Report of Dagstuhl Seminar 16262

Automotive User Interfaces in the Age of Automation

Edited by

Andreas Riener[1], Susanne Boll[2], and Andrew L. Kun[3]

1 **University of Applied Sciences Ingolstadt, DE,** andreas.riener@thi.de
2 **University of Oldenburg, DE,** Susanne.Boll@uol.de
3 **University of New Hampshire, US,** andrew.kun@unh.edu

Abstract

The next big change in the automotive domain will be the move towards automated and semi-automated driving. We can expect an increasing level of autonomous driving in the coming years, resulting in new opportunities for the car as an infotainment platform when standard driving tasks will be automated. This change also comes with a number of challenges to automotive user interfaces. Core challenges for the assistance system and the user interface will be distributing tasks between the assistance system and the driver, the re-engagement of drivers in semi-automated driving back to the driving task, and collaborative driving in which cars collectively work together (e. g., platoons). Overall, in the coming years we will need to design interfaces and applications that make driving safe while enabling communication, work, and play in human-operated vehicles. This Dagstuhl Seminar brought together researchers from human computer interaction, cognitive psychology, human factors psychology and also from automotive industry and OEMs to discuss the new interface paradigms for (semi-)automated driving.

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1 Executive Summary

Andreas Riener
Susanne Boll
Andrew L. Kun

The next big change in the automotive domain will be the move towards semi-automated and automated driving. The pathway to autonomous driving supported by rapid advance of a wide range of novel vehicle-related technology presents industry, academia, and regulatory agencies with new opportunities and challenges in re-imagining human interactions in the vehicle. While expectations are high towards automated driving the revolution will proceed in incremental steps; with the progress of technology new tasks and driving phases will be supported by automation. All of this will unfold in traffic scenarios in which different levels of automation will coexist for many years in which user interfaces play a key role.

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We see three core challenges for automotive user interfaces in the age of automation, which we have addressed during the seminar.

- **Transforming vehicles into places of productivity and play.** People in automated vehicles will be able to turn their attention to non-driving tasks some of the time, or even much of the time. This will allow user interface designers to explore a range of possible interactions, which are might be too distracting in manually driven vehicles. For highly automated vehicles our constraints will have to do less with the driver's attention to the road, and more with the characteristics of the vehicle, such as the area available for interaction, the motion of the vehicle, as well as its computational power and the sensors that are available in the cockpit. User interactions will include other people in the vehicle, but might also include people in other vehicles. Novel user interfaces may turn the car into an infotainment and entertainment platform in which the automation allows for new secondary tasks in the car with driver and passengers that were not possible before.
- **Re-engagement of drivers into the driving task.** As automated driving makes advances, drivers will often be able to disengage from driving, and safely turn their attention to a secondary task. But until our vehicles are fully automated, drivers will eventually have to re-engage in driving. As the non-driving tasks may vary in time but also in the engagement of the user, it will be a challenge to safely and timely return to the primary task. For handling a critical situation the driver must perceive, and act upon, a sequence of information and entities. This can be a complex maneuver in a traffic scenario but also a time critical course of actions in the treatment of an emergency case. Much work needs to be done on user interface design in order to make re-engagement in different kinds of situations and different kinds of complexity safe.
- **Collaboration in mixed traffic scenarios.** Traffic automation will come to the streets peu-a-peu. Thereby and for many years, mixed scenarios in which vehicles with no-, partial-, and full automation will coexist and cooperate in daily traffic. This road sharing involves communicating autonomous operations to the driver of the autonomous car and also a communication strategy to keep non-autonomous vehicles and their drivers in the loop. Road sharing means avoiding collisions, but automated vehicles will also cooperate, for example by traveling in platoons in order to save energy and improve the utilization of the road infrastructure. Research is needed to create user interfaces that allow for safe operation of the vehicle in all of these mixed traffic scenarios.

Along with these topics, we also discussed the role of trust, e. g., how user interfaces will support the communication of trust in typical situations with mixed levels of automation. We further discussed about future technologies in and around the car (e. g., novel sensors, interaction concepts, and feedback systems) and about the recent strategy change of automakers to fund apps and invest a lot in app development to make car dashboards/instrument clusters more sustainable.

This Dagstuhl Seminar brought together researchers from human computer interaction, cognitive psychology, human factors, psychology, and also from automotive industry and OEMs to discuss the new interface paradigms for (semi-)automated driving.

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3 Topics Discussed in the Seminar

Based on an in-depth understanding of the many needs of the individual driver(s), individualized design and human factors-centered design is expected to be "the success factor" for automated (maybe even autonomous) driving. Assuming further that stresslessness and wellbeing of the passenger (or, perhaps, the inactive driver in autonomous vehicles) will play a major role in the design of the transportation experience in future cars [1], the exploration of new quality aspects is an important research task to support the broad application of autonomous cars. In addition, autonomous cars may involve entirely new forms of interaction (with drivers, but also with persons in the exterior area) and new in-car services (e.g., sharing of experience changed interaction requirements (negotiation), and car-to-x communication on a broad scale. Driven by the identified research of future automotive user interfaces we will address the following topics in the seminar.

In advance to the seminar we asked the participants some fundamental questions in the area of the seminar, e. g., what they find to be the urgent questions in the coming age of automation, which work inspired them, or what papers they authored in the broader area of automotive UIs in the age of automation.

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3.1 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 user interfaces in the age of automation technologies?"

Here is the summary of responses (for sure, some sources were mentioned more than once).

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3.2 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."

Summary of responses:

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3.3 Research Questions

> *Question 3*: "What do you consider to be the most interesting research question related to user interfaces for autonomous vehicles? (If you have more than one question, that's great, send them all.)"

The following list of questions (no particular order) was identified by seminar participants before meeting at Dagstuhl and used to structure the seminar and initiate discussions in the field.

- How do we need to design UIs to support adequate situation awareness when driving (highly) automated vehicles?
- How can the automated vehicle act as a cooperative team player and how can this be supported by the UI?
- How can the UI support the development of adequate trust in automated vehicles?
- How can autonomous cars improve life? An increased mobility is expected to be available when autonomous cars are on the road. How can they be part of a better life? How can an autonomous vehicle be integrated harmonically in everyday routine? Once this is explored, designing interventions for the detected scenarios will be more targeted and meaningful. Older drivers who still wish to maintain their driving ability, passengers who are not interested in driving or find it non-ecological or mobility-impaired individuals who will find benefit by the presence of such cars are example personas to design for.
- What are the expected interactions in the car?
- Will the autonomous car be used as a mobile living room? Or maybe as a mobile office?
- How can autonomous cars promote a sustainable society?
- If autonomous transportation becomes a service, as has been suggested, then there is a big change to be expected in mobility. If having one car for many people (even more so an electric car) is more sustainable than having one car per family or per person, why not encourage this? This direction of sustainability in autonomous cars is very promising and little explored, while the persuasive research potential is exciting.
- Can the driver's attention be recaptured by a well-designed DVI after the driver has been doing something other than driving in an SAE Level 3 automated vehicle, and if so how quickly and under what conditions?
- Can driver abuses of SAE Level 2 and 3 automated driving systems (well documented in YouTube videos for available Level 2 systems) be deterred by suitable DVIs, and if so how? What information does the DVI in a highly automated vehicle need to display to the driver and vehicle occupants in order to give them adequate confidence in the competency of the automated driving system?
- How should a highly automated vehicle communicate with vulnerable road users (pedestrians and bicyclists) about its awareness of their presence and its maneuver intentions?
- Under what conditions (if any) should the DVI delay or prevent the driver from stopping or re-taking control of the motion of a vehicle that is being driven by an SAE level 4 or 5 automated driving system?
- These are the three high-level ones I usually set to my students in a lecture I give each year on "HCI in cars" ... For me these are all critical to the success of fully/highly automated vehicles
- How do you design the Human-Machine Interface for automated driving functionality? – including the management of transition periods/warnings, and provision of shared situation awareness for vehicle/driver.
- How do you design the Human-Machine Interface for non-automated driving functionality? – given the freedom for radically different vehicle interiors?
- How do you design the vehicle as a whole as a Human-Machine Interface? For instance, considering how the vehicle communicates its intent to other road users.
- What is the future of Autonomous UI: dull standardized UIs or dynamic, adaptive highly personalized interactions? How can we design a system that allows UIs in Autonomous vehicles to support ALL possible personalized interactions?
- How can we allow for coexistence of automotive UI regulations and personalized information desires when driving is not the primary task?

