Touch Screen Maneuver Approval Mechanisms for Highly Automated Vehicles: A First Evaluation

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Abstract
Prototypes of highly automated vehicles are already able to drive on public roads, however fully automated rides where humans in the vehicle have only the role of a passenger regardless in which environment they travel are far away. Major issues are limited sensor range, mixed traffic, and an insufficient capability of classifying situations. We propose that vehicles can cooperate with the human inside to overcome such system boundaries. A possible input modality for driver-vehicle interaction in such scenarios are touch screens. We investigated three implementations regarding different confirmation processes to avoid erroneous inputs. Our evaluation in a driving simulator with 18 participants indicates that drivers prefer a one-tap selection, however they accept error prevention mechanisms like a confirmation dialog to approve maneuvers in more dynamic and complex scenarios. Moreover, these mechanisms did not have a negative effect on usability and workload.

Author Keywords
Automated driving; human-machine cooperation; study.

CCS Concepts
•**Human-centered computing** $\rightarrow$ **Touch screens; Empirical studies in HCI;** *Natural language interfaces;* Usability testing; Laboratory experiments; Graphical user interfaces;

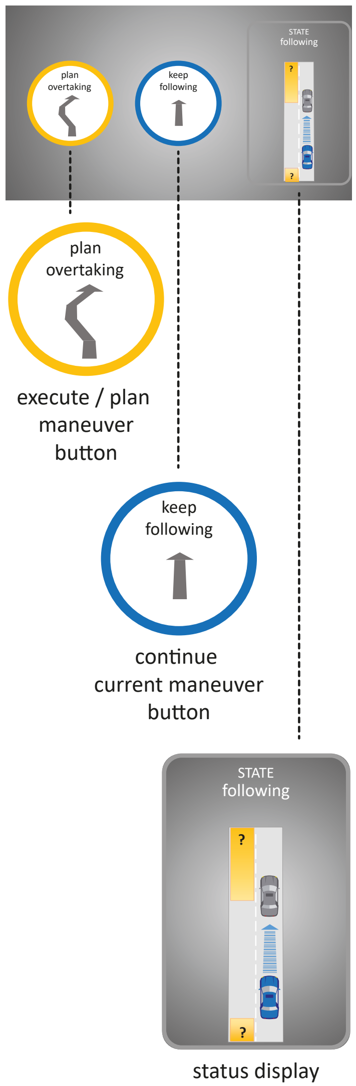

Figure 1: GUI schema.

Introduction

Autonomous driving is already possible as long as the system's requirements are met, for instance on the highway or at tracks where a high-definition map is provided. Moreover, there are already highly automated vehicles on the road in less controlled environments like urban areas – yet, these vehicles cannot handle every situation [3, 12] and still rely on (safety) drivers as backup. Other situations can be handled from the system but in a less efficient way compared to a human driver (e.g. slowly entering a junction).

Backup drivers are experts who have been trained to intervene in problematic and unforeseeable situations. If highly automated driving should be rolled out before autonomous systems can handle every possible situation, there is a need for interfaces that cooperate with human drivers [13] who did not receive a special training. These interfaces have to be designed for novice users and in consequence should implement mechanisms to avoid erroneous inputs. Moreover, highly automated systems should avoid transitions to manual driving in precarious situations; instead cooperative interfaces that "allow human operators to focus the power of the automation on particular sub-problems, or to specify solution methods that account for unique aspects of the situation which the automated agent may be unaware of" [2, p. 8] are a promising approach to such shortcomings.

We conducted an in-lab usability study to investigate three different input strategies for maneuver approval. These strategies varied in the way they implemented mechanisms to avoid erroneous inputs. 18 participants were challenged with different scenarios in which they were asked to approve maneuvers on a touch screen. Our study reveals, that participants prefer a one-tap solution, however they were aware that systems with safety mechanisms suit better in more dynamic and complex situations.

Related Work

One of the *Ten Usability Heuristics* of Nielsen [10] is *error prevention*: interfaces should be designed in a way that prevents users from making wrong inputs. Such erroneous inputs open up an entirely new dimension in the domain of automated driving, where user inputs cause a vehicle to execute maneuvers automatically. A way to deal with error-prone inputs is a confirmation option [10].

