Cooperate Rather Than Hand Over: Overcoming System Boundaries in Highly Automated Driving

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Abstract
A vast amount of research is being conducted in the field of automated driving and step by step this technology is being introduced onto the market. Nevertheless, there are still limitations and system boundaries that do not allow yet for fully self-driving vehicles regardless of situational circumstances on public roads (e.g., bad weather conditions and complex urban traffic scenarios). A major research question in the HCI field concerns how to deal with system boundaries in automated driving. There has been a vast amount of research regarding handovers—entire control shifts. However, due to human factor issues like the lack of situation awareness that arise with automated driving we propose that there should be less binary interaction concepts: driver-vehicle cooperation. We propose involving the driver in vehicles' decision making and in approving maneuvers. Further, we want to spark discussion on advantages and potential challenges of this approach.

Author Keywords
Automated driving; human-machine cooperation.

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H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction

Vehicles that implement automated-driving technologies are already on our roads. However, the vision of future mobility in which humans are solely passengers who enter automated vehicles that chauffeur them to the desired destination are still a long way off. There are still situations which automated systems cannot handle [10]. As a result, users have experienced unexpected behavior of their commercially available systems [2, 4]. With the advent of automation in cars, the role of drivers is changing over time from being the controller to a supervisor and maybe eventually to a passenger. This shift causes several human factor issues: *overreliance*, *behavioral adaption*, *erratic mental workload*, *skill degradation*, *reduced situation awareness*, and an *inadequate mental model of automation functioning* [9].

The technological limitations can be overcome with the help of the "driver". It has been proposed to hand over control to the driver when the system reaches its boundaries (see [7, 8, 13] for an overview). It has been shown that such handovers are feasible, but due to human factor issues like lacking situation awareness, cooperative interfaces are promising to overcome system boundaries without shifting the control entirely [13]. One facet of cooperative interfaces is haptic shared control [1] (e.g. H-Mode [6]) wherein system and driver control the vehicle together at the same time with varying amounts of influence. In contrast, we focus on interaction paradigms that are more abstracted from the actual lateral and longitudinal control and that require driver engagement only at system boundaries, for instance approving maneuvers [11, 12] or making decisions [14].

Asking the Driver What to do Next

As mentioned above, automated vehicles reach their system boundaries from time to time. In cases when automated driving is only supported on highways and the vehicle is about to exit a highway, a transition to manual driving is necessary. In contrast, there will be situations where an automated vehicle cannot continue the journey on its own because the system cannot decide how to deal with a specific situation. For instance, if a vehicle senses a non-moving vehicle in front on a rural road it might not be able to classify the situation correctly – is someone parking inappropriately, has there been an accident and the driver should act as a first responder, or did the accident victims already get help? In such situations, the vehicle can provide alternative actions like stopping, overtaking or taking a detour, among which the driver can choose from [14]. We propose that such cooperative interaction is beneficial compared to handovers, as the drivers that are likely out-of-the-loop and lack situation awareness are not involved in the actual lateral and longitudinal control of the vehicle.

Using the Driver as an Additional Sensor

Besides letting drivers decide what action should be performed, it is also feasible to use them as an additional sensor, as they might have a better overview and understanding of the traffic scene. For instance, if there is a slower vehicle in front of the ego vehicle on a two-lane rural road that blocks the sensor range and in consequence impedes an automated overtaking maneuver, the driver can approve the overtaking maneuver [11, 12].

Challenges for Cooperative Interfaces

As mentioned earlier, relieving drivers of the actual driving task—be it handovers or cooperative concepts—leads to several human factor issues which open up new challenges for interface and interaction design. The drivers may lack situation awareness but are asked to approve maneuvers or to decide what the vehicle should perform next. In consequence, such cooperative systems should know the driver state and only allow for cooperation when they can be sure

that the driver is able to cooperate. In more general terms, four basic requirements for driver-vehicle cooperation have been suggested to enable automated driving with imperfect automation: *mutual predictability*, *directability*, *shared situation representation*, and *calibrated trust in automation* [13].

Conclusion

Automated vehicles will reach their boundaries occasionally, thus a large amount of research has been conducted to investigate the binary handover concept in which one agent is in charge at one time. In unforeseeable situations handovers are problematic due to human factor issues like the out-of-loop performance problem [5]. On the general subject of human-machine interaction, Dekker and Woods have proposed that "system developers should abandon the traditional 'who does what' question of function allocation. Instead, the more pressing question today is how to make humans and automation get along together" [3, p. 243]. Applying this concept to the field of automated driving, we are investigating cooperative interaction on a high level of abstraction from the driving task (e.g., decision making, perceiving and classifying complex situations, and approving maneuvers). We recommend the use of cooperative interfaces to broaden the circumstances in which automated vehicles can drive on their own and to avoid entire handovers whenever possible. Moreover, we hope to spark a discussion about our vision of automated driving—we hope to see automated vehicles and their driver become a team where both parties complement each other. Furthermore, we hope to learn from other domains and prompt potential collaborations to explore how automated vehicles and their drivers can mutually benefit each other.

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