- What is the right UI approach to move cognitive resources from a non driving to a driving task and what control mechanisms do we need to develop measurements for? Conversational agents are increasingly popular (Siri, Alexa, Cortana, OK Google) are autonomous cars going to produce similar systems like the ones depicted in Science Fiction (KITT, HAL, Jarvis, etc.)?
- What strategies can UI follow to condense and explain effectively highly complex driving scenarios to an unprepared/untrained human driver?
- How removed do users expect to be from the perception-action loop of driving in order for automated driving to be an appealing option?
- How frequently will the user fatigue of (which) non-driving activities and feel compelled to re-evaluate the driving mission (for which aspects)?
- What is an appropriate level of user activity to ensure sufficient user arousal without handicapping vehicle take-over? To what extent can we already measure this from device interactions without the use of physiological measurements?
- Some futurists predict we will not own our car any more in near future. But we can just pick and drive any car in front of our house. If the cars are all equipped in the same way and shared with everyone, and so there is no more "personal" car, how can we "pick" a car and customize it into "my car" when pick? (just put our mobile phone/sim card into the deck?) DeepMind has recently developed a "big red button" to prevent its AI from causing harm. When and how can we stop/turn off AI of the car?
- How can the design of a human machine interface in highly automated driving assist drivers in the transition from driver to passenger role and vice versa?
- How to keep drivers aware of the driving context while they engage themselves in other secondary tasks? What information and presentation forms can increase human's trust in automation?
- How to communicate the intentions of a fully automated vehicle to other non- or semi-automated cars in a mixed traffic situation?
- How can the car become a more central part of people's information lives?
- How can experiences in the vehicle broader our understanding of interaction and emotion?
- How can cars understand and respond to differences in culture and individual preferences in interaction?
- What is expected from interactive cars in long-term relationships with users?
- How do we best approach user testing, in terms of: (a) longitudinal testing (and finding the unexpected use cases), (b) exploring ways of inducing AD experiences by means of non AD-technology?
- How can autonomous cars provide long-term value, i.e. by services, future designs?
- How can we avoid mode confusion and over/under trust, in the process towards fully autonomous cars?
- How do we approach a more holistic communication by the car than predominantly only the visual/audio HMI? I.e. to whom (the "driver" or all passengers?) and by what (how/should we make more use of the vehicle as a whole)?
- According to some statistics in the Western world we'll soon have 50 percent of the drivers licence holders being older than 60–65 yrs: what will be an intuitive automotive user interface/interaction that takes care of legacy habits of a population that learned how to drive when there were NOT Smartphones, Touchscreens, Internet. What are their expectations to feel involved and not disengaged, to develop an appropriate level of trust in the growing automation?

- What are opportunities for keeping the driver in the loop and establish a kind of shared control between user and vehicle?
- How are we going to inform the user about the capabilities of the vehicle (enable the user to build a mental model of the system)? Related questions here are what the users needs are in this respect and how they may change over time as a function of exposure
- Given that autonomous vehicles will capitalize on safety, we may expect that other road users may start to abuse AV technology (in particular, other road users like pedestrians, bicyclists and drivers of non-autonomous vehicles may take advantage of the fact that an autonomous vehicle will have a very defensive driving style). How can we develop the technology such that we find a proper balance between the interests of the users and the interests of other road users?
- How to provide drivers/users (not only in cars) with appropriate levels of transparency and control when interacting with intelligent automated vehicles/systems Ready for a cruise? How to tell an autonomous car where to go
- Is there an uncanny and unsafe valley (of automation) between partial and high automation? Is the region which SAE calls conditionally automated already in the unsafe valley?
- How can we secure the unsafe rims of the valley and build a bridge of safe transitions across the valley?
- What can we do while we drive/are transported with autonomous vehicles?
- How to implement reliable real-time trust calibration in vehicles?
- How could a vehicle provide training to maintain a driver's driving performance?
- How can automated cars provide "driving fun"?
- Driver or Pilot – how to obtain a driving license in the future?
- How do we support drivers to stay in-the-loop and take over in case of emergency?
- How we can get people to feel in an automated vehicle like as sitting in a public transport? Does a antromorphized car concept improve peoples trust in automated vehicles?
- How can evaluation processes of the experience with automated vehicles adapted into the practical work of the industry?
- Identity spoofing – Can driving patterns/profiles (or inspection of driving style) help to uncover faked identities (i.e., normal car pretending to be an emergency vehicle and getting right of way all the time?)
- Overarching question: How do we keep situations of shared or distributed control safe for humans? This has sub-questions such as "How do we keep the human in the loop and aware of their surroundings?" and "What is the fastest and most accurate way to communicate information from the car to the human?".

4 Contributions by Seminar Participants

4.1 Crafting the Foundation of Autonomous Vehicles User Interfaces

Ignacio Alvarez (Intel – Hillsboro, US, ignacio.j.alvarez@intel.com)

The Dagstuhl Seminar on Automotive User Interfaces in the Age of Automation has brought to public discussion the differences and similarities in perspectives, problems, focus and solutions existing in automotive user interface in a multicultural variety of professionals from academia and industry. The introductory talks and discussions made clear that we all share common problems and questions such as trust in autonomous systems, data collection, simulation, creation of scenarios, tools and methods. There are fundamental differences in how we define terms, what methods and tools we apply and how we approach scenario creation and simulation from practices in UI Design / Human Computer Interaction, Psychology, Human Factors and Systems Engineering. However, we proved that exercising focused discussions for agreement and cross-field mapping of definitions and methods we can start to create a framework for common understanding and positioning of our individual research contributions. This has helped us understand our own limitations and the potential or collaborative work. This seminar has created an approach, from a multidisciplinary perspective, to the symbiotic relationship of a highly automated vehicle and human passengers / operators. There are multiple gaps we still need to bridge and evangelize across both industry and academia to design and develop the user interfaces of the next generation of automated vehicles but we have successfully identified common trends in agency and control mechanisms and value propositions. We have also agreed on methods, metrics and systems and the tools that we need to develop to accelerate the adoption of autonomous vehicles.

Main Research Fields: Automotive, HMI, Human-Centered Computing Artificial Intelligence, User Experience.

4.2 Automated Vehicles Should Be Team Players!

Martin Baumann (Universität Ulm, DE, martin.baumann@uni-ulm.de)

My vision of an intelligent automated vehicle is a system that behaves as a team player. This means that the automated vehicle does not substitute the human driver but acts as a supportive agent for the human driver in the driver-vehicle-system. It is transparent, flexible, adaptive, and reliable and possesses a high interactive competence. It takes over control of the driving as much as the driver desires or needs, keeps the driver in the loop if necessary, communicates efficiently, explains in an appropriate way its status, behavior, intentions, and is able to adapt both to the individual driver and the current and upcoming traffic situation. I strongly believe that only with such an automated but interactively competent vehicle it is possible to create a driver-vehicle-system that shows optimal, robust and safe performance by exploiting the strengths and counterbalancing the limitations of each partner in an efficient way.

Main Research Fields: Human Behavior in HMI, Human Factors, Cooperative Driver Assistance and Automation, Cognitive Psychology.

4.3 Attention Shift in Automated Environments

Susanne Boll (Universität Oldenburg, DE, Susanne.Boll@informatik.uni-oldenburg.de)

Even with greatly increased automation in the future, the human will need to be in the loop for monitoring. However, interaction with cyber-physical systems like cars, ships, robots, smart homes, or emergency rooms will change dramatically: (1) humans will interact much less frequently with the larger automated cyber-physical systems than with today's simpler automated systems; (2) human interaction will be needed to a much greater extent for tasks in which the human is superior to the machine and where automation finds its limitations; (3) humans will be free to dedicate more and more of their cognitive resources to other tasks, with their attention shifting only when needed to interact with the automated system.

Future automated cyber-physical systems need to address the challenge of interaction with the human for efficiency and safety under this new paradigm of interaction and shared control. Interfaces currently addressing these requirements for decision making are rather primitive, mostly limited to single, unspecific alerts and auditory cues for gaining and dragging the attention to information and entities. Frequent, often unspecific alerts are leaving the human with the demanding task of identifying and localizing the problem. In the future intelligent attention management will be crucial to successful cooperation between human and machine.

Main Research Fields: Multimodal pervasive interfaces, peripheral and ambient displays for attention shift.

4.4 Research Needs for Designing Vehicle Automation to Be Safer Than Drivers

Linda Ng Boyle (University of Washington – Seattle, US, linda@uw.edu)

Automation is changing the nature of driving. Our vision for the future is often constrained by our knowledge of how things work today given existing infrastructure, policies, and our perceptions of "what is driving". Developing "out of the box" solutions implies that we know how to examine the impact of vehicle automation in the context of the user, vehicle, and environment. There are several key research areas related to the users' ability to adapt appropriately to increasing levels of automation. This includes appropriate trust in the automation, willingness to use, and the operators' ability to be aware of changes in the vehicle state. The changes can include varying levels of automation at the strategic, tactical, and operational level. Drivers' use of automation and their ability to adapt to varying levels of automation is greatly impacted by their experience with the system; which can change negatively, positively, or not at all (Peng and Boyle, 2015). A classification framework for examining human-autonomous interactions is important for future research, one that considers the agents, scenarios, and environments

Main Research Fields: Human Factors in Driving Assessment, Driving Behavior Analysis, Crash and Safety Analysis, Statistical Modeling.

4.5 Driver-Vehicle Communication as the Key for Future Automation

Nora Broy (BMW Group – Garching, DE, Nora.NB.Broy@bmw.de)

Automation plays an increasing role in our everyday life. From switching in telephone networks over automated processes in the industry to the steering and stabilization of ships and aircraft, there are various recent and emerging applications with minimal or reduced human intervention. Also the automotive domain faces a paradigm shift to automated driving which will have a significant impact on our everyday life, our relation to cars, and our mobility behavior. As the automated car offers fantastic possibilities for comfort and safety it also gives the drivers valuable lifetime in order to increase their productivity or to simply find some time to relax while approaching different locations. However, the automation of the driving task will never be perfect, in particular regarding the upcoming decades. Both humans and machines have certain imperfections that make the "driver" vehicle communication as a key for the future of automated cars. I am curious about to see exciting and innovative user interface concepts that contribute to driver vehicle collaboration. In particular, it is necessary that the driver can better understand the complex automation of the vehicle in every situation but also the vehicle has to know its driver and their capabilities. It is up to us HCI and human factors researchers to identify the optimal UI design parameters which ensure an ideal interaction between the automated car and the "driver(s)".