A system for maneuver-based guidance is *Conduct-by-Wire* (CbW) [7]. CbW is designed for a driver who is in the loop. The driver is not responsible for lateral and longitudinal control of the vehicle but for the selection of maneuvers (e.g. lane changes) and setting parameters (e.g. speed). A first input implementation for CbW was a touch screen with buttons for maneuver selection positioned at the steering wheel [8]. A evaluation revealed that users looked longer and more often on the input device than when using usual controls [5]. In consequence, another input mechanism, that decoupled visual representation (head-up display) and input (touchpad on armrest), called *pieDrive* [6] was implemented. To select a maneuver, the driver touches at a central area, then drags onto the desired maneuver on a semicircle (maneuvers are ordered according to the direction of the respective trajectory) and lifts off to select.

The driving task can be separated into four levels: *navigation*, *maneuver guidance*, *trajectory guidance* and *stabilization* [4]. Albert et al. [1] investigated interaction concepts that assigned parts of the driving task differently between automation and driver according to these levels. This resulted in two concepts that implemented maneuver approval: First, *trajectory control* where a touch triggered the selected maneuver instantly. Second, *maneuver planning* where the user had to drag the desired maneuvers in a queue which will be executed by the automation.

	overtaking
O1	*If you would like to overtake, you are responsible for the maneuver.*
O2	*Please select.*
O3	*If you intend to overtake, check the lane to the left and approve the maneuver.*
O3a	*Check the traffic on the lane to the left and approve the maneuver.*

	T intersection
T1	*You can speed up the continuation of the journey by checking the lanes at the intersection.*
T2	*Please select.*
T3	*You can approve the maneuver if the traffic from the left and right allows merging.*

Table 1: Speech message content.

	base-line	confir-mation	count-down
1	O1|T1 O2|T2 O3|T3	O1|T1 O2|T2	O1|T1
2		O3a|T3	O2|T2 O3|T3

Table 2: Dialog composition.

In contrast to the previously presented concepts that were designed for partial and conditional automation, Walch et al. [14] investigated a touch screen maneuver approval system for highly automated vehicles to overcome system limitations with the help of drivers who were out-of-the-loop. The presented maneuver approval concepts have in common, that they do not provide mechanisms to check whether the input was executed intentionally. In consequence, we implemented two different strategies to avoid erroneous inputs in maneuver approval contexts – these seem especially important when maneuvers are triggered instantly.

Maneuver Approval Strategies

We implemented three different maneuver approval strategies: first a *baseline* condition without any safety mechanism, second a classic *confirmation* dialog, and third a disabled button that becomes active after a 3.5 s to 6 s *countdown* (depending on the scenario). Our system allows drivers to support the automation to overtake a slower moving or standing car or to merge faster on a priority road at a T intersection. The system cannot execute the overtaking maneuvers on its own due to blocked sensors or an insufficient sensor range caused by a car ahead or the environment (see Figures 2 & 3). In case of the T junction (Figure 4) the system would enter it very slowly. Drivers are able to approve maneuvers or express their intention (confirmation) via a touch screen in the center console. Figure 1 shows a schematic view of the GUI with an *execute / plan maneuver* and a *continue current maneuver* button as well as a *status display* that presents the automation's current plan, the preceding vehicle and the areas on the lanes which cannot be sensed. The label of the execute / plan maneuver button differed between conditions and scenarios, e.g. in the overtaking scenarios: "overtake now" (baseline & countdown) or "plan overtaking" followed by a confirmation dialog with a "lane free" button (confirmation). The system informed the driver with speech messages regarding the available options and resulting consequences. The snippets in Table 1 are displayed at different points of time depending on the conditions as shown in Table 2. In the baseline condition, the system gave all the information at once. In contrast, in the confirmation condition, the system first asked the drivers to make a selection and then informed them what traffic elements to check when approving. In the countdown condition the drivers were only informed about the optional maneuver and what they have to do to conduct it. In the second step (after the countdown activated the button) the system asked them to select and informed them what they have to check. All spoken information was given prior the maneuver approval via the "lane free" / "overtake now" buttons. Participants had the option to cancel the maneuver execution with a "cancel" button.

