Report from Dagstuhl Seminar 19132

Users and automated driving systems: How will we interact with tomorrow's vehicles?

Edited by

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Abstract

In today's vehicles, the driving task is increasingly often shared between the driver and the vehicle. It is expected that this will become the norm rather than the exception in the foreseeable future: on some road segments the driving task will be automated, and drivers will become passengers. Thus, we need to design automotive user interfaces with partial automation, and even full automation, in mind. This was the underlying motivation to propose and run this seminar. In the Dagstuhl seminar, six inter-related key research questions were addressed: First, "how to design user interfaces to support the driver's transition back from the role of passenger to the role of driver?". Second, "how user interfaces can support work and play for drivers while the vehicle is controlled by automation?" and third "how we can support communication between all transportation users, from drivers, to pedestrians, to bicyclists?". Furthermore, we explored "how the design of automotive user interfaces affects trust in automation?" and finally discussed "how novel technologies, such as augmented reality displays or advanced spoken dialogue systems can support drivers, and others, in and around partially-, and fully-automated vehicles?". As an umbrella topic, the question "how all of these questions relate to the legal aspects of deploying automotive user interfaces?" received also high attention and lively discussions amongst participants. Dagstuhl seminar 19132 is a follow-up of the 2016 Dagstuhl seminar 16262 "Automotive User Interfaces in the Age of Automation" and brought (again) together researchers from HCI, psychology, cognitive science, human factors, automotive industry/OEMs and people active in the standardization process to discuss critical problems on the way to automated driving.

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1 Executive Summary

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For much of the time since the invention of the automobile, human-machine interaction (HMI) in vehicles was reasonably clear: drivers controlled the vehicle by manipulating the steering wheel, pedals, and a few levers, buttons, or similar mechanical input devices [2]. They received information about the state of the vehicle through dials, warning lights, and sounds. And, they interacted with a relatively simple in-vehicle entertainment device: the radio, or perhaps the cassette- or CD player.

It is true that the number of input and output devices increased dramatically over the years — for example in the late 1950s, the Ford Edsel was described as a "devilish assemblage of gadgets" [5]. The Edsel was soon out of production, but the number of gadgets kept climbing. It is also true that drivers sometimes operated the vehicle when they were tired, and fell asleep at the wheel. Other times they consumed too much alcohol, and were not able to safely control their vehicle. Yet, the basic concepts of human-machine interactions in the vehicle were well-defined for research and development purposes. The driver's primary task was to drive: keep the vehicle on the road, avoid crashes, maneuver through traffic, and ultimately reach a destination. The driver also engaged in secondary tasks, such as manipulating the radio, as well as other non-driving-related tasks, such as talking to passengers, and eating. Creating good human-machine interfaces meant supporting the driver in these primary and secondary tasks, while assuring safety for everyone on the road.

Then, with the introduction of mobile computing devices, engagement in secondary tasks, such as talking to remote conversants, as well as sending text messages, and manipulating the interfaces of various mobile applications, became a significant issue in cars. In a sense these distractions were the same as those that drivers faced with the myriad buttons in the Ford Edsel. But, there were differences too: the Edsel did not allow the driver to communicate to remote conversants, nor did it have a touch-screen with ever-changing content.

Today, we again find ourselves at a crossroads. Our cars have myriad buttons, as well as different mobile technologies, both for drivers and for passengers. But, additionally, the primary task of driving is often shared between the driver and the vehicle [9]. Most studies in distracted driving tend to focus on how non-driving activities serve as a distraction from the primary task of vehicle control. In the context of highly automated vehicles (HAV), driving will be the distraction from non-driving activities [6]. Sometimes, the vehicle can effectively take over the driving task, and we can expect that this will become the norm rather than the exception in the foreseeable future: the driving task will be automated, at least on some road segments, and the driver will become a passenger. Yet, in this same foreseeable future we can also expect that the vehicle will sometimes hand the driving task back to the driver, who will have to transition back from the role of passenger to the role of the driver [14], [18]. This is the new landscape of in-vehicle human-machine interaction, and it presents a number of research questions that we addressed in this Dagstuhl seminar. In the rest of this report, we introduce pre-workshop tasks and summarize the activities and outcome of the seminar. Automated traffic is a challenge not limited to the interaction between a human driver and an automated vehicle. Automated vehicles will be part of a mixed traffic with other traffic

Figure 1 Traditional group picture of participants of seminar no. 19132 on the stairs of Dagstuhl castle.

participants of less or no automation. Also further traffic participants such as pedestrian and bicycles are part of this and requires a certain level of communication and recognition of the vehicles intention and actions among vehicles and the surrounding traffic participants.

Research questions tackled in Dagstuhl seminar 19132

1. **Handover:** One of the key questions in designing in-vehicle human-machine interaction for partially automated vehicles is, how can the vehicle safely hand back the task of controlling the vehicle to the driver. In the short term this is one of the most important questions for those designing vehicles with automation, because in the short term such vehicles will have to hand control back to the driver relatively often [14], [15]. We need to understand how the modality, conveyed information, and reliability of take-over requests (TORs), engagement in non-driving tasks, and motion perception can influence drivers performance in task switching in highly automated driving context [6].
2. **Trust:** Drivers must trust the automation features in order to take advantage of them [19]. We need to individually understand the trust in the individual actions of the vehicle starting out from assistance systems [21] to more automated functions [13], [20].
3. **Creating a place for work and play:** One important benefit of automation would be that drivers can become passengers, and thus use the time in the vehicle to either be productive (work), or relax (play). How can human-machine interaction for automated vehicles be designed, such that drivers can take advantage of their newfound freedom from driving [9], [12]? How can we do this, taking into account the physical and computational characteristics of the vehicle, as well as the potential for motion sickness?

4. **Communication between all traffic participants:** With the advent of automation, the transportation environment will include partially and fully automated vehicles. Yet, manually driven vehicles will remain for the foreseeable future, as will pedestrians, bicyclists, and other transportation users. For safe driving, all of these transportation users will have to communicate, but it is not yet clear how this can best be accomplished [16].
5. **Advanced technologies for in-vehicle HMI:** The technologies that are available for human-machine interaction are continuously improving. Two exciting technologies that will be worth examining in the context of automated vehicles are speech interaction (e. g. [8]), and augmented reality e. g. [11] and [10].
6. **Legal aspects of in-vehicle interfaces:** Automation, as well as the user interfaces built for partially and fully automated vehicles, will have to fit into the legal structures of the countries where the vehicles are used [7]. What are these structures, what do designers need to know about them, and how can they help develop the future legal structures?

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3 Pre-Workshop Tasks

In advance to the seminar we asked the participants some fundamental questions in the area of the seminar to be able to better prepare the Dagstuhl seminar and to ensure it is a valuable experience for all the participants. The following three questions were sent-out to participants and responses collected.

Suggested Readings

Question 1: "What is some publicly available work (e. g., a paper, an app, a prototype, etc.) created by someone else that you find very inspirational in your work related to the interaction with automated driving technology? Please send us one or two PDFs or references/links."

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Work Authored by Seminar Participants

Question 2: "What is one (publicly available) work of yours (e. g., a paper, an app, a prototype, etc.) related to the seminar topic that you would like to share with fellow Dagstuhl seminar participants? Please send us a PDF or reference/link (two are also ok)."

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Research Questions

Question 3: "What do you consider to be the most challenging/interesting research question related to interaction with tomorrow's vehicles? (If you have more than one question, that's great, send them all..)"

The following list of categorized research questions (no particular order otherwise) was used to structure the seminar and initiate discussions in the field.

- **Trust calibration**
  - How can calibrated trust into automated vehicles' capabilities be achieved by HMI design? (M. Baumann)
  - What influences long-term trust development into and interaction behavior with automated vehicles? (M. Baumann)
  - How to establish a purposeful user understanding of the usefulness and boundaries of the (semi-) autonomous driving system? (I. Pettersson)
  - What are suitable strategies for long-term trust development? (J. Ziegler)
  - How can you measure trust objectively? (G. Burnett)
  - What is an appropriate level of trust? (G. Burnett)
  - What HMIs can help in the development of calibrated trust? (G. Burnett)
  - What factors will affect trust in automation? (B. Walker)

- **AV-driver/passenger interaction**
  - How can automated vehicles made cooperative team players for the drivers? (M. Baumann)
  - How can automated vehicles interact smoothly with surrounding non-automated traffic? (M. Baumann)

  - How to make sure that both are aware of the other in a correct way, also if there are changes over time? (C. Janssen)
  - If they can't "sit back and relax", how do we keep them alert and awake in an appropriate way? (C. Janssen)
  - Collaboration metaphor as a concept of driver-vehicle interaction in an autonomous vehicle. (J. Sodnik)

- **Ethical/legal issues**
  - What right do vehicles have to judge the competencies and limitations of their users? (L. Chuang)
  - What should go to ISO? (J. Krems)

- **System transparency, Explainable UI**
  - Should vehicles communicate their limitations to their users? How often, which, and how? (L. Chuang)
  - If things do go wrong and human assistance is needed: How can the driver be informed/warned correctly and timely? (C. Janssen)
  - Future vehicles will be equipped with a wide variety of automation features that provide differing degrees of automation of the dynamic driving task within different operational design domains. Individual vehicles are likely to be equipped with several such features, each with its own driver interface. How will the driver of the future be able to understand the capabilities and limitations of these systems? (S. Shladover)
  - Should automated vehicles be able to explain their behavior and if yes, at which level and how? (J. Ziegler)
  - How can the user be informed about decisions of the autonomous system? (N. Rußwinkel)
  - Implicit or explicit signals? (J. Krems)

- **User state assessment**
  - How to correctly assess both the human's and the systems attention, understanding of system functioning, situational awareness? (C. Janssen)
  - How to evolve driver/car sensing & communication? (I. Pettersson)
  - How important is it to correctly detect driver's state (physical and mental)? (J. Sodnik)
  - How can/should the driver be made aware of the status of the world and the state of the (automated) vehicle? (B. Walker)
  - The need for new types of information means that we need new technological approaches: Driver Monitoring to determine driver state for decision making concerning driver ability, availability, receptivity and what we do with that information? (J. Harbluk)

- **User experience**
  - How to balance "safety" with "pleasure" and being relaxed. That is: if cars get better, at what stages can people truly "sit back and relax"? (C. Janssen)
  - How to balance between branding vs. consistency? (I. Pettersson)
  - What is an acceptable level of notifying drivers with ads or location-based recommendations (POIs, activities, services etc.) and how should they be presented? (J. Ziegler)
  - Can automated vehicles be „creepy“ and for whom? (J. Ziegler)
  - In a shared economy with no individual car ownership, what is the concept of a car manufacturer to gain customer loyalty? (A. Riener)

- **Mode confusion**
  - How to prevent mode confusion & misuse? (I. Pettersson)
  - How can the driver interfaces be designed to support safe and proper usage of these systems (while also deterring or preventing improper usage)? (S. Shladover)

- **Driving safety**
  - Is driving behavior safer when using automated functionalities in the vehicle? (J. Sodnik)
  - How different is driving distraction between automated and conventional vehicles? (J. Sodnik)
  - Safer road traffic, especially for young people. (C. Sutter)
  - Traffic safety issues in traffic 5.0. (C. Sutter)
  - How to make sure that AI works in automated vehicles as designated? (...will not have seen many situations/scenarios in training data before; how to identify edge cases?) (A. Riener)
  - How do we assess safety? How will we evaluate this? How will we know when we have accomplished this goal? (J. Harbluk)

- **Human individuality, user preferences**
  - HMI concepts for urgent take-over situations – can one concept fit all driver groups (age, gender, experiences)? (J. Sodnik)
  - How will different users respond to varying types of monitoring? (G. Burnett)
  - How can an HMI adapt accordingly based on user data? (G. Burnett)
  - How can we predict the impact of cultural background on UX design? (G. Burnett)
  - How can we objectively assess cultural differences for future vehicle designs? (G. Burnett)
  - How will automated vehicles help/hinder persons with disabilities (as drivers, passengers, pedestrians, etc.)? (B. Walker)
  - How to address human individual preferences (vehicle dynamics, driving speed, overtaking behavior) in (fully) automated vehicles? (A. Riener)
  - Will it be possible for the individual to parametrize the driving algorithm? (A. Riener)
  - How do we best characterize the mental models of the users and the vehicles so that we can design to support successful and safe interactions? (J. Harbluk)

- **Future research directions**
  - How do we "accurately" predict the short-term/long-term capabilities/limitations of AV technology so that we can better direct our research efforts? (B. Donmez)
  - Predictive policing in traffic safety (cf. DDACTS). (C. Sutter)
  - What factors will affect uptake/adoption of automated vehicles? (B. Walker)
  - The need for new methods: What to measure, how to measure and the interpretation of new complex & types of data? (J. Harbluk)

- **Transition of control**
  - What information do people need for transitions in/out control? (G. Burnett)
  - What is an acceptable level of human performance in resuming control? (G. Burnett)
  - What exactly, is a handoff/takeover request and how the heck will the engineering/design match human capabilities? (B. Walker)
  - In what situations should the control be handed to the driver and in what situation the driver would be incapable to take control? (N. Rußwinkel)
  - What are the relationships between usability and inadvertent operation for transition HMIs? (G. Burnett)

- **Motion sickness**
  - What HMIs can alleviate motion sickness? (G. Burnett)
  - How can we predict motion sickness? (G. Burnett)
  - Is yawning an accurate predictor for motion sickness? (A. Riener)

- **Situation awareness**
  - What role can multimodal interfaces play in automated vehicles, especially related to situation awareness? (B. Walker)

- **Remote operation, teleoperation**
  - Teleoperation has the potential to employ L5 functionality already at L3+. What needs to be done in order for the passenger to accept remote operation by a human (instead of an automated driving function)? (A. Riener)
  - How to design the user interface for the remote operator to get full awareness of the situation? (A. Riener)
  - Will there be a bi-directional communication between passenger and remote operator to enhance operation quality and improve on trust/acceptance? (A. Riener)

4 Overview of Talks

4.1 Striving Towards Safe Collaborative Interactions in Automated Driving

Ignacio J. Alvarez (Intel – Hillsboro, US)

I am excited to take part in this seminar because it aligns with my user-centered philosophy to automated driving. I see the purpose of automation in augmenting the human driving potential to achieve safer and more enjoyable driving experiences. And I am a firm believer that intelligent connected automated vehicles is the solution to provide safer and more effective means of transportation to fulfill society needs. My work is focused on the development of intelligent automated driving systems and the development of tools to create human – system collaboration which include simulation environments, HMI prototyping, and research processes. Some of the biggest challenges we currently face are how to design automation systems that understand humans in all their complex needs but also how can we design interfaces that allow users to understand automated driving systems, their decisions and operational envelopes. The reconciliation of human vs system judgment is a first step to solve the human-in-the-loop conundrum. The next step is to develop vehicles that adapt to the particular user needs while at the same time guaranteeing societal needs which might come at the expense of the individual. The first and most important interaction challenge in partial or full automation we need to solve is safety and the calibrated trust interactions it requires to work collaboratively. To this end Intel has released an open-source library on responsibility sensitive safety that will enable researchers to integrate it into automated driving systems and simulators to study the required user experience needs from the human end. I expect the seminar will help us share tools, methods and results. I see the time here as critical to define a common strategy that through collaboration in our next research phases will give us the answers and solutions we need to influence the future of the transportation industry.