Main Research Fields: Human Factors, Human Machine Interaction.

4.6 Eyes off the Road: How Autonomous Vehicles Will Change In-Car Activities

Duncan Brumby (University College London, GB, d.brumby@ucl.ac.uk)

Just as the arrival of the car more than 100 years ago changed the way that we lived in the past, so the arrival of autonomous vehicles has the potential to profoundly change the way that we live in the future. In the short-term autonomous vehicles hold the potential to alleviate some of the problems currently associated with driving: allowing greater packing of vehicles on highways to ease congestion and freeing the driver from mundane control activities to engage in more rewarding work and leisure activities. In the longer-term there will be further, as yet unimagined, opportunities that will emerge following the mass release of autonomous vehicles on to our roads. The purpose of this Dagstuhl seminar has been to discuss critical issues on the path to an autonomous driving future. For me, the most critical issue is how to manage the handover situation between drivers and automated cars when the driver is immersed in an unrelated activity (i.e., watching a movie, working on a document, having a video chat, etc.). This need was brought into focus today with the tragic news that a person has been killed in a crash while driving with Tesla's "Autopilot" active. The accident occurred when a tractor trailer drove across the highway "against a brightly lit sky". The brakes were neither applied by the Autopilot nor the human driver. How can we design better human-machine interfaces to avoid tragedies occurring again.

Main Research Fields: Multitasking and Interactive Search.

4.7 HMI Design for 2020 and Beyond

Gary Burnett (University of Nottingham, GB, gary.burnett@nottingham.ac.uk)

The research community in Automotive HMI needs to consider how to design interfaces for automated, non-automated driving functionality, as well as the design of the vehicle as a whole HMI for other road users. The HMI, for future vehicles will depend considerable on the level of automation. Whilst there is still a requirement/ desire to manually drive, HMIs will have to be highly adaptive/ adaptable to cope with the move between different ways of the vehicles. Also to deal with the transfer of control issues, an HMI will need to facilitate considerable mutual situation awareness. There is growing desire that a natural language HMI combined with full windscreen Head Up Displays/ ambient displays provide significant potentials for successful outcomes. For fully automated driving, the scope for radically different interiors is much. In this respect, there is a considerable scope for the vehicle to allow more physical movement and use of our bodies, rather than the constrained posture we currently encourage in a car. Many drivers experience considerable problems with their lower back and our sedentary lives lead to rising obesity levels and poor health/ quality of life outcomes. This workshop in Dagstuhl has been extremely rewarding as a mechanism venue for discussing such issues with interesting people in a beautiful location.

Main Research Fields: Human Factors in Transport, Driving Psychology, ADAS, Future of Traffic.

4.8 Driving Headlong into the Uncanny Valley of Automated Driving

Lewis Chuang(MPI für biologische Kybernetik – Tübingen, DE, lewis.chuang@tuebingen.mpg.de)

We expect machines to perform tasks just as we would ourselves, only safer, faster and with less effort. For example, we rightfully assume that shovels move piles of dirt at a faster rate than we could with our bare hands by virtue of their larger "hands". Assuming task competencies by analogies to our own capabilities will not be valid with regards to artificial intelligence, as with self-driving cars. This is because we tend to misunderstand the architecture of our own minds. Artificial intelligence present the semblance of superior human intelligence. Every demonstration of automation in automobiles, from gear transmission to lane change maneuvers to route-planning, further perpetuates the illusion that we are within reach of a cheap equivalent of a human chauffeur. Unfortunately, the algorithms that underlie such technologies are unlike our own minds. Falsely believing that "they" are like "us" could result in subsequent disappointments as we slowly recognize how alien "they" are to "us". As a neuroscientist, I intend to contribute to the field of automated driving by working towards a better understanding of how humans are able to operate automobiles in the first place.

Main Research Fields: Cognition and Control for Man-Machine Systems.

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4.9 H(orse)-Metaphor, Cooperative Automation, Unsafe Valley of Automation and Other Potentially Useful Concepts for Automated Vehicles

Frank Flemisch (Fraunhofer FKIE – Wachtberg, DE, frank.flemisch@fkie.fraunhofer.de)

Almost two decades ago, I threw the spear of intuition into the jungle of automation, and found: a horse. Expedition after expedition, we tamed the horse, developed stirrups and raddle, befriended a whole herd of horses, found mountains of good cooperation, and unsafe valleys of control loss. We documented as thoroughly as possible, but plenty of questions open to explore.

Two decades later at Dagstuhl, with gray hair, I met a colorful tribe of new and old explorer of the jungle. I had five minutes to tell a thousand stories, and failed. My ears, tuned to silent snorts in the distance, were stressed by the noise. How can we ride big waves of innovation and keep our sensitivity? Maybe with good wine and theater play, happy to meet old and new friends.

In our live long exploration of the jungle, in search of a good balance of humans, machines and spaceship Earth, we should beware of the false gods out of the machine, and enjoy our company.

Main Research Fields: Cooperative Automated Driving, Driver Assistance Systems, Human-Machine Interaction.

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4.10 Automated Driving Evolution: from Concrete to Wild Ideas!

Anna-Katharina Frison (TH Ingolstadt, DE, anna-katharina.frison@thi.de)

How is the state of the art of automated vehicle concepts? What are the main topics researchers are interested in? Which methods can be used to generate and evaluate automated driving UI concepts? These were my question I had before coming to Dagstuhl, with a vision of continuous testing application in automated vehicles, which evaluates the passengers experience in a loop and reacts at once by adaptions of the system.

Within the seminar week we collected topics, discussed them and generated and visualized new ideas. All this helped me to answer fragments of my questions.

The state of the art of automated driving seems to be controversially discussed by concrete ideas and concepts which can be already tested with simulators and in the wild, other topics are discussed generally from an overall perspective, e.g. why we are doing "this" (= automated transportation including all levels)? About higher levels of automation, only assumptions can be done, and specific problems concerning methods can only be solved by generative and formative methods. My vision about a continuous evaluation system in an automated vehicle with just-in-time adaptions need a more general contemplation of methods and the special needs of automated vehicles with observing and keeping the evolution of automotive user interfaces in mind.

Main Research Fields: Automated vehicles, Human-Centered Design, User Experience Evaluation Methods.

4.11 Distraction in the (Semi-)Autonomous Car

Christian P. Janssen (Utrecht University, NL, C.P.Janssen@uu.nl)

In a future where vehicles are automated, there might still be situations where the vehicle is (a) not able or (b) not allowed to execute all aspects of a drive. In these instances, the human driver might need to take over or assist the system. To be successful, a driver is required to have some awareness of the situation, and to react in a timely and appropriate fashion to a request by the system. A challenge in this regard is that drivers might (up to that point) not be fully engaged with the driving task in an automated vehicle.

Research has shown that people multitask and (get) interrupt(ed) in many situations (e.g., [1]). This includes distraction in the car (e.g., [2, 3]]). Moreover, initial studies suggest that multitasking and distraction increases with an increase of automation of the car [4]. In the end, with an increase of automation, drivers are less aware of their surroundings and take longer to respond to critical incidents.

This suggests that more research is needed on understanding human attention, multitasking, and distraction in automated vehicles. To be successful, insights are needed on how to measure human behavior, perception, cognition, and actions, as well as on how to predict the impact of human action on traffic system and safety. Such research can then contribute to the prevention of accidents. For example, by helping the user to dedicate sufficient attention to driving or by detecting a lack of attention.

Given the complexity of the problem, a multi-disciplinary perspective is needed (cf. [1]). In this way, careful consideration can be given to systems, humans, design, and safety. The Dagstuhl workshop was fundamental in this regard, as it brought researchers from different disciplines together to identify the key areas that need to be investigated. I look forward to contributing to this exciting area myself. The input that I hope to provide to the community is interdisciplinary as well, including insights from neuroscience (e.g., [5]), applied research on the impact of user interfaces on driving (e.g., [5, 6]), and predictive formal models of cognition (e.g., [7, 8, 9]).

Main Research Fields: Human-Computer Interaction, Cognitive Modeling, Multitasking, Driver Distraction, Human Behavior in Automated Vehicles.

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4.12 Inclusive Design of Automated Vehicles

Myounghoon Jeon (Michigan Technological University, US, mjeon@mtu.edu)

From the traditional Human Factors perspective, a variety of research space on automated vehicles has been identified, including safety, fuel efficiency, trust, complacency, take over, etc. Another critical point is "mobility improvement" for those who used to not drive: e.g., people with disabilities (not able to drive), older adults (gradually losing the ability to drive), and children (not allowed to drive). In a similar way to the first and second waves, these populations have often been excluded in the third wave of "information revolution" (i.e., digital divide). We are interested in "inclusive design" for these people to prevent "automation divide" in the upcoming fourth wave of "AI or Automation" revolution era.

To discuss further, we can think of different scenarios. Even in the "fully automated vehicle" concept, the situation could vary. For example, on the one hand, drivers (or occupants) still "have to" be involved in the loop if the system is not perfect. On the other hand, drivers still "want to" be involved in the loop even though it is not necessary. In either case, an inclusive design approach leads to important research questions.

