Shared Control and the Democratization of Driving in Autonomous Vehicles

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Abstract
This paper presents design concepts for multi-user interaction for influencing driving style in autonomous vehicles. Since there is no real 'driver' in autonomous vehicles, it is relevant to look at the role of all the passengers in the car. By democratizing the decision making process surrounding the driving style of the car, all passengers have the opportunity to contribute to the travelling experience. The presented concept is an exploration aimed at inspiring designers of human-computer interaction in the car to let go of conventional hierarchies between passengers in a car context, which will be especially relevant in designing autonomous vehicles and car-sharing systems.

Author Keywords
Multi-user; autonomous vehicle; driving style; physical interaction; light behavior

CCS Concepts
• Human-centered computing ~ Interaction paradigms ~ **Collaborative interaction**
• Human-centered computing ~ **Interaction design**

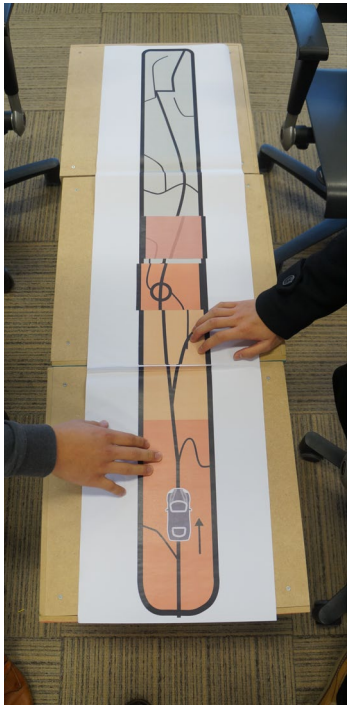

Figure 1: First paper design exploration. Shared control through a long touchscreen interface. Passengers can determine the driving style of the car for certain parts of the route.

Introduction

As car sharing and autonomous vehicles become more ubiquitous, standards for driving and transportation will change. However, the user of future concepts for interaction design in autonomous cars is usually still 'the driver' (e.g. in [2,9]), even when the cars are fully autonomous (automation level 5 [4]). In autonomous cars, this traditional role of driver does not exist anymore. There are just passengers, without necessarily any specific hierarchy between them. An existing area of research focuses on shared control between 'the driver' and the car which focuses for example on handover moments (e.g. [1]), but assuming that there is often more than one passenger, it becomes relevant to look at shared control between the different passengers as well as between passengers and the car.

We used a Research through Design approach [6] to explore the design of a multi-user system for level 5 autonomous vehicles that allows for shared control of the vehicle's driving behavior between passengers. Through such a system, decisions on the behavior of the car can be democratized by allowing all passengers to express their preferences. Tailoring the behavior of the car to the group instead of the individual can create a better transport experience for all passengers instead of only one.

While defining concepts for shared control in autonomous vehicles, we used aspects that are important in shared control systems in general, such as multi-user dynamics and social translucency [3,7]. We defined the driving behavior of the car as 'driving style', as it has been found to influence people's subjective experience of a ride in an autonomous car [8]. We focused on 'assertive' and 'defensive' driving styles presented in the literature. A shared control system with which passengers can provide the car with input on its driving style gives back autonomy to the passengers, while sustaining the newfound safety and ease provided by autonomous vehicles.

In the following sections, two concepts for shared control in autonomous vehicles are presented, as well as design considerations for future multi-user systems in autonomous vehicles.

Concept Design

Concept 1

A first design concept represented the shared control system as a long touchscreen located in the middle of the car, such that all passengers have access to it (Figure 1). On the screen, the route that the car is following is displayed. Passengers can change the driving style of the car on a scale from defensive to assertive for parts of this route by swiping through different driving styles.

While the shared control aspect is clearly present in this concept, there is still a certain hierarchy between the passengers, as the passengers in the front seats can overwrite any preferences indicated by the passengers in the back. Also, the car has little agency in the interaction, as it has to obey the settings as determined by the passengers. In a second iteration, these aspects were explored further.