4.2 Vehicle Automation as Team Player

Martin Baumann (Universität Ulm, DE)

The technological progress in recent years makes the vision of fully automated vehicles in the near future plausible. These vehicles will change the driver's role dramatically. They will take over many if not all of driving tasks for some or even all the trip time. By definition these vehicles are able perceive their environment, assess the situation and the possible actions and carry out the actions on their own. Consequently, these vehicles constitute a second autonomously acting intelligent agent next to the human. This creates the danger of so called automation surprises, that is the human in the vehicle does not understand, what the automation is currently doing, why it is doing this, and what it is going to do next. Such a lack of understanding may lead to safety critical interventions by the human, to low trust into and low acceptance of such systems. This in turn will significantly reduce the possible positive impact such systems can have on traffic safety, efficiency and the human drivers' comfort. To avoid such problems it is of pivotal importance that the vehicle can act as a team player to the driver. For this it is necessary that the automation possesses the ability to communicate with the human inside the vehicle to achieve a shared situation representation between human and machine agent. On this basis the human driver is able to predict the automation's action and to direct the automation in case the situational characteristics require it. This provides the basis for successful trust calibration and in the end a successful, efficient and satisfying driver-vehicle cooperation.

4.3 Social Interaction of Vulnerable Road Users with Automated Cars

Susanne Boll (Universität Oldenburg, DE)

We currently see the advent of automated driving. In the near future there will be mixed traffic scenarios in which vehicles with no, partial, and full automation will coexist and have to cooperate with traffic participants, including pedestrians and cyclists. Road traffic appears to be a highly regulated system in which agents act according to traffic code rather than their normative beliefs and values. Many interactions in urban traffic, however, are not or only weakly legally regulated and observed. They base on established social practices by social norms. There are many traffic situations (e. g., flashing when turning, overtaking or leaving a roundabout, narrow places where a lane ends on a multi-lane road, e. g., due to construction sites or obstacles) in which cooperative, reciprocal behavior is needed to avoid conflict.

Hence, we need to understand the effect that automated vehicles might have on the established interaction between traffic participants in urban traffic. How will automated and autonomous vehicles change social practices of cooperating in urban traffic scenario? How is social behavior changing in traffic with increasing numbers of automated vehicles? How much social behavior should an automated vehicle show for a successful cooperation in mixed traffic scenarios.

We aim to understand how the interaction between human and automated traffic participants changes social norms. We investigate in which way trust and respect among traffic participants change and a "dehumanized" traffic participant maybe be treated with less respect or forgiving as a human traffic partner. We are developing paradigms of interaction for a social signal for relevant traffic scenarios. The result of this part of our research will be intuitive and unambiguous cues that automated vehicles can give to surrounding traffic participants, such as pedestrians, cyclists, and drivers of non-automated vehicles.

4.4 The Future of Research in Autonomous Vehicles

Linda Ng Boyle (University of Washington – Seattle, US)

Technology continues to revolutionize the way we travel. While a truly driverless society will most likely not occur in our lifetime, it is the promise of our future. As research moves forward, the limitations of the technology, the infrastructure and the human user will need to be considered for some time to ensure appropriate design, training and policies. Research in autonomous vehicles (ground transportation) benefit from insights from other domains that include manufacturing, health-care and aerospace. For example, in aviation, extensive work has been conducted in supervisory control [1], shared control [2], shared perception of risks, and shared understanding ([3], [4]). This includes interactions with the human pilot, co-pilot, traffic controller, and automation. Research questions need to take into account the context and the human operator's goals when traveling (work, play or relax) as these will impact the operator's ability to interact, trust, accept and use their transport system [5]. Qualitative as well as quantitative approaches are needed to account for "hand off" as well as "take over" issues [6], this needs to be considered from the system as well as the human's perspective. Along with this, comparable test scenarios and test cases are needed to ensure that research is reproducible and repeatable.

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4.5 Designing New User Interfaces for Cars and Passengers

Stephen Brewster (University of Glasgow, GB)

The amount of time spent traveling is on the rise: 3.7 million workers in the UK alone travel for two hours or longer every weekday [1], and this situation is mirrored across Europe, with 8.1 % of commuters traveling to different regions and 0.9 % commuting across borders [2]. The proportion of this time spent as passengers is increasing, thanks to new technologies such as driverless cars [3], a market expected to reach $42 billion by 2022 [4]. Consequently, more people will be passengers wanting to fill their travel time usefully. The potential for technology to help passengers reclaim this lost time is impeded by 3 significant challenges:

- Confined spaces – These limit our interactions and force us to use small displays such as phones, tablets, dashboards, and seat-back/rear-seat systems [5].
- Social acceptability – We may be sharing the space with others, whom we may or may not know, inducing a pressure to conform which inhibits technology usage.
- Motion sickness – Many people get sick when they read or play games when in motion. Once experienced, it can take hours for symptoms to resolve and productive time is lost.

VR/AR Head Mounted Displays (HMDs) have the unique possibility to overcome these challenges in ways no other technology can, but only if bold new research is undertaken to unlock their potential. ViAjeRo will perform the breakthrough research needed in HCI and neuroscience to enable passenger usage of XR HMDs, with the underlying goal of making more effective, comfortable and productive use of travel time. If people are productive during their commutes, a better work-life balance can be achieved (e. g. spending less time at work); if they can consume media then they can support the creative industries and the content they produce. Our research at Glasgow will expand the XR market, allowing for new applications, services and peripherals to be developed, and provide the tools and techniques to allow European developers to lead the way in passenger experiences.

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4.6 Why do we Travel? On the Importance of Understanding the Drivers of Human Mobility

Duncan Brumby (University College London, GB)

Humans have a deep and intrinsic need for mobility. We travel great distances to gather for work and leisure. We run errands for daily essentials, but sometimes just for something to do. We eagerly await the next vacation to a distant shore as a reward for our toil. We quickly become bored and restless staying in the same place, so much so that being locked up in prison has long been used a punishment for committing crime.

Over the past 100 years, the car ushered in an era that has given many people the freedom to travel great distances in a relatively comfortable and private space. This personal mobility comes at the cost of requiring a trained, alert and responsible driver. Mass public transportation systems on the other hand delegate this responsibility to a single professional driver, freeing the passengers to sit back and enjoy the ride. This is all well and good but is often seen as both inconvenient for people because of the constraints imposed by an inflexible travel schedule as well as being undesirable because of travelling in a shared space surrounded by strangers.

Self-driving cars are appealing because they promise a way to break this trade-off between driving a car and riding public transportation: the freedom of personalised mobility in a comfortable private space without the need to take responsibility for the actual driving. A privilege once reserved for the elite few becomes accessible to the many – a chauffeur for everyone!

A fantastical future is imagined by the arrival of self-driving cars. Personal mobility will be enabled among those previously excluded from driving: from children and teenagers, to the elderly and people with disabilities. Self-driving cars will reduce the cognitive, attentional and emotional demands of driving. This will free drivers from the monotony of the road so that they can focus on more valuable activities instead, whether that be work, rest, or play. The number of accidents on the road will be cut and there will be substantially improved traffic flow that will rid populated areas of the scourge of traffic congestion. Drink driving, driver distraction, road rage, and driver fatigue, all of these things will become problems of the past, or so we are told.

This technological utopianism is mirrored by a dystopian vision of the future. Once liberated from driving, will this bring just yet more time to be filled in the day looking at a screen; is this really more interesting and rewarding than driving? What of the people who make a living out of driving, the taxi drivers and truckers, what opportunities will be made for new and interesting work to do instead? Which journeys will remain necessary in the future?

The Internet has already begun to have an impact on human mobility. The rise of remote work, and greater flexibility over when and where work is done means people do not need to travel to the office everyday when a virtual meeting will do just as well instead.

So, just as the arrival of the car 100 years ago changed the way that we lived in the past, the arrival of self-driving cars has the potential to have a profound impact on the way that we live in the future. As a first step, it is important to understand why we travel and what drives human mobility. Without understanding this there is a real risk that people will simply fail to adopt and use this new technology because it is not needed or wanted.

4.7 Navigate, Automate, Levitate: Human-Machine Interface Design for Future Vehicles

Gary Burnett (University of Nottingham, GB)

A modern vehicle has been likened to a 'computer on wheels' utilizing a wide range of computing and communications-based technologies aiming to improve safety, efficiency, inclusivity, and the comfort/experience of users. It is commonly predicted that future vehicles will include more automation functionality with some researchers now anticipating the science fiction vision of flying cars. Users of such cars will demand fundamentally different experiences compared with the drivers and passengers of today. In this respect, a plethora of Human Factors issues will be central to defining what that experience will be, including fundamental topics such as trust, motion sickness, user-system transitions, behavior change, etc. At the University of Nottingham, we have conducted many studies since the 1990s investigating how people can and could/should interact with future vehicles. Initially, the focus of research was on distraction issues for the now ubiquitous in-vehicle navigation systems – and many of our experimental studies have had a direct influence on the development of the interfaces we now take for granted (e. g. [2]). More recent work has considered the design and evaluation of the Human-Machine Interface (HMI), often in the context of a vehicle which is not always being human-driven – including the use of natural language interfaces [4], augmented reality [1] and gesture-based interaction [3]. A particularly important study [5] we have recently conducted with 52 people who experienced a SAE Level 3 vehicle for a week demonstrated the myriad of problems associated with the resumption of the driving task following a long period of automation.

As for 2016 when I was here, I have benefited immensely from the in-depth and extended conversations with colleagues on human-centered design issues for future vehicles. I have learnt about many interesting theories, methods, studies that can inform our work and look forward to working closely with my Dagstuhl friends in years to come.

Keywords: Driving, Automation, Human-Machine Interface

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4.8 From Control to Partnership: Challenges of User-Vehicle Communication

Lewis Chuang (LMU München, DE)

With increasing vehicle automation, our interaction with vehicles is steadily transitioning from controlling them to partnering them. More interestingly, this represents a directionality shift in communication. In a control relationship, information flows primarily in one direction. The human is responsible for perception, which proceeds cognition, resulting in fine motor limb actions that are communicated to the vehicle in order to generate powerful joint outputs. The vehicle primarily communicates to the user in terms of its actions and the user is responsible for determining how compatible this is to their intent. Automation means that the vehicle assumes the responsibility for setting intent for vehicle operations, especially at the levels of control and tactical. If the vehicle sets intent, it too determines what constitutes an error that must be corrected. All of this can proceed, so long as vehicle automation is capable of estimating error and correct for it accordingly. An automated vehicle could be incapable for correcting an error that it has accurately discerned. We could choose to put such instances aside because it is debatable as to whether users can, themselves, correct for such errors even if they were in control.

Instead, I raise for study the following instance, namely where vehicle automation realizes its incapability to perceiving/estimating error and communicates this inability to the human. This could occur either because the vehicle's sensors are unreliable, or the vehicle is incapable of setting intent or does not own the prerogative to do so. In the first case, the vehicle should submit a request to rely on the user's sensors. This request might not be noticed, either because the user is especially engaged in what they are doing [1], [2] or because they do not expect a request in the first place [3]. The latter could be mitigated by providing a compelling cue that sustains redirected attention for longer than usual durations [4]. The complexity, however, lies in that we have to develop two-way communications from the vehicle to the user and from the user to the vehicle, whereas, it used to be a simple and unambigious one-way communication system. Furthermore, aspects of system reliability might have to be effectively communicated to the user to instill a sense of authority and perceived responsibility [5]. Without communicating uncertainty or reliability, it is possible for the user to assume that vehicle automation is assuming the responsibility of estimating error for a given aspect of driving when it is no longer doing so [6].

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4.9 Driver Mental Models of Automation

Birsen Donmez (University of Toronto, CA)

With vehicles becoming highly automated, the driver's role is changing from one of direct control to one of coordination with and supervision of automation. These new driver tasks are arguably more cognitively complex than tasks associated with direct vehicle control. Mental models allow people to explain how a system works, predict the outcomes of their actions, hypothesize where certain features might be accessed within the system, and interact with the system in general. Supporting the development of accurate driver mental models becomes increasingly important as more complex automation systems are being introduced or are planned to be introduced to the vehicle.

In order to support accurate driver mental-model formation, the research and the design community need a better understanding of how different automated systems function currently and will function in the future. For example, unexpected failure events occur when the automation turns off, or acts in an unforeseen manner, thereby requiring the driver to regain manual control from the automation. Some of these events may be predictable by the driver (i. e. through external cues indicating that a failure may occur) or unpredictable. Our research focuses on how these two different failure types affect driver monitoring and take-over quality. In general, researchers and designers need a complete understanding of how and why vehicle automation failures may occur in order to design interfaces that can support driver mental models.

We also need to understand what driver behaviors can be considered appropriate and safe in an automated vehicle context. There are no commonly accepted standards or metrics to assess the risks associated with different driver behaviors in automated vehicles. For example, two seconds is the threshold adopted by government agencies for risky off-road glances [1], but this threshold is based on research conducted in non-automated vehicles.

Keywords: mental models, automation failures, standards, vehicle displays

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4.10 Cooperative, Highly Automated Systems to Bridge the Unsafe Valley of Automation

Frank Flemisch (Fraunhofer FKIE – Wachtberg, DE)

After over 40 years of intense and increasingly interdisciplinary research, the incremental revolution towards automated traffic systems has successfully started, but is far from finished. Partially automated systems are successfully on the road, but in low numbers. A hype towards autonomous systems has created some progress in the abilities of vehicle automation, but has also created false expectations which can lead developers and drivers into an unsafe and potentially deadly valley of automation. The Tesla and Uber accidents might only be a forerunner to a major series of safety problems, which will slow down or even stop the incremental revolution. To solve this problem, partially and highly automated systems should be designed not for maximum autonomy, but for a maximum of cooperativity between machines and humans, between the machines and not to forget, between humans and humans. This has to include traffic participants without automation or other technological support. In addition to cooperativity and performance, a maximum of safety, resilience, usability and joy of use should be designed, built and tested into these complex traffic systems.

Key challenges regarding the users, vehicles and infrastructure will be:

- Safe, resilient and human-compatible automation and V2X capabilities, which have a SIL level (Safety Integrity Level) high enough for partially, highly and fully automated driving.
- Clear modes of automation, which combine the (SAE- and BASt)-levels of automation with the scientific stages of automation and with layers of cooperation, providing a good inner and outer compatibility leading to an intuitive understanding and interacting with the automation. Open questions here are, whether 2, 3 or 4 different modes satisfy the balance between performance, flexibility, controllability and usability.
- Good HMI design for those modes, which combine
  - The need of the OEMs to differentiate themselves.
  - The need of users and the public to have standardized pattern, that allow a safe operation and change of vehicles.