1) In the "have to" be involved case, are these populations allowed to be in the loop? It is rather a "hard" problem because it would require drivers to be involved in the "maneuvering" level (e.g., blind or older adults for lane keeping when sensors for road markings fail) and/or "control" level (e.g., children or people with mobility disabilities for accelerating/braking when the auto-cruise control fails). 2) In the "want to" be involved case, these people do not need to be engaged in the loop, but they can just ride or transport in a "train-like" concept. Another possibility is that they want to be in the loop, which asks the system to be polite enough to accept the driver's engagement even in the non-necessary case. Then, we need to consider how they could/should/would be involved in the process; whether it is just passive involvement, such as being provided with consistent situation updates or it is more active involvement in which they interact with vehicles by negotiating and making joint decisions. As discussed, this inclusive approach requires more fundamental questions to be answered about the automation concept as well as what type of user interfaces with which modalities we design for them. Moreover, this inclusive design approach is expected to provide a more

comprehensive perspective to prepare futuristic automation services, which will also result in better system design for traditional drivers.

Main Research Fields: Human-Computer Interaction, Affective Computing, Automotive User Interfaces, Driving Psychology, Assistive Technology.

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4.13 Using Design to Understand Interaction with Automation

Wendy Ju (Stanford University, US, wendyju@stanford.edu)

Due to Google [1] and Tesla [2], automated driving has gone from being a fantastical possibility to a practical reality in a short period. The advent of automated driving has important implications for the automotive user interface. To better understand these implications, we might ask: How should the vehicle respond in real-time to changes in the driving environment and the driver's state? How will autonomous vehicles determine and respond to regional and cultural differences in driving style? and How can the car leverage user modeling and adaptation already taking place online and on personal mobile devices?

At Stanford's Center for Design Research, we are performing research on shared control with automation, the driver experience with automated driving, and the opportunities for learning and adaptation in the cars of tomorrow. We are looking to use design research techniques to understand how people will respond both in [3] and out [4] of the car. Methodologically, we employ on-road platforms, in-vehicle experiments, wizard of oz protocols, novel simulator environments and online studies. Moving forward, we seek to define new research areas in autonomous vehicle HMI, to understand methods and measures to be used in autonomous vehicle interaction studies, and to generate cross-cultural and transnational research methods.

Main Research Fields: Human-Robot Interaction, Interfaces for Automated Vehicles, Interactive Device Design, Interaction Design.

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4.14 Transforming Automated Vehicles into Locations for Work and Play

Andrew L. Kun (University of New Hampshire – Durham, US, andrew.kun@unh.edu)

When will cars be truly automated? When will we be able to simply summon a vehicle, and instruct it where to take us, without having to worry about actually driving ourselves? While we do not know the answer to this, it seems fair to say that this day is upon us. Automation is making rapid progress, and there are clear reasons to pursue it aggressively. First, there is safety: an automated vehicle will not fall asleep, it will not be drunk, and it will not be distracted by a text message. Thus, we can reasonably expect that automated vehicles will be safer than human-operated vehicles.

But, there are very good reasons to embrace automation beyond safety. After all, the vehicle can now be transformed into a place where passengers (and we will all become passengers, not drivers), can utilize their time in many different ways. Two of the likely ways are work and play. However, there are many questions regarding the design of the in-vehicle user interfaces for such safe automated vehicles, and a number of these questions were discussed at the Dagstuhl seminar. Relevant questions include, how to design interfaces to promote work and play utilizing the space, computational power, location with respect to other vehicles, as well as without passagers experience motion sickness.

Main Research Fields: UI for Ubiquitous Computing, Cognitive Load in In-Vehicle Settings, Human-Inspired HCI Systems.

4.15 Why Are We Doing This?

Andreas Löcken (Universität Oldenburg, DE, andreas.loecken@uni-oldenburg.de)

I came to Dagstuhl to learn about user interfaces for automated driving. My question was "WHY" or "do we actually need an interface for drivers/controllers/owners, if the car is driving all by itself". Further, I was interested in which new interfaces we will need. For example: "how can we visualize the car's mode to other traffic participants and/or the passengers" or "should we communicate the car's intention, situation awareness, certainty of assessment, etc. in order to increase the driver's acceptance of, or trust into the automation". I had very interesting discussions on which information need to be communicated, which driver's characteristics might be relevant and how to design or test the interaction. I learned much about how researchers with different backgrounds see the problems and where we need to have better terms to be able to discuss more efficiently. I really enjoyed getting to know many smart people and am looking forward to continue the exchange after the seminar. Thank you Andreas, Andrew and Susanne, and also thank you to Dagstuhl!

Main Research Fields: Ambient Automotive Displays.

4.16 To Be Aware or Not to Be Aware, Is That a Question?

Rod McCall (Luxembourg Inst. of Science & Technology, LU, roderick.mccall@list.lu)

Autonomous vehicles open up a whole range of opportunities for the occupants ranging from being able to work or sleeping. However, these new possibilities bring challenges especially as the "driver" may be asked to take back control under certain conditions. We therefore need to map out how vehicles and occupants can create a shared situational awareness, so that both can understand each others abilities, limitations, and current contextual model. Related to this we need to understand the impact of the new possibilities on the construction of situational awareness and which approaches and technologies can be used to overcome the challenges highlighted earlier. There is also a need to discuss and examine the basics of cockpit design.

Main Research Fields: Automated Driving, Augmented Reality, Commuter Behavior, Gamification in Transport.

4.17 A View from the Other Side, Or: the Risk of Driving Blindly on the Road Towards Autonomous Driving

Alexander Mirnig (Universität Salzburg, AT, Alexander.Mirnig@sbg.ac.at)

Coming from an Analytical Philosophy background, I always find it beneficial for all parties involved (and like it personally, I must admit), when things are clearly defined and well-structured. In automated driving research, a good number of concepts, ideas, and even dreams meet, which are not all necessarily compatible with each other. This ranges from automation vs. autonomy (and which of the two we actually want), all the way down to the different levels of automation, where we tend to mix levels, depending on the argument we are trying to make. Want to sell the idea of automated driving to someone? Describe an SAE level 5 scenario with 100% penetration. Want to talk about the current state of usable technology and research? Talk about a fully level 3 scenario. Want to scare someone away from automated driving for years to come? Describe a realistic mixed traffic scenario, with drivers of all skill levels, vehicles of all automation levels, and everything this explosive combination implies. What are our real expectations of automated driving? Is it really "just" about safety and sustainability? What about fun? efficiency? or even vanity? And what about the shift from normal to automated driving? We can't expect to simply flip a switch and skip the mixed traffic phase (which might be considerably longer than we currently anticipate). Many uncertainties and potential hazards in manual traffic are solved via eye contact or estimating the other drivers' behaviors. But if a vehicle has no driver at the wheel or if said driver is reading a book, then how does one execute the normally simple task of establishing eye contact? Similarly, how does one learn and adequately interpret the (standard) behaviors of an automated vehicle? This is only the tip of the proverbial iceberg and it requires a discipline-crossing effort in order o untangle the web of concepts, ideas and expectations surrounding the (sometimes a bit too) intriguing phenomenon of automated driving.

Main Research Fields: Cross-Discipline Knowledge Transfer, Intelligent Handovers in Automated Vehicles, Philosophy of Science for HCI and Definitions.

4.18 New Perspectives on Autonomous Driving

Sebastian Osswald (Audi AG – Ingolstadt, DE, sebastian.osswald@audi.de)

First of all, I really enjoyed getting to know so many new people in the same field of research/interest and meet with colleagues from all over the world I knew before. Dagstuhl provided a great environment for this and the rather remote location is perfect for such a seminar. From an research perspective, it was really great to discuss the up to date topic autonomous driving with so many people from different disciplines. It is very interesting to monitor how oneself is limited sometimes in not being able to change the perspective towards a certain topic. The seminar was further really well structured and the lively group work with so many demonstration videos ended very well. I am looking forward to continue the exchange in the following year and the next seminar.

Main Research Fields: Future User Interfaces and Mobility Concepts, User Behavior, Multimodality in Transport.

4.19 Living Room on the Move? Researching the New Car Space

Ingrid Pettersson (Volvo Cars & Chalmers – Göteborg, SE, ingrid.pettersson@volvocars.com)

As an industrial PhD student from Volvo Cars and Chalmers University of Technology, I research methods for user experience design and evaluation, where autonomous driving provides an interesting study case ([1], [2]). Autonomous vehicles needs to be developed in line with human needs and capabilities, and I find that concepts such as trust [3], emotions and experiences are especially important to explore in relation to the autonomous driving. I believe it is important to explore about how these systems are learned and adopted over time. Thus I am especially interested on how we best approach user testing, from the early explorative studies to longer-term, more directed studies. Furthermore, the introduction of the technology provides a need as well as a possibility to rethink the in-vehicle space and the communication between the car and users.

Main Research Fields: Interaction Design with Focus on Automotive User Experiences.

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4.20 Non-Driving-Related Tasks in Mixed Traffic

Bastian Pfleging (LMU München, DE, bastian.pfleging@ifi.lmu.de)

Automated driving will change how we get from A to B. For the first time the driver will not have to perform the (traditional) driving task during all times of the ride. This will have implications for the automotive user interface due to multiple reasons. On the one hand, the system needs to optimally support hand-over and take-over situation when switching between different levels of automation and shifting responsibility between driver and vehicle. On the other hand, one important aspect are the non-driving-related activities ([1] , e.g., office work, communication, relaxation, media consumption) since drivers want to make use of the time when they do not have to maneuver or monitor the car. Performing such activities poses many questions: Which activities do drivers want to perform while driving automated? Which activities will drivers be able perform during automated driving due to legal, technical or human limitations (e.g., to prevent motion sickness or to ensure safe take-overs)? How can we adapt the cockpit and the user interface to support such activities? Can we design activities in a way that they can be continued seamlessly when switching to lower levels of automation? I expect that the set of supported non-driving-related activities will be a major feature when distinguishing different vehicles and brands. Therefore, it will be important to understand and shape this novel aspect of automotive user interfaces.

