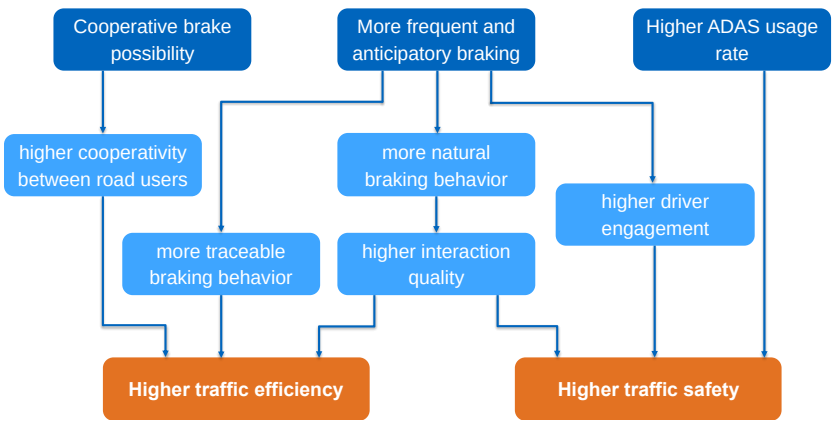

Figure 3: Impact of fully shared control on the traffic.

Conclusion

Fully shared control ADAS promise to advance availability, comfort, acceptance of ADAS, driver engagement, and the driver's driving experience. Additionally, it could positively impact traffic efficiency and safety. They seem to be a valuable advancement of the current state-of-the-art ADAS. The results of this thesis partly verified the results from the preceding driving study by Illgner et al. [2] and expanded the knowledge about cooperative driving functions.

References

[1] F. O. FLEMISCH et al., “Towards cooperative guidance and control of highly automated vehicles: H-Mode and Conduct- by-Wire,” Ergonomics, vol. 57, no. 3, pp. 343–360, 2014. DOI: 10.1080/00140139.2013.869355.

[2] J. ILLGNER et al., “Improving Driver Engagement with Level 2 Automated Systems: The Impact of Fully Shared Longitudinal Control,” in Proceedings of the 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, (Stanford, USA), Association for Computing Machinery, 2024, pp. 43–52. DOI: 10.1145/3640792.3675708.