The key challenges for the community are:

- In over 40 years of research, a tremendous amount of knowledge and wisdom has been generated, of which the first 30 years are not so easy to access. To avoid that the wheel has to be re-invented all the time, and all the errors and mistakes replicated with them, the more experienced colleagues should make the old papers available also online, and report not only their successes, but also their failures. The younger colleagues should not only do a Google search with a cut-off-line of a few years, but root themselves a bit deeper into history, and patiently encourage their older colleagues to discuss the past successes and failures.
- As the traffic systems get more complex, more people are needed to handle the depth of the details, but also more people are needed to handle the width of complexity in a systematic way. Interdisciplinary and system thinking have a good chance to be the key to success, which needs a certain openness and willingness to go beyond the "own" community and integrate technology, people and organizations. In Dagstuhl, there was

already a good openness, and especially a good mixture of technical, human factors and design expertise. The next disciplines that should be integrated are the colleagues understanding the legal system, the infrastructure and the business models.

4.11 Human-Automated Driving System Interaction: New Roles, New Models, New Methods

Joanne Harbluk (Transport Canada – Ottawa, CA)

The relationship between the user and the vehicle is very much changed from what it was only a short time ago. As a society, we are now asking questions about what it means to be a driver/user/human and what it means to be a vehicle. The vehicle/human relationship is now characterized as a cooperative one rather than the vehicle merely being a tool used by humans. This new relationship leads us to ask new questions of both humans and vehicles. And of course, we face many new challenges. How do we design for mutual cooperation and safety during complex interactions such as requests to intervene (for handover or shared control) when requested by the vehicle or the human? How does this interaction change over the various forms of automated driving? How do we support these?

New challenges:
- The need for new types of information means that we need new technological approaches: Driver Monitoring to determine driver state for decision making concerning driver ability, availability, receptivity and what we do with that information?
- How do we best characterize the mental models of the users and the vehicles so that we can design to support successful and safe interactions?
- The need for new methods: What to measure, how to measure, and the interpretation of new complex & types of data?
- Safety: How do we assess safety? How will we evaluate this? How will we know when we have accomplished this goal?

Thank you to our organizers, Susanne, Andreas, Andrew & David, for this amazing opportunity to gather with old and new friends, to think deeply, and to consider these important issues from many perspectives. And thank you to Schloss Dagstuhl for taking such good care of us all this week making this a wonderful experience.
Joanne Harbluk

4.12 Dynamic Humans, Machines, and Contexts in Human-Automation Interaction

Christian P. Janssen (Utrecht University, NL)

Different types of (semi-)automated vehicles have different abilities and technological features, such as adaptive cruise controle and lane assist. The ability to use these features depends on the context and the user. The contexts of driving can change dynamically, for example due to weather or roadworks, and limit the ability of the vehicle to use automated features (e. g. lane assist). The correctness of the user's understanding of the system can also change dynamically, for example they might miss an alert that tells them that a system goes off ([1], [2]). These dynamics of context, user and vehicle make it hard to predict over time what the exact system state is, and requires formal models and frameworks to do so [3].

My perspective is therefore that it is important that these dynamics are taken into account in the design and evaluation of new technologies. To minimize accidents, stake holders should not make the incorrect assumption that users/drivers know exactly what the system does at all times. Human user and non-human automated system have a need to understand each other's perspective. For the non-human automated system in particular, this would require maintaining some sort of user model of the person.

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4.13 Cross-Cultural Driving Styles

Wendy Ju (Cornell Tech – New York, US)

As we consider future interactions with automation, it is important to consider how we will co-construct how interactions should work with real users in real environments facing real constraints. This requires novel design and simulation methods, which allow us to observe how people will behave in various alternative futures. The Future Autonomy Lab at Cornell Tech is looking at how to design interaction with autonomous systems, novel simulation methods, cross cultural issues in driving, field research techniques for human-vehicle interaction, and dataset generation for machine learning.

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4.14 Human Factor Issues for Vehicle Automation

Josef Krems (TU Chemnitz, DE)

Prototypes of highly automated cars are already being tested on public roads in Europe, Japan and the United States. Automated driving promises several benefits such as improved safety, reduced congestions and emissions, higher comfort as well as economic competitiveness and enhanced mobility in the context of demographic changes. These benefits are often claimed on the basis of a technology-centered perspective of vehicle automation, emphasizing technical advances. However, to exploit the potential of vehicle automation, human-machine-related issues are considered a key question, shifting the perspective towards a human-centered view on automation. Research on human-automation interaction pointed out already "ironies of automation" that can undermine the expected benefits. Relevant issues mainly relate to the role change in various levels of automation, i. e. mode awareness and transitions from manual to automated control, reduced vigilance due to the monotony of supervising tasks in partially automated driving, changes in attention allocation and engagement in non-driving tasks, out-of-the-loop unfamiliarity resulting in reduced situation awareness, mental models of automation, trust calibration as well as misuse and overreliance. For reducing negative automation effects and enabling successful human-automation interaction, feedback on automation states and behaviors is considered a key factor. The focus of our own research is on take-over-requests, communication between highly automated cars and other road users, and on comfort and acceptance. For example, we try to identify pedestrians intentions by analyzing micro-trajectories based on motion-tracker data. Another open issue is to identify cues that indicate intentions of highly automated vehicles (e. g. give way) to VRU. It also has to be discussed to which extend these results can be used for defining regulations through the ISO process.

4.15 Interfaces for Work-Related Tasks in Automated Vehicles

Andrew Kun (University of New Hampshire – Durham, US)

Automated vehicles hold out a number of great promises for the future ([1],[2]). Critically, they should make driving much safer than today. They should also free up time for their users to engage in non-driving tasks, including tasks related to work. However, we do not yet know how to best design in-vehicle human-computer interaction for work-related tasks. This is an important problem, especially in the context of cars that are not fully autonomous, and the driver periodically needs to take over the responsibility of controlling the vehicle [3]. Which types of work tasks should the interface support so that users can safely return to the driving task? Which tasks would be of greatest use for different workers, from engineers, to managers, to technicians? How can we design interactions so that they do not result in motion sickness? Which interface modalities are the best match for the tasks to be performed in the relatively small vehicle cockpit? These are some of the questions that we need to answer as we work towards enabling users to engage in work-related tasks in automated vehicles.

Keywords: automated driving, future of work

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4.16 How to Make the Driver Aware of the Role he has to Play?

Sabine Langlois (IRT SystemX and Renault, FR)

The topics I would like to discuss at Dagstuhl are related to the different levels of automation, because our future vehicles will be equipped with systems partially or highly automated. One of our challenges is to make clear for the driver which role he has to play so that the team "system + driver" can manage a safe and pleasant drive.

With a Level 2 system (ACC+ Lane centering), the driver must continuously supervise: is it OK for humans to assume this role for a long duration? How can the system and its HMI support the driver in this role?

With a Level 3 system, the car takes the responsibility of the driving task, but the driver must stay "receptive" (term as used in [1]) because he will have at some point to take over. Even if the car performs a minimum risk maneuver in case the driver does not hand over, the maneuver could be under his responsibility. Does this mean the driver should stay in the loop? If yes, how can the car persuade him to do so because it is contradictory to his expectations? At some point, the compatibility between the system performance and driver?s response (to perceive, analyze, decide and act) could be lost. We should also consider that the driver may lose confidence in his own capacity to correctly intervene. According to Captain Chesley "Sully" Sullenberger, "we need to make sure we're assigning the proper roles to the human and the technological components" Could an answer to the problem be to display system uncertainly level? If yes, could it be used as an alternative or in conjunction with a takeover request?

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4.17 The Environment, Standards and Vehicle Occupant Experiences

Roderick McCall (Luxembourg Inst. of Science & Technology, LU)

The emergence of the semi and fully autonomous vehicle coupled with the desire to be greener either through government policies or vehicle buying patterns presents challenges for researchers and industry. The vehicles of the future must provide radically new in vehicle experience which offer a driving, work and play space in order to remain desirable. The challenge is further amplified by the emergence of car sharing schemes, which potentially mean that the "driver" will not necessarily be able to specify exactly the vehicle they want. This necessitates the needs for interaction standards across manufacturers, so that a driver can get into any vehicle and know how they expect any (semi-) autonomous system to behave. A positive challenge is now how to create driving experiences in (semi-) autonomous vehicles which have the aim of reducing carbon footprint and congestion.

4.18 Automated Vehicles and Novel Forms of User Experiences

Alexander Meschtscherjakov (Universität Salzburg, AT)

We live in a time of tremendous change due to the increasing automation in many areas of our lives. May it be industry, home or the mobile context. This increase in automation brings many challenges for the design of interaction with automated systems, that seem to act autonomously in a certain way. This is especially true for automated vehicles due to the fact that they will be objects of our daily lives, across all cultures, across all social strata.

The notion of usability and user experience will change when there is no "user" of a vehicle anymore in the traditional sense acting as a driver, but more as an operator or the supporter of the automated driving vehicle. Since the transition of manual driving to assisted driving to automated driving will not run smoothly the design of interaction and cooperation between the vehicle and the user (i. e. driver) as well as other (vulnerable) road users (VRUs) will become one of the most important question in the next decade.

How can we design the interaction of a system that changes its behavior between being purely reactive (i. e. manual driving), to assistive (e. g. adaptive cruise control, lane change support) to (semi-)automated. Questions such as how to design safe and convenient hand-over-situations [1], driver de-skilling [2], or how not to fall into a trolley-dilemma [3] needs to be resolved. Another big issue will be the transformation of VRUs interaction with driverless vehicles. When we have solved these issues, we can think about other sensible tasks in a moving vehicle and how to fight motion sickness.

I argue that we need more real live data, and that the scientific community, politics, as well as the economic stakeholders need to work tightly together to make automated driving a long-lasting success.

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4.19 Reflection Statement by Ingrid Pettersson

Ingrid Pettersson (Volvo – Goeteborg, SE)

Automated cars come with many possibilities and promises, but also pose many hard development challenges. The vehicles need to be developed in line with human needs and capabilities, and I strongly believe in early incorporation of users in the development process and seek to address user experiences (UX) of automated driving in my research (e. g.[1], [2]). User research should be deployed from early stages of development and ideation, to evaluation and iteration of ongoing concepts, addressing the various sorts challenges and possibilities of autonomous cars (e. g. [3], [4]).

I am especially interested on how we best approach user experience research from early stages of development [5], and techniques that allow us to study user interaction in as natural conditions as possible are important [6]. I see the need for extensive further research regarding for example:

- How to establish a purposeful user understanding of the usefulness and boundaries of the (semi-) autonomous driving system.
- How to prevent mode confusion & misuse.
- How to evolve driver/car sensing & communication.
- How to balance between branding vs consistency.

I look forward to learning from the very experienced researchers present, and to possibly start up new research collaborations, especially within tools and methods to address user research in the field of interfaces for autonomous driving.

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4.20 Mobility of the 21st Century – Automated Driving and Future Mobility Concepts

Bastian Pfleging (TU Eindhoven, NL)

Before the inventions of trains and the automobile, transportation was a very challenging, expensive, and potentially dangerous activity – especially over longer distances. This heavily influenced how people lived: Especially home and workplace were often at the same location or close to each other. Once mobility became affordable – especially in form of cars, motorcycles, bicycles, trains, and busses – this led to a massive change for many people in large parts of the world, since they gained the opportunity to easily reach a remote location. Today, people spend a considerable amount of time in their cars, be it for the daily commute, for shopping, business trips, or to go on vacation.

With assisted and automated driving, we hope to not only increase driving safety and reduce road fatalities. At the same time, we hope to enable the drivers to make use of the time in their cars and convert their cars into a new space for (non-driving-related) activities: One of my current research goals is therefore to understand how we can adapt the design of the car to accommodate for these activities and make the automated ride (again) an enjoyable comfortable activity.

Once driving time becomes time for other activities, this may have huge societal effects: For instance, this can influence how we perceive our daily commute: If we already can start with our daily work when entering the car (or have breakfast during the commute), we might care less about the length and duration of our commute. This can in turn impact the decision where we want to have and, thus, have an influence on future urban planning.

Beyond the interaction in the automated car, we also need to understand how these cars interact with the outside world, especially other road users such as pedestrians, bicyclists, and drivers of manual cars. Our current research also addresses these questions.

With automated (and potentially electric) vehicles, the way how we use the car potentially may change: Already today, we see that car sharing and ride hailing are novel forms of transportation whose acceptance seem to rise. With automated vehicles, we expect that this trend will continue towards using mobility as a service: Similar to using a music streaming service instead of buying, and playing CDs or music files, we might pay for the access and use of shared cars. We can imagine that this increases the user's flexibility: While using only a small "bubble", like a car for individual use during the morning commute or on the way to the train station, we might use a different (bigger) car when returning from the grocery store. In the evening, we might invite the partner in a sporty car to the theater, while a spacious and comfortable vehicle offers flexibility when going on vacation. In combination with a better link between different modes of transportation, this could drastically change the patterns how we use mobility in the future.

For all the cases explained above, we see challenging and inspiring research questions with regard to human-computer and especially human-vehicle interaction. The Dagstuhl Seminar on "Users and automated driving systems: How will we interact with tomorrow's vehicles?" therefore is a timely seminar to identify and discuss these research questions and shape the roadmap for (joint) future research in this area with the goal to improve our mobility.

4.21 Level 0, Level 1, ... High ... 3.78 ...Autonomous?

Andreas Riener (TH Ingolstadt, DE)

After having organized the predecessor seminar in 2016, we came back to Dagstuhl to see how research (and industry) has evolved/progressed since then and what new challenges have been identified (have arised). Interestingly, many topics in 2019 are similar to the ones identified in the previous seminar, but are discussed in much more details, with much more enthusiasm and flavors, and arguments brought-up are well underpinned with recently published related work (partly co-authored by Dagstuhl seminar 16262 participants). The big topics identified in 2019 are 1) conflicting mental models – an interface issue in human-machine interaction around for quite a while and 2) the levels of automation. There was a long debate on the appropriateness of subdividing automated driving systems (ADS) into 5 subclasses. Quite a few people argued that the classification should be more fine grained (i. e., level x.y), others provided arguments to abolish the levels at all. Already in today's automated vehicles, it is sometimes hard to discriminate between levels, as a car model is likely to have automated driving functions on different levels while one function can also come in variants on different levels (for example a parking assistant). It is rather intransparent for the driver/passenger, which "mode" is currently on and how (if allowed at all) to interact with the vehicle in that mode or with the function currently engaged. This problem domain was an ideal starting point for the seminar 19132 with the underlying question "how to interact with tomorrow's vehicles"? 31 participants tried hard to come-up with solutions by applying different creativity methods, such as brainstorming rounds, break-out groups, prototyping sessions, amongst others. Even though we have not solved concrete problems, it was (again) a fun week and we (=co-organizers) are pretty certain that the discussions will have an influence on the future work of our participants. We've been already asked to propose another follow-up seminar in 2 years time for the next round of interaction. We will definitely consider!
Thanks for the warm hospitality,
Andreas

4.22 Understanding and Designing Plausibility and Self-Awareness into Automated Systems

Maria Rimini-Doering (Robert Bosch GmbH – Stuttgart, DE)

As a Senior Expert in Human-Machine Interaction within Corporate Research of Robert Bosch Gmbh, I coordinate publicly funded projects for the division of Software intensive Systems (e.g. Embedded Systems, User Interaction Technologies, Consumer IoT).