Main Research Fields: Multimodal Interaction, Natural User Interfaces, Non-driving-related Activities in Automated Driving.

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4.21 Autonomous Cars: What Will We Do with the Free Time?

Ioannis Politis (University of Cambridge, GB), i.politis@eng.cam.ac.uk

Autonomous cars are a major accomplishment of transportation. In my previous research the main case of focus was the handover of control between the car and the driver. In this situation, the research question was the unexplored topic of how the driver could be effectively informed about the handover (handing control to the car) or takeover (taking control from the car), while their attentiveness maintained. To address this, I envisioned a set of possible situations where a handover would be necessary and designed a set of language-based warnings for these situations. Presenting the cues to distracted drivers in an autonomous car simulator, I found that they were considered appropriate for the situations they addressed, while their urgency was recognized by drivers. In this way novel guidelines on how to provide warnings during an autonomous handover of control were provided ([1, 2]). My interest in autonomous cars also motivated me to be part of a workshop series on user experience of autonomous driving ([3, 4]). A clear outcome of the discussions during these workshops was that autonomous cars will be ubiquitous in the future, introducing the need to design new in-car interactions. The big challenge recognized is how society will use these vehicles, how they will be integrated in everyday life. This motivates exciting research directions; as driver engagement will become sparser, the resources freed will offer a variety of possibilities to utilize time in the car. The parallel blooming of the electric vehicle industry creates even greater implications on sustainability if autonomous cars become mainly electric. There have been views that the autonomous car will no longer belong to one driver. Transportation will rather be provided as a service, changing the traditional model of a personal vehicle. If this will be the case, how will a shared car integrate in the commuting routine and how will society choose to use it? If again not, how will the drivers and their peers use their free time in their personal autonomous car? The consideration when attempting to answer the above will primarily be around societal needs, the driver's mental model and the specifics of the task of operating autonomous vehicles. Interventions exploring this vision can then be created and iterated, in order to provide clear propositions on using autonomous cars for the common good.

Main Research Fields: Multimodal Displays to Alert Drivers, Usability Engineering, Interaction Design.

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4.22 Smart and Adaptive User Interfaces for Automated Vehicles

Benjamin Poppinga (AUDI AG – Ingolstadt, DE, benjamin.poppinga@audi.de)

Partly automated vehicles will become the primary means of transportation in the near future. Without doubt, this will change how we think about our daily commute or any long distance weekend excursions. Our precious time can be used in many alternative ways while we are on the ride, e.g., we can do business, chat with a friend, educate ourselves or even undergo a health checkup. In contrast, there likely will also be situations in which the vehicle will be unable to continue and we as drivers need to take over control quickly to keep the traffic flowing.

This vision illustrates how diverse and dynamic our role in a future vehicle will be. In my opinion, existing interaction concepts and interior designs are mostly unable to allow for this flexibility, because they've been optimized for a single driving task over the past decades. Consequently, a key challenge will be to design future interaction concepts in a way that they primarily support drivers in their main task – whatever this will be – and at the same time allow them to maintain trust, awareness on the traffic situation, and allow for an intuitive handover, if needed. Outside of the vehicle, I see a strong need to investigate the potential interaction concepts and metaphors for mobility services, e.g., the early reservation of a commuter vehicle while maintaining flexible working hours.

Main Research Fields: Location-Based Applications, Smart Interactive Systems, HCI.

4.23 Do We Want to Be Driven by Agents Acting Autonomously and What Are the Grand Challenges on the Way to Fully Automated Road Transport?

Andreas Riener (TH Ingolstadt, DE, andreas.riener@thi.de)

Fully automated vehicles are the future of road transportation and at least with level 5 automation it is expected that they will make our live significantly "better". But do we really want to be driven by agents acting autonomously and what are the grand challenges on the way to fully automated road transport? In this seminar, more than 30 people were meeting for one week to discuss the transition of user interfaces, the incorporation of the user in the driver-vehicle feedback loop, models and methodologies required for testing interaction concepts, transfer of control/de-skilling, etc. Interestingly, quite a significant amount of time was spent on controversial topics such as the loss of "driving fun", ethical issues, economical aspects, or trust and acceptance in future technology. Would you buy or use a vehicle that negotiates with other vehicles around whom to kill when a hazardous traffic accident is unavoidable? Maybe not. But even with one-hundred percent automatism on our future roads, fatal accidents cannot be completely avoided. Can fully automated cars be programmed to act ethically correct? And if not, should the driver be re-engaged (and how?) to make this decision instead of the machine? Will he/she accept? At THI and our newly established research and test center CARISSMA (Center of Automotive Research on

Integrated Safety Systems and Measurement Area), we are contributing to road safety from an integral viewpoint. Of particular interest for my research group are physiologic/ergonomic aspects of traffic, such as cognitive driver modeling, behavioral adaptation, trust/acceptance in technology, ethical constraints, but also the whole range of methodologies used in corporate and scientific research. It was a pleasure for me to co-organize this seminar together with Susanne and Andrew and to hang out with this great people at this great place. I will definitely come back – as organizer or participant. Thanks for your warm hospitality!

Main Research Fields: Cyber-Physical Automotive Systems, Human Factors and Driving Ergonomics, Social-Inspired Mobility Services, (Over)trust, Acceptance, and Ethical Issues in Automated Driving.

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4.24 Who Has the Control? Assisting Hand-Overs in Highly Automated Driving

Shadan Sadeghianborojeni (OFFIS – Oldenburg, DE, shadan.sadeghianborojeni@offis.de)

With the rise of advanced driver assistance systems, automated driving is foreseen to occur in the near future. This, however will not happen over night. According to NHTSA, the next generation of automated vehicles will be "level 3 of automation" which means that the driver has to be ready to take over vehicle control in cases of hazard. This is very different from level 5 automation where automation fully controls the vehicle from a human machine interaction perspective. The transition of control from driver to automation and back can be expensive if the car and human do not have a similar mental model from each others capabilities and responsibilities in different conditions. A smooth transition requires both sides to have an appropriate level of situation awareness about their limitations in different driving situations. Therefore, well designed user interfaces and cues are required to convey this information to both partners. In Dagstuhl seminar 16262 we covered different aspects of control transition which lead to a design approach for supporting handover situations.

Main Research Fields: Human Machine Interaction, Automated Driving, Attention Directing Cues.

4.25 Self-Driving Cars Will Come Faster Than You Think!

Albrecht Schmidt (Universität Stuttgart, DE, albrecht.schmidt@vis.uni-stuttgart.de)

Efficient mobility is essential in a modern society. In many areas of the world (e.g., Beijing, Stuttgart, or the Bay Area) commuting from home and work is becoming more difficult as roads are overcrowded and much time is spent in traffic jams. This hinders productivity and decreases the quality of life for many. Building and improving the road infrastructure is extremely difficult and offers only a long term solution (e.g., creating a new motorway in Germany will take decades). To me, automation in driving is the only viable short-term solution to this problem, as the throughput with automated driving will be much higher than with manual driving. In order to preserve mobility for the masses I expect that automated driving, at least on motorways, will happen much quicker than many people expect. In the automotive industry we are moving towards the most fundamental transformation since its creation over a hundred years ago and we see a clear trend towards automation in research [1]. Even though the way we control cars is rapidly changing, and even though the outcome leads to a new paradigm (self-driving vehicles), I argue that the change is not perceived in this way by the drivers or users. I foresee that drivers experience a gradual and not a radical change. Conceptually, we see a change in control in two dimensions: 1) granularity and 2) immediacy. Traditional car control was on a fine grain timescale, e.g. parking meant to steer and accelerate on a sub-second level. As cars advance parking becomes a higher level decision and the fine grain steering is done automatically. In the future you may get out of the car, and the car parks itself. It can be seen as just another step up in granularity. A car from the 1950 offered very immediate control (e.g. no power steering). As technologies progressed, immediacy was and it will be further reduced. The upcoming transition will nevertheless not be straightforward. There are many technical challenges. I expect that designing the user experience and the interaction requires to address fundamental questions, such as:

- How to deal with different levels of engagement required?
- How to make the users understand what is expected from them at different times while being in the car?
- What activities can be done while being in the car?
- How can we increase the value of the time we spend in transit? Is it entertainment, relaxation, work, communication, or sports?

Overall, I am very optimistic that personal mobility will quickly change to make our life simpler. In the future we may look at phenomena like road accidents and traffic jams and wonder why the transition was not made faster and why we believed for so long that people enjoyed driving.

Main Research Fields: HCI Beyond the Desktop, User Interface Engineering, Driver Assistance Systems.

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4.26 Different Levels of Automation Pose Different Opportunities and Challenges

Steven Shladover (University of California at Berkeley, US, steve@path.berkeley.edu)

The multiple levels of driving automation systems have significantly different driver interface needs and constraints, based on different driver roles and responsibilities. This diversity of levels of automation sometimes makes it challenging to reach common understanding about interactions between the drivers and the automation systems. At the highest levels of automation, the interface mainly needs to provide sufficient information to the vehicle user (who may or may not be a driver) to induce comfort and confidence that the vehicle operations will be safe and dependable. The most challenging issues arise at Level 3, where the driver needs to take the role of "fallback-ready user", who can do whatever he or she wants while the automated driving system (ADS) is driving successfully, but this user also needs to be prepared to intervene very quickly when the ADS encounters a situation that requires driver intervention for safety. This poses such significant challenges with regard to human capabilities to quickly shift attention to a new task and to the design of an effective interface that it raises serious doubts about the viability of Level 3 automation until considerably more research on the control transitions has been accomplished.

