Challenges of Explainability, Cooperation, and External Communication of Automated Vehicles

Mark Colley[1], Enrico Rukzio[1]

[1]Institute of Media Informatics, Ulm University, James-Franck-Ring 8, 89081 Ulm, Germany

Abstract

In this position paper, we describe current research questions in the area of interaction with automated vehicles from the viewpoint of users within the vehicle (i.e., passengers) and from the viewpoint of parties outside the vehicle (e.g., other manual drivers or pedestrians). First, we briefly introduce the topics of *Cooperation with Automated Vehicles*, *External Communication of Automated Vehicles*, and *Explainability of Automated Vehicles* before posing, in total, nine research questions guiding these three areas.

Keywords

Automation, vehicles, eHMI, explainability, cooperation, HMI

1. Introduction

Automated vehicles (AVs) are expected to change journeys and, in general, traffic fundamentally [1]. Despite the numerous anticipated advantages (fewer accidents, more time for non-driving-related activities [2], reduced fuel usage), currently, there are two major research areas targeted towards the successful integration of AVs in the life of non-expert users (i.e., the passengers) and also the bystanders of AVs, that is other (vulnerable) road users that have no say in whether they want to interact with them such as pedestrians or bicyclists [3].

Regarding the passengers, current work can be (among other areas) broadly distinguished into take-overs [4, 5], cooperation to overcome system boundaries [6, 7, 8, 9], explainability of the AV's actions [10, 11, 12, 13, 14], and simulators to enable valid experiments [15, 16, 17].

Regarding bystanders, especially the (potential) need to replace current driver-road user communication via external Human-Machine Interfaces (eHMI) is investigated [18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32].

In this position paper and based on our work in these areas, we describe what we see as current challenges of AVs as highly automated systems that permanently interact with other road users and their primary intended users (i.e., the passengers).

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mark.colley@uni-ulm.de (M. Colley); enrico.rukzio@uni-ulm.de (E. Rukzio)
https://m-colley.github.io/ (M. Colley)
0000-0001-5207-5029 (M. Colley); 0000-0002-4213-2226 (E. Rukzio)

2. Cooperation with Automated Vehicles

Figure 1: The user interface of the ORIAS system for cooperation in AVs; taken from [8].

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Besides the classical take-over process [33, 5], cooperation has been suggested as a way to overcome both the shortcomings of today's technology, for example, in object recognition [6] or when integrated knowledge is necessary (e.g., legal requirements to parking somewhere). Such an approach will leverage the capabilities of automation and the integrated understanding of the user to enable safer and more pleasurable journeys. Here, the main question is:

1. *When is cooperation between an AV and a user possible, and which level of engagement has to be maintained during the monotonous part of the journey?*

While we presented first supportive work on this [8, 6, 34, 35] (see Figure 1), this area of research is still under-explored.

3. External Communication of Automated Vehicles

Recently, eHMIs have become a popular topic in the automotive domain [27]. External communication of AVs is researched to enable communication between AVs and other road users. This includes other manual drivers [36, 37] and vulnerable road users such as bicyclists or pedestrians. Numerous aspects have been investigated, including anthropomorphism [38], challenges of overtrust [39], various target groups such as children [40] or people with vision impairments [23]. However, in our opinion, several key questions remain:

2. *How can the aspect of scalability, that is, the communication of multiple AVs with multiple vulnerable road users, be solved?* [22]
3. *How can we as researchers include and aid people with disabilities, a group which is even more in danger in the heavy traffic of today's cities?* [20]

4. *What are the long-term effects of eHMIs?*
5. *How can eHMIs be visually pleasing and effectively integrated into the general concepts of automobile manufacturers?*
6. *Can eHMIs be useful for more than communication regarding the crossing decision?* (e.g., see [24, 41, 31, 32])
7. *Are eHMIs necessary or when are they necessary?* [42]

This field is especially interesting as people that are not instructed nor did they actively consent to using AVs in any way are involved in interacting with the AV. Therefore, this topic is one of the first to fully incorporate true novice users of automation.

4. Explainability of Automated Vehicles

(a) Derived pedestrian intentions; taken from [10]. (b) Displayed semantic segmentation result; taken from [11].

Figure 2: Examples from previous publications regarding the visualization of detected objects and intentions.

Schoettle and Sivak [43] found that 75% of respondents were at least slightly concerned about a possible system failure in unexpected situations. Additionally, the reliability of AVs is a worry of users [44]. Therefore, numerous works have investigated potential visualization concepts to communicate with the user of an AV [45, 12, 14].

One primary rationale regarding the explainability of AVs is to enhance and calibrate trust. Hoff and Bashier defined trust as "a variable that often determines the willingness of human operators to rely on automation" [46, p. 407]. They proposed a three-layered trust model, including dispositional, situational, and learned trust. *Dispositional trust* refers to the trustor's personal background (e.g., culture, age, and personality traits). *Situational trust* is categorized into internal and external variability. External variability refers to alterations occurring with changed automation complexity. Internal variability describes the trustor's mental capacity and psychological state. *Learned trust* was modeled in two layers: initially learned trust, that is trust based on known information about the automation) and dynamically learned trust (which is altered via interaction with the automation).

Hereby, the approaches target either *initially learned trust* (see Körber et al. [47]) or *dynamically learned trust* (e.g., [10, 11, 14, 12]; see Figure 2). Nonetheless, some significant questions remain unanswered:

8. *What are the long-term effects of using AVs, and how will interaction change?*
9. *How can include and aid people with disabilities, for example, people with vision impairments?*

With our approaches, we especially target to enhance calibrated trust by including uncertainty information into the communication (e.g., see [11]).

5. Conclusion

In this work, we briefly outline the two major research areas on automotive automation interaction: with drivers and users or with other road users such as pedestrians. For the three areas *Cooperation with Automated Vehicles*, *External Communication of Automated Vehicles*, and *Explainability of Automated Vehicles*, we briefly describe the previous work and define, in our view, currently relevant research questions.

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