As I prepared for the present workshop, the news about problems (and terrible crashes) of the Boeing 737 MAX were in the news. This inspired me to propose the following questions that I felt would be interesting to explore:

1. How do we learn and teach to plan, program, realize and test highly automated systems with "situational awareness" or better self-awareness and dialog capabilities?
2. What are the probable actual errors in a system, e. g.:
   - Only one sensor taken as input (no check on consistency)
   - No check on plausibility
   - Repeated unquestioned onset of the control system after several manual turn-off commands
3. How can we utilize the contribution of the workshop at the Driving Assessment Conference 2017: "Control Transfer Challenges for Automated Driving Systems"?
4. What has been done, what is still to do?

I am looking forward to discussing these and other questions at this Dagstuhl seminar.

4.23 Understanding and Anticipating the User in Semi-Autonomous Driving

Nele Rußwinkel (TU Berlin, DE)

To enable anticipation of the user by an autonomous system, we need to give the technical system the ability to understand the cognitive state of the user. For takeover situations in semi-autonomous driving it is necessary to understand what information the driver already has processed (e. g., surrounding vehicles, or cause of takeover) and what information is still missing to enable a save take over and/or deliberate decision by the user.

Such an ability could be achieved by the method of cognitive modeling. In previous work we were able to predict how quickly a user would be able to learn how to handle a new application and how quickly different system upgrades could be integrated into the user's mental model [1].

In some other work [4], we developed an intelligent cognitive system that is able to anticipate the actions of the pilot and to identify inadequacies and possible future mistake. For autonomous driving there is the need of a more details modeling approach that can also anticipating the visual processing of the environment including other vehicles, special road conditions and other relevant information.

Depending on the complexity of the environment the takeover process could be supported by additional information. The time needed for a safe take over would also depend on such processing mechanisms and could be predicted [5, 2].

Having such an intelligent cognitive system would not just help to provide an optimal take over procedure but also provides an understanding of the context to the technical system. This would be the foundation of a communication between User and system.

Questions that should also be addressed are: In what situations should the control be handed to the driver and in what situation the driver would be incapable to take control? How can the user be informed about decisions of the autonomous system?

For all these questions we need a way to provide a model of the dynamic cognitive state of the user.

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4.24 Amplification of the Human Mind and Intervention User Interfaces

Albrecht Schmidt (LMU München, DE)

My group at the Ludwig Maximillians Universität, München, is heavily involved in exploring human use of automated systems. Our guiding principle is that human-machine systems can outperform humans, as well as machines that act alone. This is important, because we believe that a large class of automated and autonomous systems allow for joint control, where the majority of decisions are automated but where users can intervene. Thus, the opportunity for creating useful systems is quite significant.

In our work we are guided by the following ideas:

- Human-computer interaction is the key discipline for creating intelligent systems
- Intuitive cooperation between humans and computers is the key challenge
- Machine learning and automation are only components in a solution

Starting with these ideas we have developed the following design principles for what we call ?intervention user interfaces? [1] ? interfaces that can help support joint user-machine work on problems and tasks:

- Ensure expectability and predictability.
- Communicate options for interventions.
- Allow easy exploration of interventions.
- Easy reversal of automated and intervention actions.
- Minimize required attention.
- Communicate how control is shared.

I am looking forward to discussing these ideas with workshop participants. Even more importantly, I am looking forward to the discussions at the workshop reassuring me that research in the area of ?users and automated driving systems? is still relevant, and not overtaken by broader research themes.

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4.25 Intention-Aware Cooperative Driving Behaviour Model for Automated Vehicles

Ronald Schroeter (Queensland University of Technology – Brisbane, AU)

The modeling of drivers in vehicles has been motivated by a desire to understand, predict and improve the driver's driving performance and safety. With AVs, the driving task will dramatically morph towards a supervisory role that cooperates with the AV, and render existing driving behavior models obsolete. New driving models are needed to capture the notion of a cooperative task between human and machine as its foundation. AVs call for a shift towards a more elaborate understanding of in-vehicle interactions, and new ways to address the pressing challenges that this transition towards cooperation raises. Theoretical constructs need to support novel cooperative principles such as negotiating activities, communicating and reconciling disparate perceptions of the environment, anticipating actions, and sharing intention, to be able to effectively (co)operate (with) AVs and other autonomous systems.

We found Intention Awareness (IA) to be a useful investigative lens to explore driving as a cooperative task. It has not been explored with the view of increasing the human's awareness of the system's intentions or in the context of improving cooperation with AVs. Our human-centric approach that explores cooperative Intention Awareness (IA) between human driver and machine may profoundly influence existing research on Situational Awareness, safety, predictability, trust, and usability in AVs. Our hypothesis is that sharing the vehicle's intention improves certainty, latency and cognitive workload in reconciling disparate SA because it focuses on the SA's high level meaning (semantics) rather than syntax.

Building on the Wendy Ju's Husband-metaphor to illustrate this: the driver signals their awareness of the driving situation (the syntax) by communicating their intention to slow down (semantics) with ostensible intentional cues, e. g. taking the foot off the accelerator and hovering it over the brake pedal. This puts the co-driver or passenger at ease, and vice versa the driver. Intentions are inferred from past individual subtle, intuitive, or direct reciprocated interaction experiences. This project seeks to understand the context-dependent interactions and chains of transactional cues between two humans in the car to inform future interfaces.

4.26 Challenges to Making Automated Driving Systems Understandable to Users

Steven E. Shladover (University of California at Berkeley, US)

I have been researching multiple aspects of road vehicle automation since the early 1970s and have seen many changes in the attitudes and expectations surrounding automation since that time. My research has addressed topics such as:

- the design, implementation and testing of prototype automation systems on cars, buses and heavy trucks to assess their technical performance and the reactions of people driving and riding in the vehicles;
- using traffic microsimulations to assess the transportation system impacts of automated driving systems at various market penetration levels;
- developing the terminology, technical standards, and regulatory frameworks needed to enable safe deployment of the more highly automated driving systems.

Based on my experience in this field, I expect that many years of additional research effort will be needed to satisfactorily address the large technological challenges that remain in the fields of environment perception and safety assurance for software-intensive automation systems. In parallel with this work, much work also remains to be done on the human user interfaces of the Automated Driving Systems (SAE Level 3 and above). Among other challenges, future vehicles will be equipped with a wide variety of automation features that provide differing degrees of automation of the dynamic driving task within different operational design domains. Individual vehicles are likely to be equipped with several such features, each with its own driver interface requirements and implementations. How will the driver of the future be able to understand the capabilities and limitations of these systems, and how can the driver interfaces be designed to support safe and proper usage of these systems (while also deterring or preventing improper usage)? How can this be done with sufficient consistency across the industry to minimize user confusion, without unduly violating the natural desire of each company to differentiate their products from those of their competitors?

4.27 Assessing Driving Performance and Driving Style of Autonomous Vehicles

Jaka Sodnik (University of Ljubljana, SI)

Driving a vehicle is a complex task requiring drivers to make accurate perceptions and cognitions about the environment, their own driving skills, their psychophysical state as well as vehicle performance and surrounding traffic. All this information has to be processed and interpreted at a high rate of speed leading to correct decisions and actions. Although all drivers have in common the task of save driving, as individuals, they are all unique. We can study this driver's uniqueness and skills in a simulated driving environment by observing their reactions to different critical situations, unexpected traffic and weather conditions and their attitude towards other traffic participants. The final result is individual's personal driving profile and risk assessment score which can be used to predict future behavior and potential hazardous reactions in real traffic. Automation of driving task on the other hand is progressing fast and different forms of (semi-)automated vehicles (AVs) have been in operation for quite some time. There are many challenges accompanying this transition, ranging from technical and safety related issues, to the issues related to driving style and driving behavior in relation to other traffic participants. This high level performance of AVs should also be assessed in order to operate in a way that nobody is harmed, endangered and not even hindered or bothered unnecessarily. There is a need to find certain quantifications for this assessment by taking into account human behavior and capabilities to handle different traffic situations. We therefore propose the same approach and similar driving style assessment system as for human drivers. It should incorporate rules and testable guidelines for one vehicle as well as all other traffic participants and should be included as a mandatory part of AVs verification and certification.

4.28 Road Traffic Safety and Human Errors in Automated Driving

Christine Sutter (Deutsche Hochschule der Polizei – Münster-Hiltrup, DE)

What are we talking about?

More than 1.3 million road users die of road traffic accidents every year [1] and an even higher number of road users are severely injured per year worldwide. In children and young adults, aged between 5 and 29 years, road traffic injury is the leading cause of death [1]. This is a depressing fact, with fatalities mostly rising in low-income countries and stagnating or only slowly decreasing in higher-income countries [1].

How to improve road traffic safety?

Pillar 3 of the Decade of Action for Road Safety aims at providing safer cars [1]. Driver support features (SAE level 0-2, [2]), and automated driving features (SAE level 3-5, [2]) increasingly support or even substitute the human driver. Using those features is helpful to reduce human errors in driving, so they have the potential to decrease the risk of road traffic accidents.

From a psychological point of view, I am not convinced that this will be the case. Systems operating on level 3 automation and the take-over procedure are complicated to handle for human drivers. The switch between manual or assisted driving to supervising the system during automation and the take-over on request is highly demanding for the human information processing system. The critical part is the successful take-over, and the troubleshooting in case the system malfunctions. One might suspect that circumstances even increase human errors with level 3 automation. I also question that human errors decrease with level 4 automation, as we increasingly trust in human capabilities in software development and teleoperation. In my opinion, it remains unclear if vehicle automation solves the problem of human errors in driving, and maybe we can reach the same goal with alternative concepts of mobility.

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4.29 Reflection Statement by Bruce N. Walker

Bruce N. Walker (Georgia Institute of Technology – Atlanta, US)

Bruce N. Walker (Georgia Tech Sonification Lab) has a broad range of research interests, including Human-Technology Interaction, Sensation & Perception, Multimodal User Interfaces

& Sonification, Human-Automation Interaction, Trust in Automation, Technology/Automation Acceptance, and Assistive Technology.

Some interesting questions in the realm of automated vehicles include:

- What factors will affect uptake / adoption of automated vehicles?
- What factors will affect trust in automation?
- What, exactly, is a handoff / takeover request, and how the heck will the engineering/design match human capabilities?
- How can/should the driver be made aware of the status of the world, and the state of the (automated) vehicle?
- What role can multimodal interfaces play in automated vehicles, especially related to situation awareness?
- How will automated vehicles help / hinder persons with disabilities (as drivers, passengers, pedestrians, etc.)?

Prof. Walker's goals for the Dagstuhl seminar include:

- Community Building: Connecting us all, a little more formally.
- Learning: What are all of you working on?
- Friend Raising: Collaborators for potential research projects.
- Planning Some Projects.
- Fund Raising: Finding support to do research.

4.30 Designing Automated Vehicles for All Road Users

C. Y. David Yang (AAA Foundation for Traffic Safety – District of Columbia, US)

As more advanced technologies are being introduced into the vehicle fleet to assist drivers with the ultimate goal of automated driving systems, it is important to also examine and assess how future vehicle technologies will impacts other road users such as pedestrians, cyclists, and people with special needs to ensure safe and efficient transportation operations. Research needs to be carried out to establish a comprehensive and fundamental understanding of the interactions and dynamics between automated vehicles and vulnerable road users.

As a group, vulnerable road users could constituted high variability and individual differences. Consequently, understanding variability within this group and their individual needs must be considered in the design and functionality of automated vehicles. Some of research questions that need to be looked into are listed below:

- How can human-machine interface (HMI) be made intuitive for vulnerable road users?
- How can automated vehicle mode be communicated to different vulnerable road users?
- What system functionality and information feedback is most important for different road user groups?
- What kinds of pedestrian/cyclist behaviors represent the most problematic for automated vehicles and drivers?
- What design guidelines/principles should be considered for elderly drivers or those with other needs?

Main Research Fields: Human-Machine Interface, Vulnerable Road Users

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4.31 Transparency and Explanations for Automated Behaviors in Future Vehicles

Jürgen Ziegler (Universität Duisburg-Essen, DE)

Automated vehicles use a range of machine learning techniques which for the user act essentially as black boxes. Our group's current research addresses the problem of increasing transparency and user control for recommender systems which so far mainly function as black boxes. We have developed several methods that let users influence the predictions of statistical models of recommending, and are currently working on system-generated explanations for recommended items based on user reviews. My aim for this seminar is to discover new connections between our current research focus on interactive recommender systems and user-related aspects of automated vehicle. In line with the emerging research field of explainable AI, we aim at developing methods for explaining the behavior and decisions of intelligent systems also in the field of automated vehicles. Such explanations should be constructed and presented in a way that can be easily perceived and understood by the human driver without increasing cognitive load. Furthermore, we see various options for integrating recommender functions into future vehicles, be that at the level of setting appropriate parameters for the driving behavior, for recommending routes, or for providing commercial and other services to the driver or passenger of an automated vehicle.

5 Seminar Activities: Break-Out Groups, World Cafe, Discussions, and Prototyping Sessions

5.1 Intro Presentations, Brainstorming Wall, and Clustering

After an introduction to the seminar by the co-organizers Susanne Boll, Andrew Kun, Andreas Riener, and David Yang, most of the first day was spent with short intro presentations by the participants followed by discussions and Q&A. Figure 2 represents a quick overview of research areas presented/discussed during the intro presentations on day 1. In total, 170 terms/research questions/issues were collected during day 1 and used to generate this word cloud.

To make the sure that the rest of the week fits the seminar participants' actual research interests, the co-organizers did not choose to define topics for the break out groups on the remaining days in advance, but to find topics worth being discussed in form of a "brainstorming wall". During the introduction rounds (that were already opened for short discussions with the whole group), most-often mentioned topics were collected on PostIts,

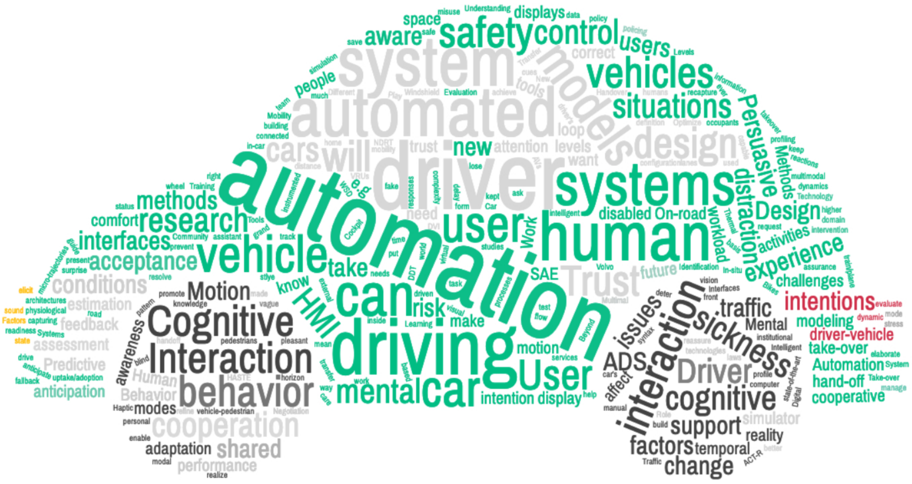

Figure 2 Word cloud from the intro presentations on day 1 (Source: A. Riener).

organized into associated groups and pinned them on a pin board visible to all participants. In the afternoon of the first day, each participant was invited to vote for his favorite topics of interest using self-adhesive colored dots. The result, after re-organization by the workshop organizers on Monday evening, is shown in Figure 3. The identified "blobs" were finally selected as the topics for the break out groups on Tuesday and the WorldCafé on Thursday as well as for the prototyping session on Wednesday.