Main Research Fields: ITS, Cooperative Transport Systems, Automated Driving, Automation Levels.

4.27 From Horses to Cars and from Cars to Fully Automated – Inclusive – Live-Long Mobility

Christine Sutter (TU Darmstadt, DE, c.sutter@iad.tu-darmstadt.de)

The transition from semi-automated driving to fully automated transportation opens up a vastness of future mobility scenarios and human-machine interactions. Currently, my research interests join the discussion about decisions on function allocations as well as take over procedures for different levels of automation, and centers – from a psychological perspective – specifically around the (limited) capabilities of human information processing and (potential) system failure. Future fully automated transportation will impact traffic safety, hedonic quality of traveling, travel time and lifestyles, and many other aspects in many ways nobody can yet foresee. But anyhow, in future human-technical interactions will still be defined by human capabilities and limitations. And, creatively uniting the best methods, knowledge etc. of different disciplines will still be the most promising way to get people and technical systems adjusted.

Main Research Fields: Ergonomics, Stress and Strain Research, Multimodal Information Processing.

4.28 Why Is My Autonomous Vehicle so Blunt and Why Are Others Treating It so Badly?

Jacques Terken (TU Eindhoven, NL, j.m.b.terken@tue.nl)

Autonomous vehicles are an excellent case for investigating how people deal with novel (and often intelligent) technologies. All kinds of issues come together: acceptance, trust, control, safety, convenience, comfort, to name the most obvious ones. Interesting is that it brings safety-critical automation into the heart of the consumer market. Some of the questions that we have to face are:

- How are we going to help users construct a mental model of what the system can do and cannot do (NOT by a 500 p manual!)?
- Given that autonomous vehicles capitalize on safety, how can we avoid other road users to start abusing the technology ("it's going to stop anyway")?
- How can we build technology that also satisfies the interests of individual people (I want a vehicle that is polite the other road users, except when I'm in a hurry)?

For the interface, I think of the body as an interface; similarly, I see the vehicle itself (both the interior and the exterior) as the interface. Exciting times ahead of us!

Main Research Fields: Automotive Human Factors, Driver Experience.

4.29 Human-Robot Cohabitation in the Age of Autonomous Driving

Mohan Trivedi (University of California, San Diego – La Jolla, US, mtrivedi@eng.ucsd.edu)

Systematic exploration of the role of humans in the age of self-driving and highly automated vehicles is the central focus of our research. With recent advances in embedded sensing, machine perception, learning, and planning, technology takes a step closer towards self-driving automobiles, but many issues are still left unresolved. Toward this end, we highlight research issues as they relate to the understanding of human agents which interact with the automated vehicle. Self-driving and highly automated vehicles are required to navigate smoothly while avoiding obstacles and understanding the high levels of scene semantics. For achieving such goals, further developments in perception (e.g. drivable paths), 3D scene understanding, and policy planning are needed. Designing fully autonomous robotic vehicles that can drive on roads does typically did not require models of drivers and how they interact with vehicles. In contrast, design of intelligent driver assistance systems, especially those for active safety that prevent accidents, requires accurate understanding of human behavior, modeling of human-vehicle interactions, activities inside the cockpit, and prediction of human intent. A human-centered framework for a distributed intelligent system includes the driver, vehicle and environment as three key components. The main idea is to develop an approach to properly design, implement and evaluate methods and computational frameworks for distributed systems where intelligent robots and intelligent humans cohabit, with proper understanding of goals, plans, intentions, risks, and safety parameters. We emphasize the need and the implications of utilizing a holistic approach where driving in a naturalistic context is observed over long periods to learn driving behavior and to predict driver intentions and interactivity patterns. The exciting and expanding research frontiers raise additional questions regarding the ability of techniques to capture context in a holistic manner, handle many atypical scenarios and objects, perform analysis of fine-grained short-term and long-term activity information regarding observed agents, forecast activity events and make decisions while being surrounded by human agents, and interact with humans. Moving towards vehicles with higher autonomy opens new research avenues in dealing with learning, modeling, active control, perception of dynamic events, and novel architectures for distributed cognitive systems. Furthermore, these challenges must be addressed in a safely and within very tight time constraints to avoid collisions or unstable operation.

Main Research Fields: Intelligent Vehicles, Novel Experimental Test Beds, Human-Centered Driver Assistance, Driver Affect.

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4.30 Towards a Seamless Integration of Secondary Tasks

Philipp Wintersberger (TH Ingolstadt, DE), philipp.wintersberger@carissma.eu

From a future highly automated vehicle, I expect it to be a companion rather than a tool. On the one hand, the vehicle should help me to maintain (and of course increase) my driving skills, while on the other it should assist me in side activities. Some of those activities will need more concentration than others, thus knowledge about my schedule, the route, upcoming traffic and potentially hazardous situations might allow a system to help deciding when things are to be done.

For instance, by predicting the chance of an urgent Take-Over, some could derive suggestions on what to do next: The weather is find, streets are clear, sensors work reliable – time to concentrate on important correspondence. String rain, filthy road, high traffic volume – the vehicle presents today's headlines, but expects the driver to be ready for Take-Over. The route is a coastal road with an astonishing view at the sea – now would be the perfect time to do some practice and experience the fun of manual driving (step on the gas – the vehicle will intercept in case of danger). Here at Dagstuhl, reasonable but also provoking ideas can be discussed with colleagues and prominent researchers, and hopefully, some ideas will find their way into upcoming vehicle generations!

Main Research Fields: Human Factors in Automated Driving, Affective Computing, Attentive User Interfaces, Artificial Intelligence.

4.31 Trustworthy Intelligent User Interfaces

Jürgen Ziegler (Universität Duisburg-Essen, DE), juergen.ziegler@uni-due.de

My main motivation for attending this Dagstuhl seminar is to obtain a broader view of the research questions involved in integrating more and more automated functions in cars. The background of my own work in this area is in developing personalized, driver-adaptive navigation systems [1] and user preference models for multimodal transport. I see interesting research questions in providing intelligent user interfaces for future navigation systems which will go beyond directing users to a specific destination but which will also include services like recommending routes and venues that are of interest to the user. Here at Dagstuhl, I particularly liked the open discussion atmosphere and the creative group work. From the discussions I obtained valuable input and ideas concerning topics such as how to increase trust in automated functions. I found it particularly useful to start a discussion on "calibrating trust" for autonomous functions pointing at the fact that we also need to make drivers aware of situations or functions they cannot always trust and which should be monitored. From these discussions, the idea for a late-breaking results paper for this year's AutomotiveUI conference was born which has meanwhile actually been realized.

Main Research Fields: Human-Computer Interaction, Context-Adaptive Systems, Playful Social Interaction, Adaptive Driver Assistance in Vehicles.

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5 Break-Out Groups and Prototyping Sessions

5.1 Understanding the Scopes

To make the process more adaptive to fit the seminar participants' actual research interests, the organizers did not choose to define topics for the break out groups 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, organized into associated groups and pinned them on a pin board visible to all participants. In the afternoon, 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 1. The identified "blobs" were finally selected as the topics for the break out groups on Tuesday/Thursday and the prototyping session on Wednesday.

Who Are We Designing For?

User interface and vehicle designers as well as user experience practitioners are often challenged with the question for which user group they are designing for – each with different needs, different interests, and very different ways of interacting with technology. In vehicle production, we do not have the luxury of focusing on only one group (at least not so far), i. e., designing vehicles for specific age groups or cultures, that's why interaction designers and engineers must learn to recognize and reconcile the needs of their main user demographics. This problem will remain even with automated driving when using the car as a place for relaxation, entertainment or work.

Defining characteristics, differences, and tensions between individual user groups might help to account for different individuals. An important question in this regard is, whether or not there is a single system suitable for all (or at least most) customers and stakeholders, Is it axiomatic to target user groups differently? A subgroup of the seminar spent an afternoon to discuss this problem and finally came up with a two-dimensional model to

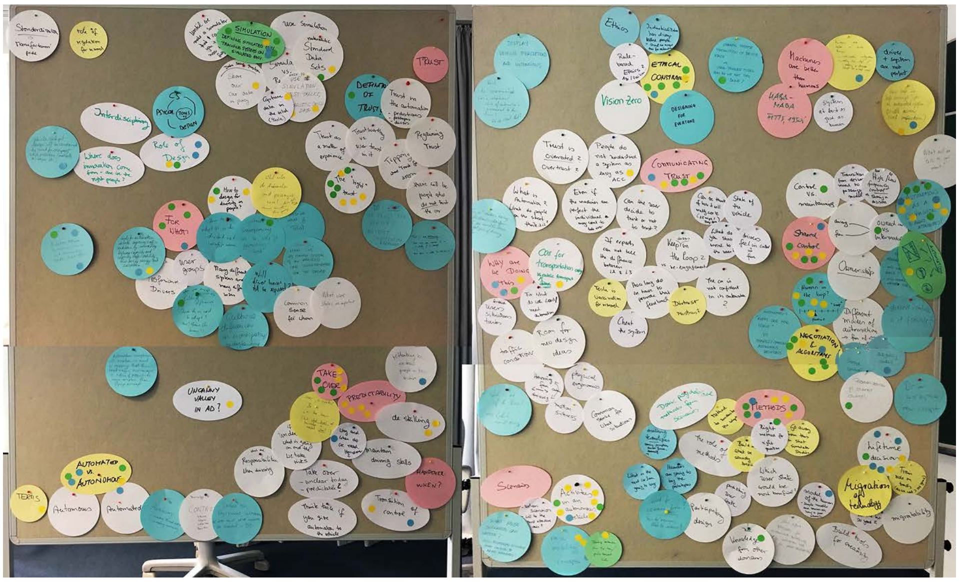

Figure 1 Result of the brainstorming wall after reorganization.