Experiment

We conducted a 3 (scenarios) x 3 (systems) repeated measures study with 18 participants (3 without driving license, 10 female) with an average age of 24.11 years ($SD = 4.11$) in a fixed-base driving simulator. Each participant experienced after a simulator training and an introduction regarding the maneuver approval system 9 trials in counterbalanced order (there were always 3 trials consecutively with the same system condition). Participants were instructed to play a quiz game on a tablet while driving automatically.

Results

The participants past in total 162 scenarios. After each of these we asked them whether they would have preferred to execute the maneuver manually. The majority of 78.94% declined. Regarding the different situations, 26% voted for a manual execution in the T junction condition, in the two overtaking situations only 19% did so.

Figure 2: Slower vehicle ahead.

Figure 3: Standing car ahead.

Figure 4: T junction, ego vehicle has to yield.

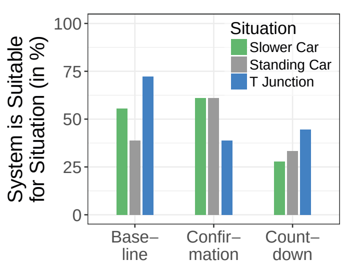

Figure 5: Suitability of systems.

Participants had to rate their workload on the *Driving Activity Load Index (DALI)* [11] questionnaire. On average, they rated their mental workload with 3.43 ($SD = 1.05$) in the baseline, 3.29 ($SD = 0.96$) in the confirmation, and 3.32 ($SD = 1.02$) in the countdown condition. These results indicate a relative low mental load in all three conditions (scale ranged from 1 – 7). There were no significant effects of situation nor of the system condition.

After the participants passed the three different scenarios with one system, we assessed the usability with the *PSSUQ* questionnaire [9]. The usability of the baseline system was rated with 5.94 ($SD = 0.76$), the confirmation condition 5.95 ($SD = 0.75$), and the countdown condition with 6.0 ($SD = 0.77$) – overall a positive result regarding the usability of all three systems. A Friedman's ANOVA did not reveal any significant differences. Moreover, we asked them whether they were aware of the system boundaries with the help of the system, they rated their agreement on a 7-point Likert scale with 5.11 ($SD = 1.41$) in the baseline condition, 5.05 ($SD = 1.43$) in the confirmation dialog version and 4.77 ($SD = 1.43$) in the countdown condition. At the end of the session we asked the participants which system was the most self-explanatory and matched the expectations to the highest degree: 15 participants (83.33%) voted for the baseline implementation, 5.56% for the confirmation and 11.11% for the countdown condition. Moreover, they had to choose which system variants are suitable in which situations, the results plotted in Figure 5 indicate that the baseline condition was voted most frequently for the T junction condition, whereas the confirmation version was chosen most for the remaining overtaking situations.

We observed some erroneous maneuver approvals in our experiment: in two cases there occurred a head-on collision (there were no safety features activated in the automation) shortly after approving an overtaking maneuver (baseline & countdown), in two other cases participants selected to overtake on an unclear section – however the automation finished the maneuver just-in-time (baseline). In two cases, participants approved to merge at the T junction although there was traffic but they stopped the maneuver with a cancel button in time (baseline & countdown). None of these situations appeared in the first run with a system, thus participants used each system at least once successfully.

Discussion & Conclusion

Our participants liked the concept that they only had to make a decision to execute maneuvers automatically rather than taking over control. The one-tap condition without error prevention mechanism was preferred, however the results indicate that participants are aware that the additional effort of a confirmation is reasonable in the overtaking scenarios. Both examined mechanisms (confirmation dialog & countdown) provide the same high satisfaction and usability scores and equally low mental workload as the baseline condition. We observed a few critical situations when participants approved maneuvers at the wrong time, this highlights the importance of mechanisms to avoid erroneous inputs. In two of these situations the participants succeeded to cancel the maneuver before an accident occurred. None of these critical situations occurred when participants were prompted with a confirmation dialog. Nevertheless, more research is necessary to get a deeper understanding under which circumstances drivers make erroneous inputs or wrong decisions and how the system can prevent these.

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