5.2 Tuesday: Break-Out Groups

After clustering and reorganizing, the top 4 topics from Monday (see Figure 4): "Models", "Levels", "Disruption", and "Teamplayer", were used for the Tuesday break-out groups (4). The other clusters identified during the brainstorming (e. g., "Safety", "Transparency", "Individualization vs. Standards", "Tools and Methods", "Social Interaction", "Teleoperation", and "Inclusivity") (see Figure 10) were used for prototyping (Wednesday) or World Café (Thursday).

5.2.1 Models – Driver-Automation Cooperation: Modes, Models, and Modeling

Summary of the group discussion as outlined in Figure 5: Models are simplified representations of the real world, and should be as simple as possible depending on the purpose but not any simpler than that. They are relevant and even essential to Automated Vehicles (AVs) because

- users have them (i. e., mental models guide their behavior),
- AVs are designed to have them (e. g., vehicle models, environment models, and user models), and
- different stakeholders can use them to guide design including the design of UX, journey experience, safety-relevant interventions, infrastructure, policy, and user mental models.

Driver mental models can form naturally or can be influenced purposefully through design. Stakeholders may use different modeling techniques to create other models related to AVs. These models can be predictive, descriptive, conceptual, prescriptive. They can be

Figure 3 Result of day 1: Brainstorming wall including results of the voting by participants.

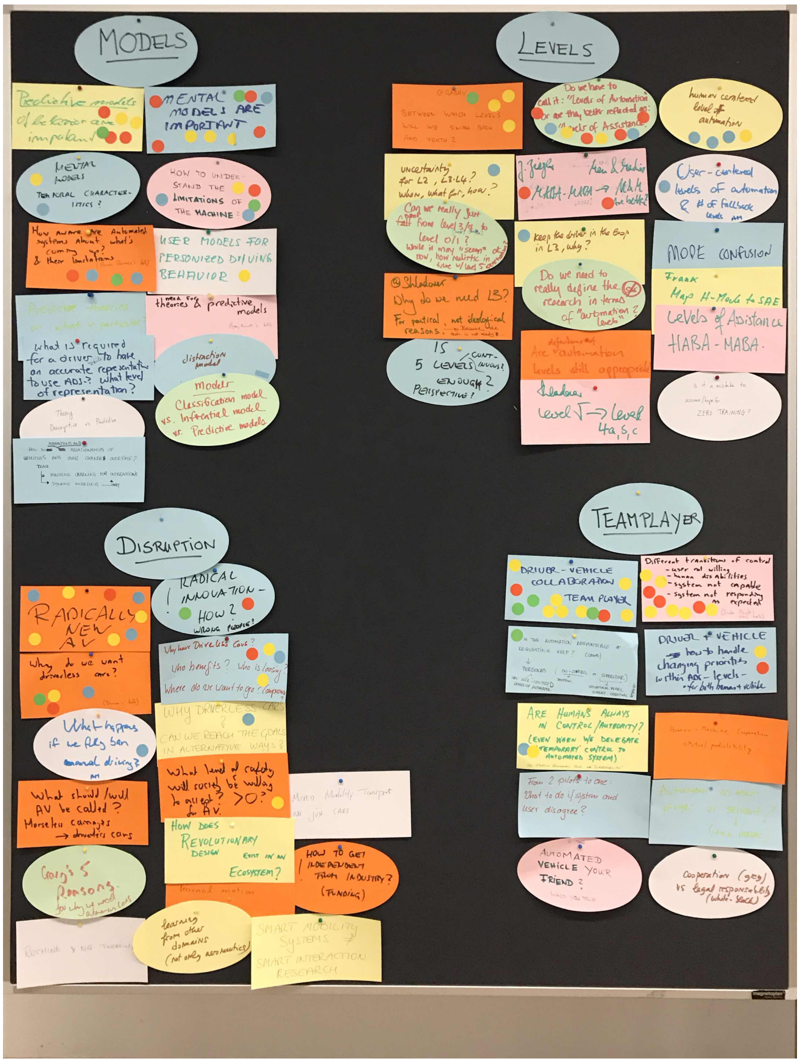

Figure 4 Result of day 1 after clustering and reorganizing by the seminar co-organizers: The 4 top topics “Models”, “Levels”, “Disruption”, and “Teamplayer” were used in the Tuesday break-out groups.

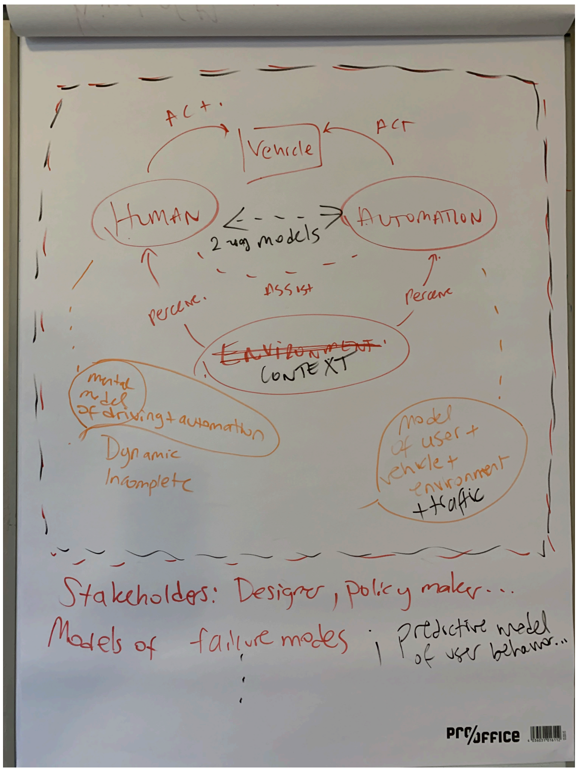

Figure 5 Brainstorming in the “Models” group.

deterministic or stochastic. They can describe cognitive architectures. Different modeling techniques have different advantages and disadvantages and a combination of them may have to be used in practice. Further, the validity of different techniques may change across different applications.

Finally, given that the behavior of different agents can change over time in the complex AV-human system (e. g., over the air updates for automation), both user mental models and stakeholder built models may have to be updated.

5.2.2 Levels of automation

The SAE levels of automation are written with limited use, but they are not as insightful for researchers when attempting to conduct comparable studies. A new framework is needed to better reflect the context that the automation can be used. The paper [3] initially discussed and structured during the break-out group focuses on the researcher’s perspective which considers the operational design domain and the distribution of control. A final version was compiled the two weeks after the Dagstuhl seminar and submitted as full paper to AutoUI 2019.

References

1 Linda Boyle, Christian P. Janssen, Wendy Ju, Andreas Riener, Steven E Shladover, Christine Sutter, Frank Flemisch. *Clarifying variations in vehicle automation: Beyond levels of automation*. Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI’2019), Utrecht, 2019. (*submitted*)

Clarifying variations in vehicle automation: Beyond levels of automation

Anonymous Author(s)*

ABSTRACT

Human operators of vehicles with automated capabilities often infer a linear progression of automation, which is often based on the Society of Automotive Engineers (SAE) Levels of Automation. The SAE levels were designed to provide a common language for use by industry and government and to promote joint understanding of the relative roles of humans and driving automation systems. However, research centered on these discrete levels of automation are not necessarily comparable as driving automation systems can vary based on the operational design domains and the distribution of control. The operational design domain (ODD) provides the dimensions (e.g., environment, traffic, other road users) and driving scenarios in which the automation can operate properly. The variations in ODD can impact the abilities, comprehension, responsibilities and intended actions of the system and the human, and thereby the overall understanding regarding who is in control when. This paper discusses steps towards a common framework that can be used by researchers to design, test, and evaluate vehicle automation given differences in the operational design domain and the distribution of control actions.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; **Interaction design theory, concepts and paradigms**; • **Applied computing** → **Transportation**.

KEYWORDS

Vehicle automation, Automated driving, Operational design domain, Control distribution, SAE J3016

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1 INTRODUCTION

There are many assumptions associated with the operational capabilities related to various vehicle automation technologies. These assumptions are fostered by popular media, who often use terms such as "self-driving," "autonomous cars" and "automated vehicles" interchangeably. The Society of Automotive Engineers (SAE) created a matrix that grouped the levels of automation into six categories from 0 for fully manual to 5 for fully automated. Researchers, regulators, car manufacturers, and others have adopted these levels as a way to communicate to one another on the automation capabilities of the vehicles they are testing, evaluating, designing and developing policies. However, even those in the automotive user interface (Auto-UI) community fail to use the SAE levels appropriately, often mistaking the levels for modes, and conflating what people could, should or would do within that automation level.

This paper proposes to resolve some of these issues by presenting a framework that goes beyond levels of automation such that we consider the *operational design domains* (ODD), which are the contexts in which different automated vehicles are intended to be used, and on *distributions of control* which address the ability, comprehension, responsibility and intended action in different automated scenarios. By considering vehicle automation applications in this broader framework, we can create more comparable studies on human interaction with vehicle automation. This can then inform discussion with other stakeholders such as manufacturers, designers, and end users.

Our framework provides a more user-centered perspective, which is important for the Auto-UI community to converge research efforts and to identify gaps in our understanding of human-automated vehicle interactions. It balances out the more technical perspective described in SAE J3016 [13] and the extension SAE J3114 [19].

Figure 6 Paper of the "Levels of Automation" group submitted to AutoUI 2019 conference.

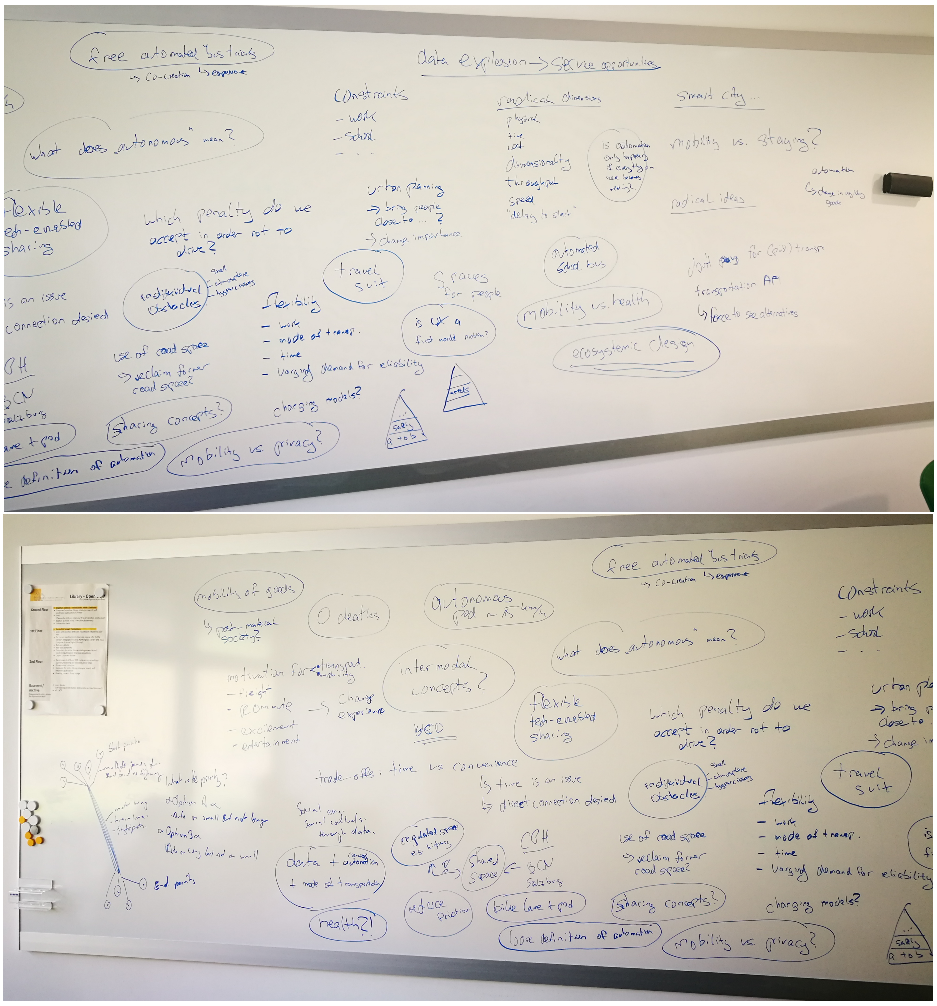


Figure 7 Brainstorming result of group "Disruptive innovation".

5.2.3 Disruptive innovation

The group work started with brainstorming (Figure 7). Below is a summary of the topics discussed.

- New opportunities
  - Data+services/"automation"+mode of transportation as design material & opportunities
  - Sharing concepts
- Many aspects related to urban planning
  - Convert(traffic) space into widely shared spaces(e. g., with pedestrians)
  - Service provisioning
  - Context-aware vehicles
  - Design AVs to operate in pedestrian-/bike-priotized areas
- Is UX for AV region-specific (a first-world problem)?
  - Do we need to focus on regions other than Europe/US?
- Transition phase manual car to AV vs. making people mobile

- More ecosystemic design approach
  - Flexibility
  - Intermodal approaches
  - Separation of personal mobility and luggage/goods (see also corresponding video in Wednesday prototyping session)
- Mobilty vs. health
- Dimensions of radical invention
  - Dimensionality: Use of vertical space
  - Time
  - Cost/payments
  - Physical
  - Throughput/speed
  - "Delay to start"

5.2.4 Teamplayers

Definition of team-player collaboration:

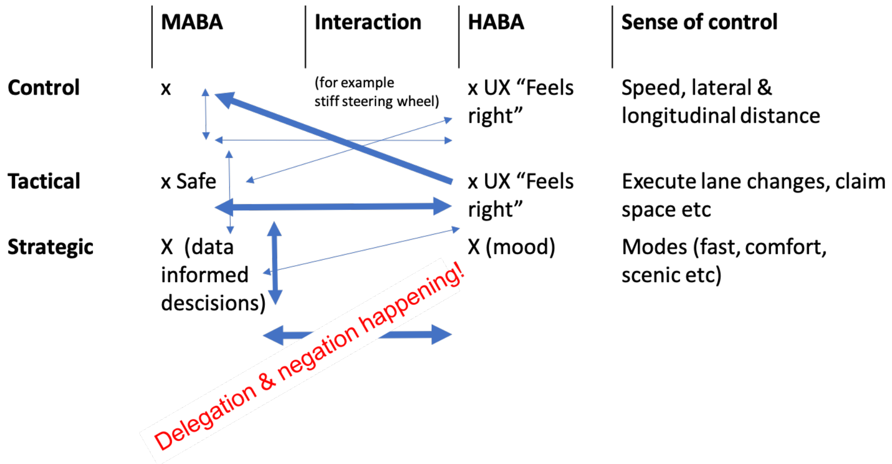
1. Interference by two agents
2. Interference solved by actions facilitating goal achievement of both agents working (towards a common goal)

Description of this type of collaboration

- Shared task between two agents
- Continuous or discrete involvement (from user perspective)
- Joined cognitive system
- Distribution of tasks is more flexible (human is supporting the automation)
- Collaborative system (mutual control, soft transition modes)
- User in control
- User impairment support
- Collaboration on higher level
- On strategic level (deciding on the destination), solving tasks together

Problems and challenges

- Problems with expectations
- Over trust/no trust at all
- Different use cases/edge cases for different metaphors
- How can users get correct understanding
- Exchange of information/the car should let the driver know it is in control
- What kind of messages to use to communicate this



		Mutual	Vehicle	Driver
	Operational levels	**"Horse" metaphor**	**"Guardian angel" metaphor**	**"Chauffeur" metaphor**
Meta-level (Recommendation system)	**Strategic**	Stop for refueling Stop for rest/food	Avoid traffic jam	Find best route to work on / finish my task
	Tactical	Overtake Follow another vehicle	Avoid risky overtake	Speed up (Drive over the speed limit)
	Control		Avoid discomfort	

Teamplayers – Classification by Collaboration Type

Meta	Level	Synchronous Cooperation	Delegation	Assistance/ Supervision	Co-Evolution
	Connection /Relational	Social communication between diff. vehicles, advise on shopping opportunities	Drive me to meet friends at 7pm	Alert other entity of medical condition	Learn about preferred co-drivers
Recommender/Advisor functions	Strategic	Jointly define route,	Find points of interest and bring me there	Avoid congested roads,	Learning preferred routes, destinations
	Tactical	acceleration in overtake maneuver	Take-over, drive in traffic jam, cross intersection, platooon	Stop for refueling	C: learn user preference for safe overtaking
	Control	Joint steering, Reenforced braking…	ACC, Lane-keeping	Observe speed limits	adapt to driving style

Figure 8 Discussion result of group "Teamplayers" (part 1).