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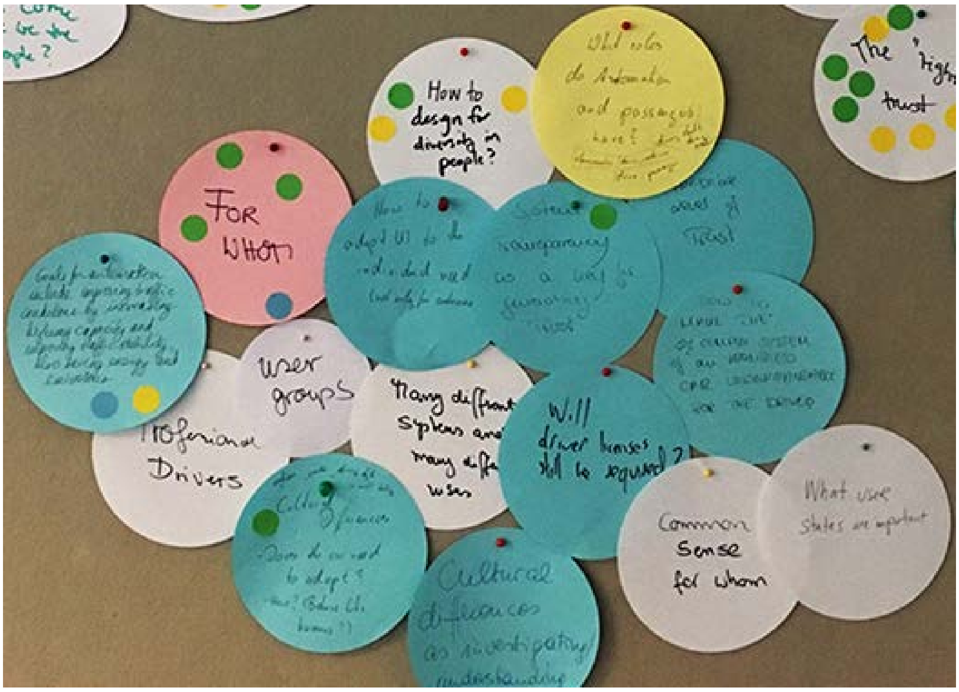

Figure 2 Detail of the brainstorming wall showing main concerns of "Who we are designing for".

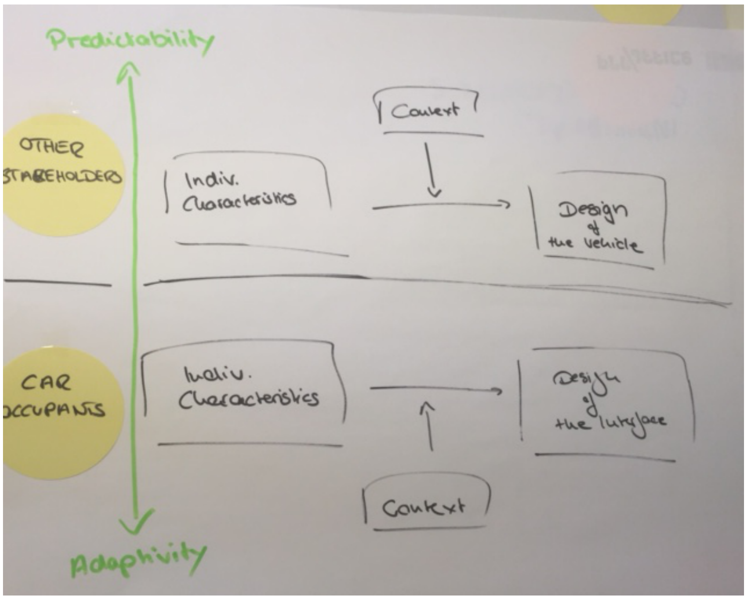

Figure 3 Preliminary model for understanding the role of individual differences in design for automated driving.

differentiate between vehicle occupants (different users) and other stakeholders in the car domain (Figure 3).

Following the discussion, the group defined the following research questions:

- How to call the "driver", e. g., controller, passenger, stakeholder, user, or simply occupant?
- How to adapt the HMI as well as automation behavior to users' characteristics – adaptive (implicit) or adaptable (explicit)?
- Which user characteristics have an impact on the interface design, what is highly important?
- How to model the user?
- What are the (static/dynamic) dimensions to classify them?
- How should HMI look like for drivers, car occupants and other stakeholders?
- Should only a driver or multiple passengers be able to control vehicle functions, and if so, is there a hierarchy?
- Who can control what, how to guarantee access control?
- How to interact with traffic participants outside of the car?
- How to define scenarios, and how link them to user characteristics?

Why Are We Doing This?

Before asking more specific questions about automated driving concepts we need to answer more fundamental questions like: "Why are we doing this?"

As the term "this" is very general and does not divide between different levels of automation it needs to be concertized to get a common understanding about what the breakout group is discussing. Therefore "this" was defined as automated transportation for a wide range of different vehicles (bus, cars, trucks, etc.). This was the basis for a brainstorming to collect possibilities what we can reach with the technology of automated driving (motivations & goals), which we clustered in three different categories: societal (S), personal (P), corporate (C), see Figure 4.

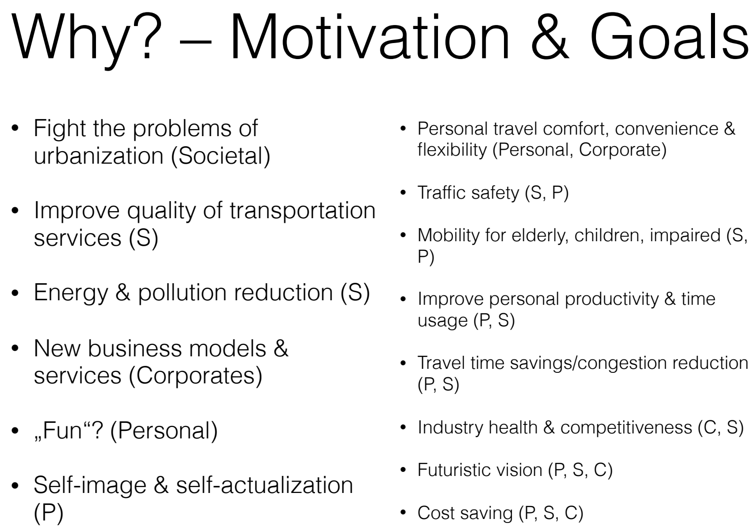

Figure 4 Result of the brainstorming to answer the question: why are we doing "this"?

Discussions showed, that the goals cannot be reached all on the same time. Some of them are now or soon available, instead others are long-term goals.

Research Questions

- How can we support multi-modal transportation?
  - Potential: Time-saving, cost-saving, pollution reduction, environmental protection
  - Approach: Integrated services & consistent view: incl. planning, making reservations, buying
  - Obstacle: companies don't cooperate, no standards
- How can we come up with economically viable business models? Quantifiable benefits & costs?
  - Technological feasibility & timing of availability
  - Safety, security & privacy
- How can we maintain hedonic quality of the driving and the car?
- What will be the purpose of future cars? How can we communicate our plans to the car?

The result of the workshop revealed several hypothesis about the general question "Why": (1) The possibilities of the technology is dependent of the energy resource. (2) Drivers personal experience is essential but dependent from different countries, personal interests, religions, capabilities, etc. (3) Transparency is as well essential for the acceptability of the technology, e.g. privacy and data protection. (4) New aspects like hedonic qualities of the concept of automated driving need to be considered.

Which Activities?

Automated driving, especially levels of high and full automation (according to NHTSA level 3 or higher), will offer a wide range of possibilities. People will be able to use the emerging free time in their vehicles for arbitrary activities, leading to yet unknown vehicle interiors. In a break-out group, we discussed about activities people might desire in future vehicles and their implication on traffic and societies as a whole. Within the discussion, we assumed that all technical constraints as present today will be resolved and only concentrated on what people might want to do, but not how this (technically) be achieved. Also, safety aspects

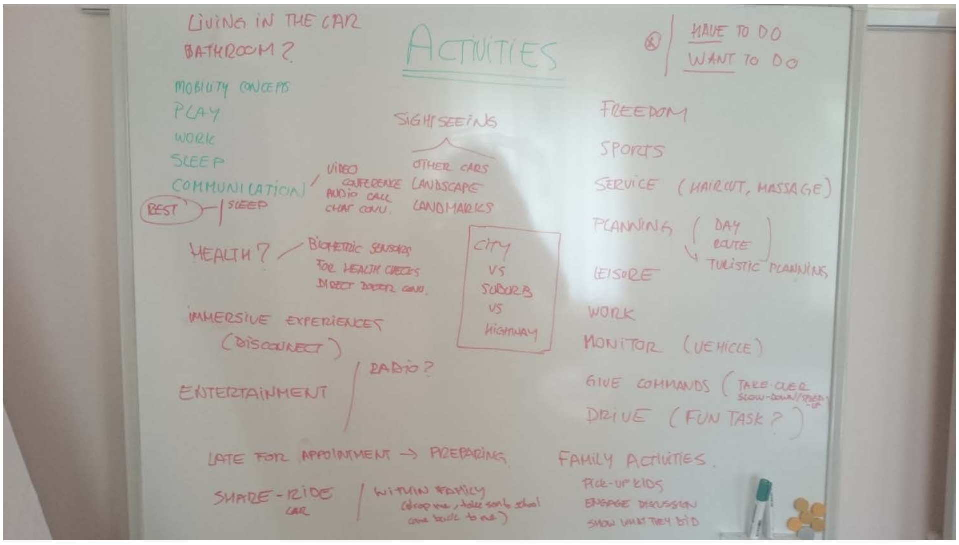

Figure 5 Different core topics emerging from the brainstorming session.

have not been considered as highly important, as latest in the phase of 100% fully connected and automated vehicles, safety measures like seatbelts or adjusted body postures might not play a major role anymore.In a brainstorming session, We collected ideas and identified two groups of activities on a higher level (Figure 5):

- **Productivity:** Including classical workplace-related activities like texting on a computer, communication with others (making the vehicle a meeting room using VR technologies), planning of other tasks, learning and education, or vehicle related activities like monitoring or issuing vehicle commands.
- **Entertainment/Relaxation:** This includes playing games, watching movies, sightseeing when driving through new areas, family- and social related activities but also sleeping and other relaxing activities.