Concept 2

In the second design concept, the car was specifically represented as an autonomous agent in the interior by integrating a circular light object in the dashboard of

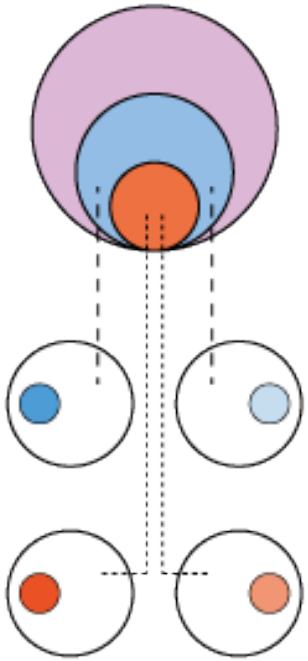

Figure 3: A schematic representation of the different design aspects of concept 2. The large circle at the top is the 'heart' of the car, the four smaller circles represent the senses. The dashed lines show which part of the 'heart' is influenced by which sense.

the car. The behavior of this object represents the state or 'heart' of the car. The colors of the lights reflect driving style, ranging from assertive (orange) to defensive (blue). The outer circle shows the overall state, the middle circle shows the preferences of the people seated in the front, and the inner circle reflects the preferences of the people in the back. Dynamics of the light show how the car feels about the input given by the passengers: flickering lights can for example show that it is not sure what driving style to use due to conflicting inputs.

Passengers can indicate their driving style preferences by interacting with the car's 'tactile senses'. These senses stretch out to the back, coming together at four places (one for every passenger). Pressing the soft sense will tell the car that the passenger prefers a more assertive driving style, while stroking it gently will show a preference for a more defensive driving style.

As the car is an agent in this multi-user system, just like the passengers, it is important that passengers are able to see it thinking and processing information. This is currently presented through traces of light appearing at different places in the car. The movement and color of the light shows how the input of the passengers travels from a sense to the heart in the dashboard, so that everyone knows that communication is happening.

The prototype can be seen in Figure 2, while a schematic representation of the different parts can be seen in Figure 3.

Design Implications

Based on the above prototyping iterations, we propose that shared control systems integrated into autonomous vehicles should consist of:

- A personal user interface for every passenger that allows them to indicate desired changes in the car's behavior;
- A communal interface which shows a combination of the indicated desired changes in the car's behavior;
- A vehicle interface where the autonomous vehicle (AV) displays its current behavior and how certain it is of the actions it must execute;
- A visualization of the occurrence of an indicated desire for change in driving behavior.

Figure 2: The prototype representing the interaction and behavior of concept 2. The purple circle of light is the 'heart' of the car integrated in the dashboard, while the black circles are the senses for every passenger.

Discussion

In this work, we deliberately took a multi-user approach, to enable shared control between the passengers of an AV, as well as between the passengers and the AV itself. Since this idea has not been explored before, our main contribution to the area of interaction design for autonomous vehicles is the idea of democratizing driving.

In the presented collaborative interaction, the visibility of the actions of system agents (in this case both the car as well as the different passengers) is an important aspect in achieving shared control and ultimately the democratization of driving. This fits within existing literature which states that the communication of intent helps to develop shared situational awareness and trust [5].

Our work poses the idea that multi-user control is an interesting option to explore. The presented concepts are however initial design explorations and have not yet been thoroughly evaluated with users. Therefore, future research might focus on how people react to the idea of multi-user interaction within a car context, which is especially relevant for car sharing systems, as well as how they deal with the levels of control we provided in our design. This can be evaluated through Wizard of Oz experiments in a simulation setting where it is especially relevant to look at the group dynamics of diverse groups (e.g. families versus people who do not know each other).

We believe that future research into autonomous vehicle design can benefit from researching into the multi-user direction, because of the changing role of 'the driver' in autonomous vehicles. We hope that future researchers can use our work as an inspiration to look in a different direction than most current research in the area of autonomous vehicles, and that they will look beyond traditional hierarchies and forms of interaction in the car.

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