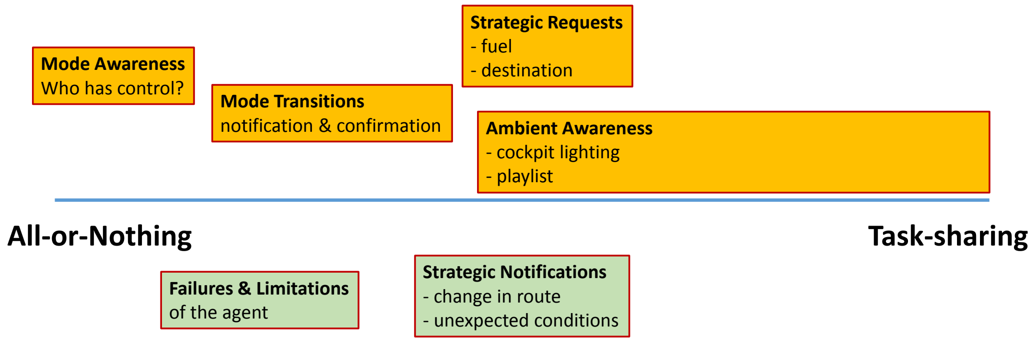


Figure 9 Discussion result of group "Teamplayers" (part 2).

Research questions:

- How does the user adapt the priorities of the system according to current goals?
- How to reconcile different perceptions & priorities in a situation?
- What are the mechanisms that can be used in the negotiation?
- How should metaphors be used – as design guidelines or as a tool to communicate technology to the user?
- Do different metaphors exclude or complement each other?
- Which modalities are appropriate for which type of communications (notifications and information)?

5.3 Wednesday: Prototyping Session

Before starting with the prototyping session on Wednesday, Susanne Boll gave a short overview talk how to prototype and what the expected output is (see Figure 11). She introduced the method of "Quick and Dirty" prototyping and presented the available prototyping material (Figure 12) and showed examples of previous prototyping sessions. Based on the results of day 1 and the subsequent clustering (see Figure 10), initial topics for the prototype session were set. In addition, seminar participants were invited to "pitch" new ideas (Figure 13) they want to work on during the next hours and try to attract supporters for their ideas.

Participants voted for the favorite topics and then organized themselves into small breakout groups and worked on creating prototypes of interfaces. All of the groups were productive and some also reported on their prototypes – these brief reports are included below.

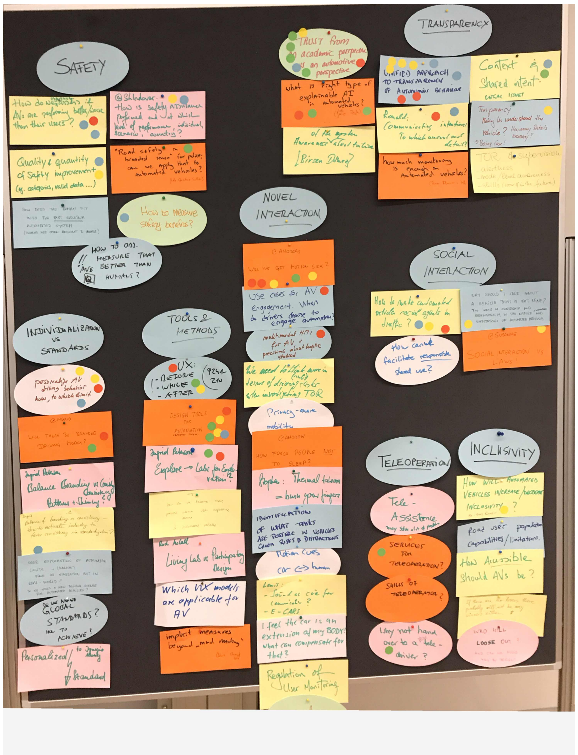


Figure 10 Result of day 1 after clustering and reorganizing by the seminar co-organizers: 4 top topics (upper chart) and other clusters (lower chart) were used in further sessions.

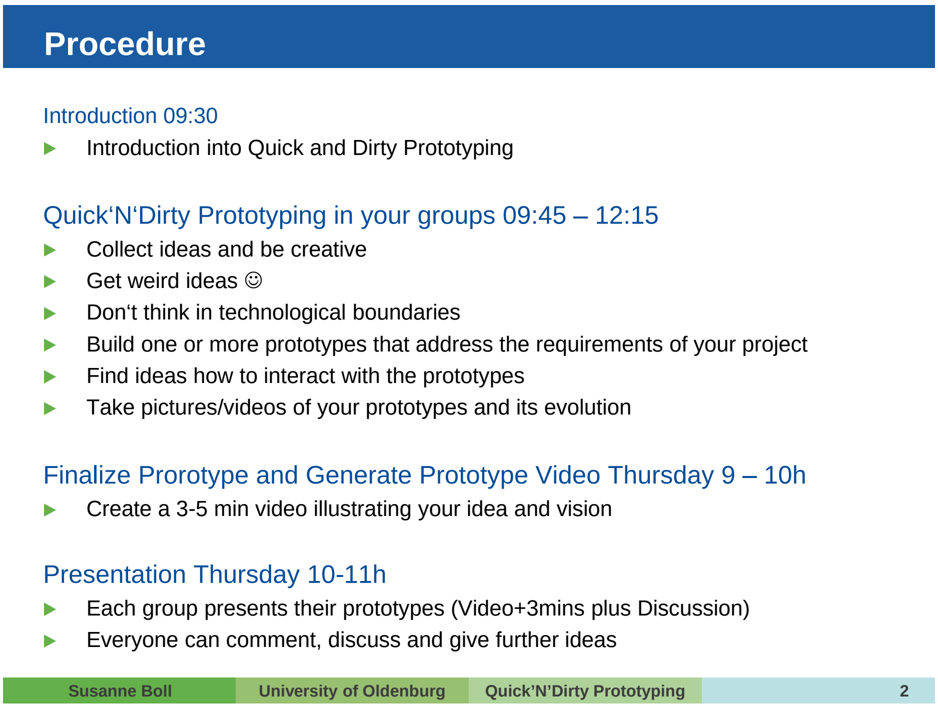


Figure 11 Overview and schedule for the prototyping session.

Figure 12 Prototyping material brought to Dagstuhl and available for seminar participants to create crazy prototypes/videos.

Figure 13 Collection of topics for the prototyping session (after the pitches).

5.3.1 Prototype: Teamplayers

(Prototype by Nele Russwinkel, Ronald Schroeter, Josef Krems, Jurgen Ziegler, David Yang, Birsen Donmez, Joanne Harbluk, Frank Flemisch, Martin Baumann, Jaka Sodnik)
The teamplayers group from Tuesday worked on a video prototype to convey their concept presented two days before. Scenario description: "We are on the way to the meeting, running late. We are approaching the roundabout with very intense traffic which contains several critical points for AV system. Therefore the system proposes collaboration with the driver (team work) to resolve the issue more efficiently."

Storyboard:

- PART 1
  1. Vehicle is approaching to the roundabout, driving in autonomous mode
  2. Driver is relaxing, exchanging some information with the IVIS
  3. Suddenly ambient light in the vehicle changes and informs the driver about the changed conditions
     - The vehicle changes its confidence state to red
     - It invites the driver to take over the control
  4. The driver takes over but it requires additional information
  5. The cyclist joins the roundabout
     - Vehicle enters to guardian angel mode
     - Vehicle performs the emergency braking maneuver
- PART 2
  1. Vehicle is capable of taking back the control and informs the driver about that
     - It changes its confidence state back to blue
  2. Suddenly the vehicle notices the unknown object and it doesn't understand the situation
     - It is a police officer indicating the vehicle to stop
     - Vehicle requests some information from the driver and changes its confidence state to red
     - Driver takes over and performs the stop maneuver
  3. Vehicle learns about this situation and remembers it
  4. Vehicle is capable of taking back the control and informs the driver about that
     - The vehicle changes its confidence state back to blue
- PART 3
  1. There is an accident (fire) on the right lane of the exit
     - Vehicle requests some information about this from the driver and changes its confidence state to red
     - The driver takes over the control again and avoids the fire by performing wider maneuver with bigger radius
  2. Conflict is resolved and the vehicle exits the roundabout successfully
     - The vehicle changes its confidence state back to blue

Figure 14 Teamplayer prototype (Martin Baumann, Ronald Schroeter).

5.3.2 Prototype: Novel Human-Machine Interfaces for the Management of User-Vehicle Transitions in Automated Driving

(Prototype by Gary Burnett, Wendy Ju, Sabine Langlois, Andreas Riener, Steven Shladover) For automated vehicles operating at SAE Level 4 capability, control could feasibly be passed from machine to human and vice versa -regardless of whether minimal risk condition exists as a fallback solution. We propose two Human-Machine Interfaces (HMIs) to assist in the management of these transitions: 1) A "Responsibility Panel" providing the necessary feedback for a user to understand who must undertake different driving related activities (look, brake, throttle, steer) and who might be liable if a fault arises (user or car company); 2) A "Readiness to Drive" testing HMI that only allows a human to retake control when a certain level of competency is demonstrated. Future work should evaluate the effectiveness of our HMIs.
Video link: http://www.andreasriener.com/Dagstuhl19132/Dagstuhl-Brexit2-mediumquality.mov

Figure 15 Video prototype "Novel Human-Machine Interfaces for the Management of User-Vehicle Transitions in Automated Driving", also submitted to AutoUI Video track [4].

References

1 Gary Burnett, Wendy Ju, Sabine Langlois, Andreas Riener, Steven E Shladover. *Novel Human-Machine Interfaces for the Management of User-Vehicle Transitions in Automated Driving*. Adjunct proceedings (Video track) of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019. (*submitted*)

5.3.3 Prototype: The (future) mobile office

(Prototype by Andrew Kun, Linda Boyle, Stephen Brewster, Christan Janssen, Duncan Brumby, Lewis Chuang)
Video link: http://www.andreasriener.com/Dagstuhl19132/The(future)MobileOffice.mp4
Camera-ready version: https://youtu.be/HrZmSb8NvBg

Figure 16 Presentation of the video prototype for concept "The (future) mobile office".

We created a video that shows a concept of a future mobile office in a semi-automated vehicle that uses augmented reality [6]. People perform non-driving tasks in current, non-automated vehicles even though that is unsafe. Moreover, even for passengers there is limited space, it is not social, and there can be motion sickness. In future cars, technology such as augmented reality might alleviate some of these issues. Our concept shows how augmented reality can project a remote conversant onto the dashboard. Thereby, the driver can keep an occasional eye on the road while the automated vehicle drives, and might experience less motion sickness. Potentially, this concept might even be used for group calls or for group activities such as karaoke, thereby creating a social setting. We also demonstrate how integration with an intelligent assistant (through speech and gesture analysis) might save the driver from having to grab a calendar to write things down, again allowing them to focus on the road.

References

1 Christian P. Janssen, Andrew L. Kun, Stephen Brewster, Linda Boyle, Duncan Brumby, Lewis L. Chuang. *Exploring the Concept of the (Future) Mobile Office*. Adjunct proceedings (Video track) of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

5.3.4 DiscHover – Next generation mobility platform

(Prototype by Susanne Boll, Alexander Meschtscherjakov, Bastian Pfleging, Bruce Walker, Maria Rimini-Döring, Christine Sutter)
In DiscHover we discussed and explore new forms of mobility and how the separation of mobility of individuals and goods could be solved by DiscHover, a hovering disc which can transport individuals but also goods such as the grocery shopping or luggage. We imagined a world in which this transportation device would allow us to freely move around along and in the company of friends without having to use a car. We prototyped very nice forms of DiscHovers, for work and for leisure, some that involve privacy such that one could even play the drums or listen to music during the ride. With DiscHovers one travel alone but also in company and different DiscHovers can join, just depending on the current transportation need.

Figure 17 Snapshot from prototype concept for DiskHover

5.3.5 Prototype: T.R.A.V.I.S

(Prototype be Ingrid Pettersson and Ignacio Alvarez)
Ingrid Pettersson and Ignacio Alvarez presenting their video concept outlining several different scenarios.

Figure 18 Presentation of prototype concept for T.R.A.V.I.S.

5.4 Wednesday afternoon: Excursion “Baumwipfelpfad Saarschleife, Mettlacher Abteibrauerei”

After 2 1/2 days of intensive work, Wednesday afternoon was reserved for a nice excursion with a relaxing hike. This time, we went to the “Baumwipfelpfad Saarschleife”, had an enjoyable walk around and finally visited Mettlacher Abteibrauerei. There, we learned how to brew (and of course drink) beer and we also enjoyed dinner at their great restaurant. The bus brought us back to Dagstuhl right-in-time for the cheese platter in the wine cellar ;-).

Figure 19 Excursion to Saarschleife and Mettlacher Abteibrauerei on Wednesday afternoon.

5.5 Thursday: World Café

5.5.1 Transparency and trust (facilitator: Sabine Langlois)

The topic concerns the trust towards a system (often also called robot) that allows the driving task to be automated, and the degree of transparency the human-machine interface (HMI) should have to help the user be trustful. The following three entities should be considered: a) the user inside the car, b) the automated driving system (ADS; or robot), and c) the persons outside the car (also called outside world). Two types of relationships among these entities can be described: monitoring and communication. Pedestrians (outside world) should be able to identity who is responsible for the driving task, either the human inside the car or the robot (monitoring). The robot should be able to monitor the user and should also be aware of its own limitations (self-awareness of the robot, thus able to monitor itself). The transparency of HMI supports communication from robot to user, and from robot to outside world. The user should have a way to interact with the robot and the outside world, but also the pedestrians (outside world) need to have a way to convey their intention of crossing to the robot.

