Human-Centred Development of SAE-2 Automation for Truck Driving

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Keywords: truck driving, driver assistance systems, vehicle automation, human-centred design, headtracking, driver monitoring.

Background

Compared with passenger cars, automating driving functions for trucks and understanding related driver behaviour are considerably less advanced, potentially due to difficulties accessing relevant technology and subject matter experts (SMEs). Project HALC's (HighwayAssist with Lane Change) first objective was to develop the HALC system, which is an automation assisting truck drivers on highways. The system performs longitudinal and lateral control of commercial trucks, including lane changes. To optimally support truck drivers' interactions with the HALC system, we developed its functionality and human-machine interface (HMI) in close cooperation with SMEs. As an SAE level 2 (SAE International, 2014) type automation, the system may require drivers to resume control anytime. Thus, the second objective was to develop a monitoring system to ensure drivers' takeover readiness. The project's third objective was to understand better truck driver behaviour based on data collected within the project. This knowledge was then used to inform the HALC system's design and implementation.

Method

Informed by the daily operational needs of a trucking company, prototypical safety-critical events, and the capability of the available technology, 160 use cases were defined to specify how the automation should behave in specific traffic situations. Based on the use cases, (a) architecture and core functionality of both the automation and the driver monitoring system were derived, (b) a simulator experiment to explore truck drivers' behaviour in safety-critical situations was specified, and (c) a focus group to gather feedback regarding HMI solutions was planned.

The simulator experiment aimed at exploring how distracted truck drivers responded in case of silent automation failures and also served to collect parameters related to head and gaze orientation. The experiment's 4x2x2 design varied four safety-critical scenarios lasting about 15 min, which 27 participants holding at least a C1 driver's license (three female, 24 male; mean age = 42.5 years) experienced in two driving conditions (manual vs automatic) and two warning conditions (audio-visual warning vs no warning). Each participant conducted two scenarios in manual, distraction-free driving, whereas the two other trials required playing a game on a tablet computer while supervising the automation. Towards each scenario's end, participants had to intervene to prevent a safety-critical event from developing into a crash, with one condition simulating the automation failing without warning. During the initial training, participants were informed about this possibility.

The focus group was conducted with six professional truck drivers (two female, four male, mean age = 29.7 years) and integrated participatory design elements. The focus group aimed to receive feedback regarding the initial HMI concept and further understand drivers' information demands. After introducing SAE level 2 automation and the initial HMI concept, we demonstrated the HMI using a simulated driving scenario free of disturbances. Participants then answered questions to evaluate the HMI regarding strengths and weaknesses and, within a group discussion, were asked for potential improvements. Based on the drivers' suggestions, we immediately adjusted the HMI concept and repeated the question phase and the group discussion. This process was then repeated twice.

Results

The simulator experiment showed that the distraction exerted by playing the game could result in safety-critical incidents, even for highly skilled drivers. Some participants missed the critical safety situation entirely; others reported difficulty taking back manual control. We concluded that most collisions would have been avoided if drivers could not orient their heads away from the front view.

Informed by the experiment's results, we implemented a head tracking-based monitoring system to prevent complete aversions from traffic. Regarding the HALC system's lane change functionality, the results supported requiring drivers to initiate lane changes explicitly. They are only executed if no objects on the target lane have been detected and drivers have visually attended the rear-view mirror.

In addition to the lane change functionality, the HALC system integrates adaptive cruise control and lane centring. The results obtained from the focus group allowed for a holistic system design such that truck drivers perceive a single system instead of three separate functionalities.

Conclusion

Truck driving differs markedly from car driving due to vehicle size, braking and acceleration behaviour, and usually being part of a commercial operation. Under constant pressure to meet delivery times, drivers frequently experience long periods of monotony which are unpredictably interrupted by safety-critical situations. As such, drivers are substantially exposed to traffic-related hazards and appreciate technical systems lowering their workload and the risk of accidents. Designing and implementing such systems requires profound domain knowledge and an iterative development approach. The SMEs' support enabled us to obtain the qualitative and quantitative insights necessary for the human-centred design process. Transferring these insights into system functionality requires effort and flexibility, which should be considered during the project planning phase.

References

SAE International (2014). Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (J3016).