Transparency has to be calibrated to support trust: There is an optimal amount of information to convey, otherwise trust decreases. This optimal transparency depends on different factors:

- **Usage duration**: first HMI should display what the robot detects (e. g. Tesla instrument cluster), then information should be provided only if there is a problem. Therefore, the threshold between what is a problem and what is not, needs to be defined.
- **User characteristics**: Two types should be considered: 1. The propensity to trust (is the user sceptic or compliant), 2. Cognitive style (is the user information seeker or avoider).
- **Level of automation**: As defined in SAE J3016 [1]

Figure 20 Discussions at the four World Café "tables" 1) Transparency and Trust, 2) Novel Interactions, 3) Tools and Methods, and 4) Remote Operation.

To evaluate trust towards an ADS, it is first useful to study the definition of trust. A first question to answer is: is trust considered as a noun or a verb? As already stated, trust depends on usage duration: trust-building starts prior usage, because of following factors: experience of ADAS/AD of the user; his propensity to trust; regulation toward AD; branding. During the learning phase, one idea to help trust-building is to refer to animal metaphor (e. g. trust building between a human and a dog). When the user encounters his first problem with the system, two types of trust evolutions can be observed: for the compliant user, trust will drop significantly (he was over-trusting the system), whereas for the skeptic user, trust will increase because the skeptic user is waiting for a problem to better understand the system (he was under-trusting the system). If an explanation is provided when the problem occurs, trust will drop less for the compliant user; an agent representing the artificial intelligence of the system could be a good way to convey this information.

Self-awareness is not an easy feature to give to the system, because there is the risk of negative and positive alarms. The self-awareness level (also called confidence level) should be an overall score of the different subsystems. If should not be too complex to understand, as such it should not be too dynamic. Two different use cases have been described: the case where confidence level fluctuates a lot, and the case where confidence level slowly drops down. Shouldn't the fluctuation, even if above threshold, be warned about? (whereas a low fluctuating level for sure should not). The following question was asked: wouldn't be easier to show the limits instead of providing a score? A simple way to show limits should then be found. The threshold should also be defined (see above: after some usage, the threshold should be modified to just to show problems).

References

1 SAE International. *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201806.* 2018

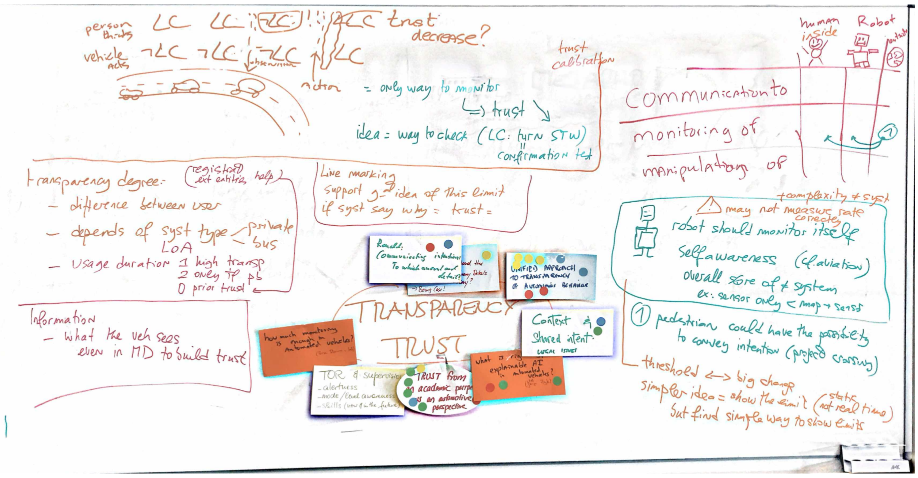


Figure 21 Final result of the World Café on "Transparency and Trust" (facilitated by Sabine Langlois) (part 1).

5.5.2 Novel interactions (facilitator: Stephen Brewster)

In this group, we discussed a wide range of topics around interaction in the car. In the area of user sensing, we discussed how we might collect data about the user (e. g. BCI, emotion, driver state, seat settings) that would be used for input into the driving system. This could be used for shared awareness between the car and driver, and also between the driver and other passengers. This could also be shared with other cars. An important issue of privacy came up with sharing this information.

Other discussion topics included knowing what the capabilities of the car were, especially for new drivers or rental situations. How learnable is a new car, and how transferable are the skills learned in one to another. There are issues of standardization here. There are also issues of updates – the car might change from one day to the next with a software update. We also discussed personalization and how the setup of your car might follow you to a new car, perhaps through your phone or profile.

We discussed "out of car interaction" or things that happen outside the car, for example how to exit the car, external lighting, other road users, summoning the car. Important issues occur with users with disabilities as how does a blind person find their Uber, for example.

Finally we discussed more unresolved issues. For example, dealing with motion sickness is still important. Information overload for the driver. Rapid design iterations vs. safety. Privacy was a big topic that came up throughout the discussions. How might data that could be used to make driving safer be collected and used in ways that preserved privacy.

5.5.3 Tools and methods (facilitator: Wendy Ju)

As a research community, we would like to share methods, protocols, scenarios, tools, and datasets. This will facilitate the practice of research and enable us to more directly compare results. One major area for this discussion is the research environments; we would like to share

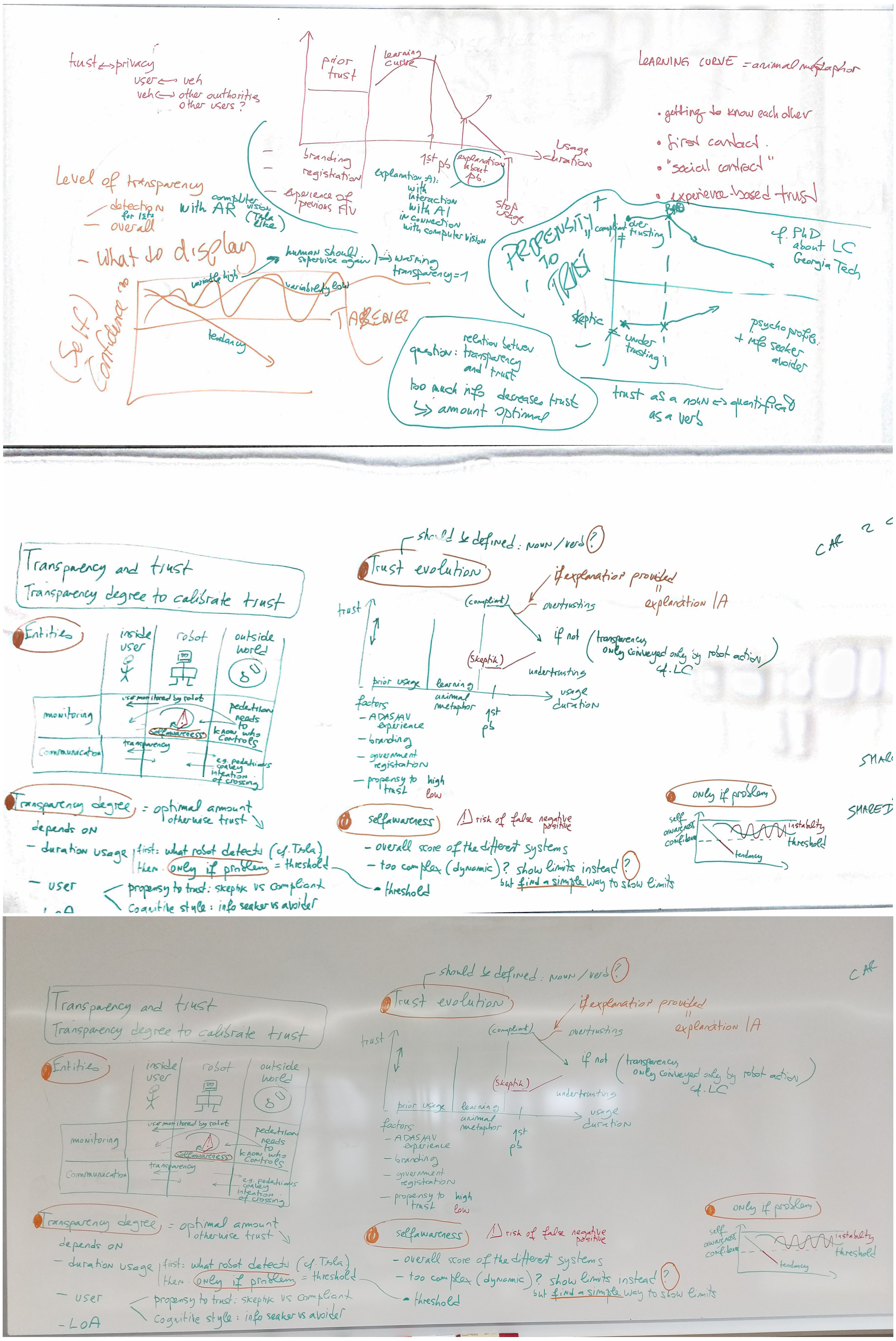


Figure 22 Final result of the World Café on "Transparency and Trust" (facilitated by Sabine Langlois) (part 2).

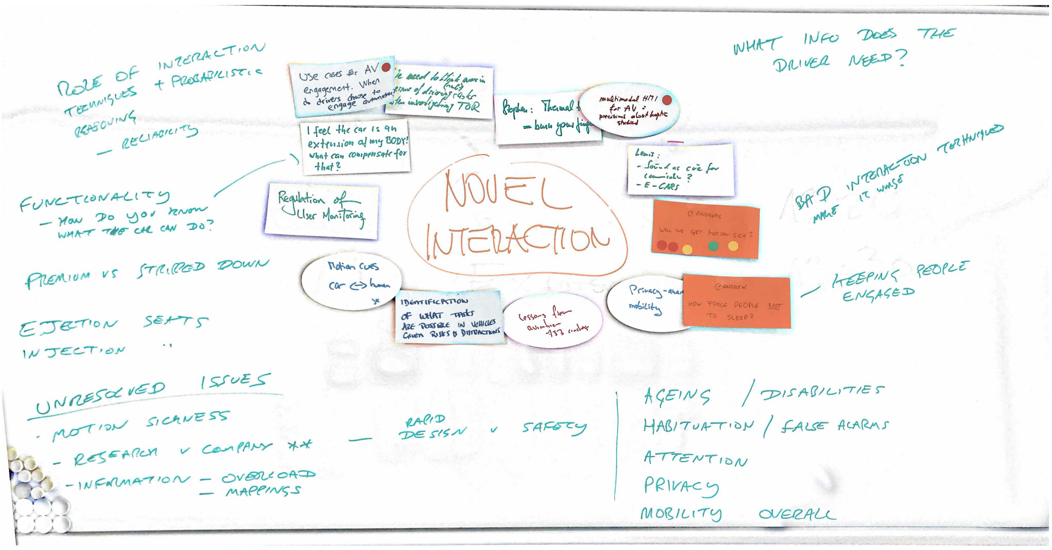


Figure 23 World Café on "Novel interactions" (part 1).

commonalities of simulators, theater/improved environments, tracks, in-vivo environments and living labs. Another major area has to do with methods. Much of the community focuses on controlled experiments in driving simulators. However, additional methods, for example, on-line video prototype experiments, or methods for creating realistic sense of risk in simulation would benefit the whole community. (A survey of methods for UX & Design is being generated by Anna-Katharina Frison, e. g., [1], [2].)

Measures and benchmarks are an important area for research community agreement. In Driving simulation, this community would like to come to agreement on measures for AV interactions. Beyond the measures and metrics inherited from traditional driving simulation experiments, trust, situation awareness and shared situation awareness are emerging as common measures. However, there is a need in this space to understand tasks, scenarios, roles, or control structures to understand what situation awareness means in the AV space. When we look at more naturalistic or observational experiments, it would be good to develop common ways of capturing and labelling naturalistic and behavioral responses. Common methods for collecting, cleaning, analyzing and validating and replicating data from studies would make for greater robustness, credibility and comparability within our field.

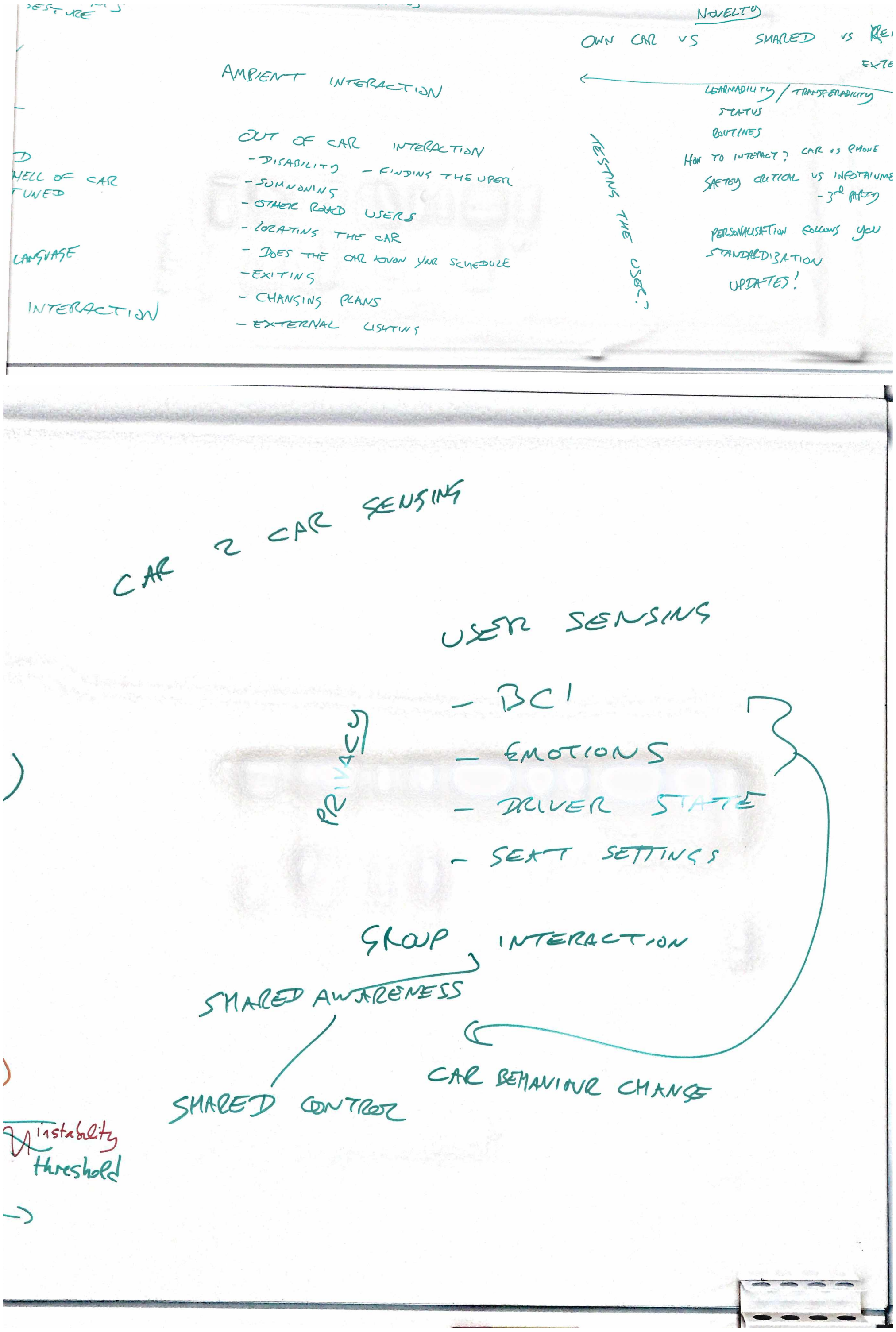
On the subject of data, we would all like to learn more about how to generate and share data. Physiological measurement, eye tracking tools, or CAN BUS sniffers might be particularly useful to understand behaviors in more uncontrolled environments. Methods for integrating data streams are also something we all need.

In terms of concrete next steps, we proposed to organize a how-to book/website of tools and methods for researching human-autonomous vehicle interaction. We plan to write proposals to fund communities of research that would help to establish sharepoints for the methods, protocols, software or datasets the community should share.

References

1 Ingrid Pettersson, Florian Lachner, Anna-Katharina Frison, Andreas Riener, and Andreas Butz. *A Bermuda Triangle?: A Review of Method Application and Triangulation in User Experience Evaluation*. 2018. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). ACM, New York, NY, USA, Paper 461, 16 pages. DOI: https://doi.org/10.1145/3173574.3174035.

2 Yannick Forster, Anna-Katharina Frison, Philipp Wintersberger, Viktoria Geisel, Sebastian



■ **Figure 24** World Café on “Novel interactions” (part 2).

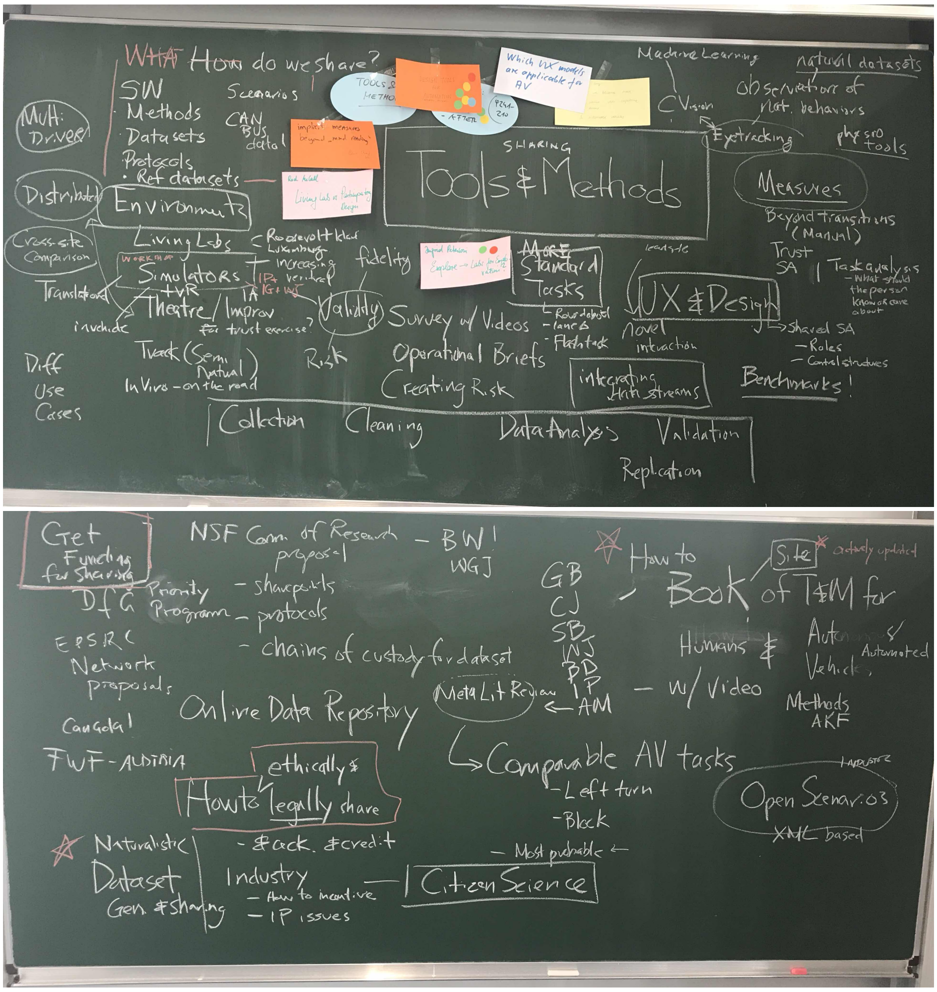


Figure 25 Summary of the World Café of group 4 "Tools and Methods".

Hergeth, Andreas Riener, Josef F. Krems. *Where We Come from and Where We Are Going: A Systematic Review of Automated Driving Studies*. Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019. *submitted*

5.5.4 Remote operation/Teleoperated driving (facilitator: Andreas Riener)

In the domain of automated driving, numerous (technological) problems have been solved in recent years, but still many limitations are around that could eventually prevent the deployment of automated driving systems (ADS) beyond SAE L3. A remote operating fallback authority might be a promising solution. In this group, we were discussing challenges and opportunities related to the tele-operation of vehicles. (With this term, we understand the hand-over of control from an ADS to an operator located in an external control room. In the discussion, we found out that there are many similarities to Unmanned Aerial Vehicles (UAV), for example related to the ratio of operators : vehicles (1:1 vs m:n). We further discovered that the skills and occupational conditions required for a teleoperator including tele-op licensing are not defined yet and discovered it rather important to inform the driver about an external take-over (transparency display). As for the situation awareness of the operator in the remote control room, we agreed that there is a need for multi-modal communication including visual information (traffic scenario, either as videos, abstractions, bird eye's view, amongst others), auditory cues (environmental perception, e. g. a honking car in the back or overtaking emergency vehicle), and kinesthetics to avoid motion sickness. We also talked about potential use cases/scenarios and classified them based on three general categories: Remote operation of a) empty cars only (send to parking garage, etc.), b) transporting goods, and c) assisting human drivers (from low "switching on windshield wiper" to high "take over the driving task"). For the latter category, trust (in the operator) is another important issue to consider.

Follow-up readings:

References

1 Alex Davies. *The War to Remotely Control Self-Driving Cars Heats Up*. online: https://www.wired.com/story/designated-driver-teleoperations-self-driving-cars/, March 26, 2019

2 Stefan Neumeier, Philipp Wintersberger, Anna-Katharina Frison, Armin Becher, Christian Facchi, Andreas Riener. *Teleoperation: The Holy Grail to Solve Problems of Automated Driving? Sure, but Latency Matters* . Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

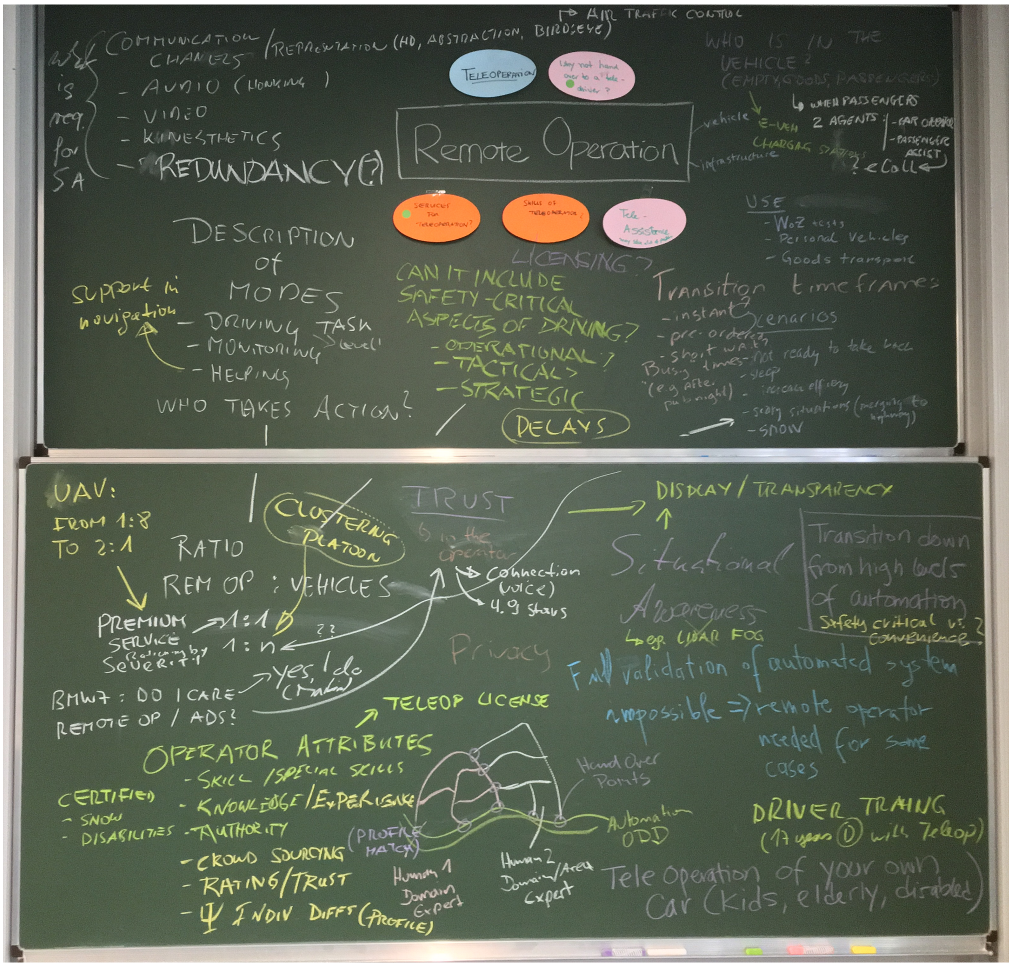


Figure 26 Summary of the World Café of group 4 “Remote operation”.

5.6 Friday: Wrap-Up and Planning of Follow-Up Activities

In the closing session on Friday, all participants discussed together joint follow-up activities to that seminar. The participants identified numerous possibilities for future cooperation, collaboration, and communication to a broader audience. These include, among others:

- Videos from the prototyping session will be finalized and submitted to AutoUI 2019, e. g. [4, 2]
- Videos will also be shared amongst participants and used for educational purposes
- Several subgroups (e. g. of break-out groups) plan to write papers for conferences or journal articles, e. g., [2, 3]
- NSF, DFG, EPSRC, NFR, FWF, COST/ITN: Joint grant proposals planned for community building (driven by World Café “Methods and Tools”)
- Participants also suggested to compile a “handbook of research methods” in the broader field of the seminar
- Follow-up workshops or a panel discussion planned are for AutoUI 2020 and similar conferences
- Tuesday group “Disruption/Radical innovation”: Q: are we the right persons? Organize a panel session with Urban planner, geologist, sociologist, legal, pedestrian/bicyclists

association, etc. related to automated driving
- Panel on governmental perspective on automated driving planned for AutoUI 2019
- Follow-up Dagstuhl seminar proposal planned (maybe more than one?)
- As a community, we should encourage people to provide open data using OSF, Github, link in the paper, etc.
- "Mobile office" NSF project (L. Boyle & A. Kun) discuss to collaborate with A. Riener on a similar project (staff exchange, workshop)
- Some participants think about special issues in journals, such as IEEE PC or Ubiquitous Computing or IJHCS journal

In another session, Frank Flemisch presented the brand new 2019 edition of the "VDA[1] Normungs-Roadmap zum automatisierten Fahren" (VDA standardization roadmap for automated driving), see Figure 27.

References

1 Philipp Niermann. *Normungs-Roadmap zum automatisierten Fahren*. Verband der Automobilindustrie e.V. (VDA), DIN-Normenausschuss Automobiltechnik (NAAutomobil), Behrenstraße 35, 10117 Berlin. 2019. pp. 29. online https://www.vda.de/de/services/Publikationen/normungs-roadmap-zum-automatisierten-fahren.html

[1] Association of the Automotive Industry

Figure 27 2019 edition of the standardization roadmap for automated driving (VDA, pp. 29).

6 Publications inspired by Dagstuhl seminar 19132

The following list summarizes publications inspired by the seminar (as of Septembre 10, 2019).

References

1 Stefan Neumeier, Philipp Wintersberger, Anna-Katharina Frison, Armin Becher, Christian Facchi, Andreas Riener. *Teleoperation: The Holy Grail to Solve Problems of Automated Driving? Sure, but Latency Matters* . Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

2 Christian P. Janssen, Linda Boyle, Wendy Ju, Andreas Riener, Ignacio Alvarez. *Agents, Environments, Scenarios: A Framework for studying Human-Vehicle Interaction*. Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019. (*submitted*)

3 Linda Boyle, Christian P. Janssen, Wendy Ju, Andreas Riener, Steven E Shladover, Christine Sutter, Frank Flemisch. *Clarifying variations in vehicle automation: Beyond levels of automation*. Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019. (*submitted*)

4 Gary Burnett, Wendy Ju, Sabine Langlois, Andreas Riener, Steven E Shladover. *Novel Human-Machine Interfaces for the Management of User-Vehicle Transitions in Automated Driving*. Adjunct proceedings (Video track) of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

5 Andreas Riegler, Andreas Riener, Andrew L. Kun, Joseph L. Gabbard, Stephen Brewster, Carolin Wienreich. *MRV 2019: 3rd Workshop on Mixed Reality for Intelligent Vehicles*. Adjunct proceedings (Workshop track) of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

6 Christian P. Janssen, Andrew L. Kun, Stephen Brewster, Linda Boyle, Duncan Brumby, Lewis L. Chuang. *Exploring the Concept of the (Future) Mobile Office*. Adjunct proceedings (Video track) of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI'2019), Utrecht, 2019.

7 Conclusion

Dagstuhl seminar 19132 brought together 31 experts in the field of in-vehicle human-machine interaction in order to discuss how our field can contribute to the success of future automated vehicles.

Workshop participants contributed to the discussion in a variety of ways. They started their efforts with pre-workshop activities: they helped us create a list of recommended readings as well as a list of important research questions. At the workshop, participants engaged in lively debates in multiple formats, from formal presentations, to breakout groups, to prototyping sessions, to world cafe-style forums.

The result of these efforts include an intellectually rich week at Dagstuhl, a set of scientific ideas that are already incorporated into documents submitted for review, as well as specific plans for collaborations between participants.

To wrap up this document, as organizers, we would like to express our deep appreciation to all of those people who contributed to the success of this workshop. First and foremost, we

thank the team at Schloss Dagstuhl for their dedication and exceptionally high-quality work, from organizing the meeting, to hosting us at the castle. And of course, we are most grateful to all of the workshop participants who took an entire week out of their busy schedules to join us in order to create new scientific knowledge in the field of human-machine interaction for future vehicles.

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1 Ingrid Pettersson, Florian Lachner, Anna-Katharina Frison, Andreas Riener, and Andreas Butz. A bermuda triangle?: A review of method application and triangulation in user experience evaluation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, pages 461:1–461:16, New York, NY, USA, 2018. ACM.
2 Akamatsu, M., Green, P., & Bengler, K. Automotive technology and human factors research: Past, present, and future. In *International journal of vehicular technology*, 2013.
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