As the discussion proceeded, we realized that most of our thoughts are still constraint by today's vehicle interiors and our narrow perception, but fully automated vehicles would allow much more freedom. We decided for the remaining time to look at a vehicle as an empty shell, leading the discussion into a new direction. We thought about the dimensions of an average minivan and realized that two standardized air plane business class seats would easily fit into it, already allowing to support many of the activities described above. This "empty shell" definition allowed us to think about more severe implications of automated traffic and revealed the great potential of automated traffic. We now briefly report two of the possibilities emerged in our discussions:

- **Vehicles as service facilities:** Imagine you have an important meeting tomorrow morning but really need your hair cut to make a good impression to your partners/customers. The classical way of thinking would suggest your automated vehicle brings you to your hairdresser early in the morning, maybe allowing you to grad some breakfast or read a newspaper while driving. But there is also an alternate future: a hairdresser could make use of a fully automated van (calibrated to generate as low centrifugal force as possible) that's interior serves as his facility. So instead of getting up early to make it to the meeting in time, you could just order a mobile hairdresser that picks you up in the morning to transport you to the place of you meeting while bringing your hair into a presentable shape. This is just one possibility that can be extended – after a hard day of work, another van might bring you home that comes with an integrated sauna and/or massage chair. Doctors, paramedics or arbitrary services could swarm through future cities, allowing people to use the time needed for transportation for something really valuable.

- **Customizable vehicle interiors:** Private fully automated vehicles could be used for many different activities that all might need special devices or vehicle interiors. So instead of designing such a vehicle to become a trade-off that supports all activities badly, some could introduce the concept of third party attachments. The vehicle interior could provide multiple standardized slots for attachments, allowing third parties to design and sell special purpose vehicle interior. People could then build their own vehicles and adjust them to their daily routines and requirements. The same vehicle that contains a mobile office with a desk and a coffee maker could become a mobile sleeping room for a long overnight drive.

Research Questions

- How do we define the space in our vehicle to support the activities we want to do and have to do?
- What does the infrastructure look like to support these activities, and support connectivity to third party manufacturers?
- What would be the business model that car manufacturers need to set up to support such connections?
- What safety/security features are needed to ensure that safety is not hindered by non-driving activities while while the vehicle is safe from external attacks?
- What kind of interface does a vehicle need to provide for a spatial-temporal game-like interface? How can we predict physics to minimize motion sickness, and can the drive be changed to fit the activity?
- Does the vehicle need to recognize what activity you are actually doing?
- What does the vehicle of the future look like?

How to Take Over?

Effective shared control between automated driving systems and human drivers is a topic with many open questions. While current work on so called "Take-Over-Requests" (TORs) often assumes a resumption of full manual vehicle control, different levels of automation (according to SAE) indicate that taking over in future AVs could have different forms at varying extent. We could split the driving tasks into multiple levels to answer the following questions:

- Who has responsibility (Human or ADS)?
- Who has capability (Human or ADS)?
- What is a concrete scenario?

Such a categorization could follow the three classical levels of vehicle control (operational, tactical, strategical), but to fit our requirements we re-define them a little bit and add a fourth level:

- Stabilization (Basic control),
- Guidance – Maneuvers,
- Guidance – Trajectories,
- Strategic – Navigation.

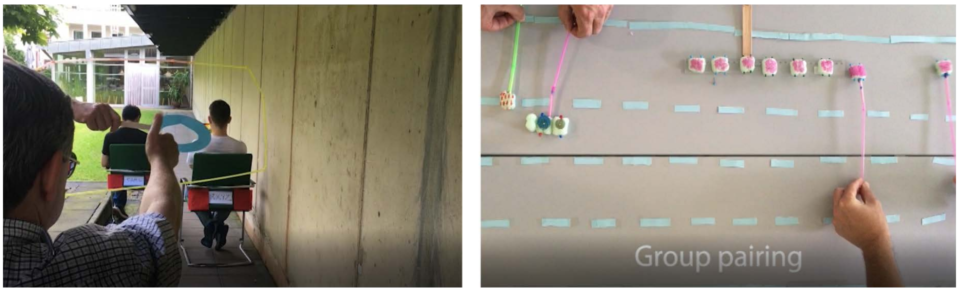

Figure 6 Screen-shots of the prototype video, which show the interaction how to enable the pairing option in a highly automated highway scenario.

A TOR situation in an AV now might contain different subsets of these levels (a driver could be requested for basic vehicle control or navigation only). Differentiating between these levels no allows us to define for each level why a TOR might be issued and how this transfer of control could look like – a TOR emerging at the lowest level (Stabilization) might result from conflicting lane markings, a TOR at the navigation level from missing information due to lost connectivity. At each level, control recovery will require a different reaction time as well as a transfer of a proper mental model to the operator. We now can find strategies to support TORs at the individual levels (a potential framework to achieve this could result from an adaption of the GOMS model). To make further progress in this domain we define the following **research questions**:

- What is the delegation of human-machine responsibilities and capabilities?
- At which level is TOR to occur?
- What is the 'mental model' of the vehicle(-designer) of human capabilities?
- What is the 'mental model' of the human of the vehicle capabilities?
- Are real capabilities in line with expected capabilities?
- How do we define transition (see perspective models)?
- What is an acceptable transition time from automated driving to manual driving?
- How should we allow for a smooth transition, since hands-on/-off is not a good model for human-machine interaction or the assumption of responsibility?
- How do we redefine Situational Awareness (for automated driving)?

5.2 Prototypes

For the prototyping sessions, no topics were given out to the seminar participants. All groups were issued to generate an idea somehow connected with the seminar's overall topic, build up a prototype and make a short video out of it. As material for building the prototype, each group was equipped with arbitrary material, from Lego over toilet paper rolls to straws.

Social Platooning in a Fully Automated Highway Scenario

Social interaction between different drivers is one big opportunity of the technology of automated driving. In a prototyping session we developed a scenario at a fully automated highway where different possibilities are imaginable. Platooning in form of individual pairings of cars to get in contact for example to enable speed dating, but as well group pairings of different vehicles so children in different cars can interact and play together (Figure 6).

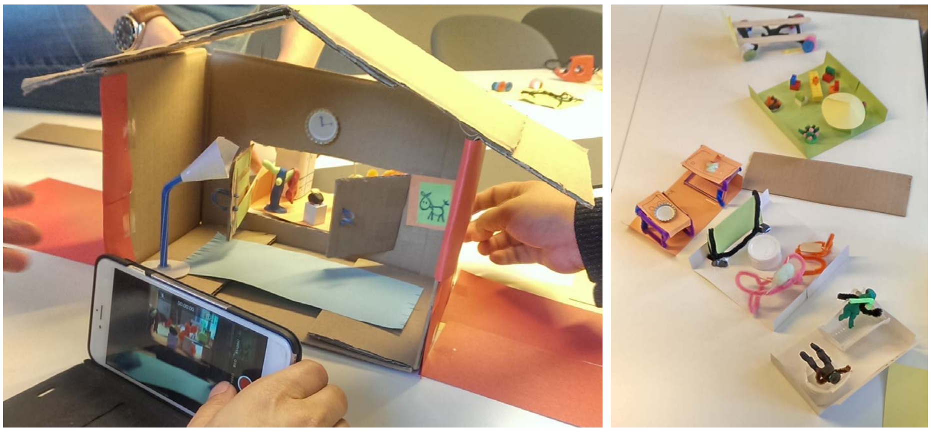

Figure 7 "Dagstuhl Towers" – A room previously mounted on/in a vehicle is now automatically mounted in a free room. The standard apartment with the automated vehicle room attached is seen on the left, various envisioned rooms are shown in the right picture.

Magnetic Moses

As the individual research interests of our group members differed, we decided to look at potential problems of automated traffic from a broad perspective. It quickly became clear, that many advantages associated with automated vehicles strongly depend on their market penetration. In our group we looked at the proposed advantages of reduced congestion and increased traffic flow (maximizing the volume to capacity ratio). Human traffic participants like manually driven vehicles could be a show stopper in this case, as only a few of them could drastically reduce the positive effects of automated driving as a result of their unpredictable behavior. Automated vehicles can drive in platoons with very short headway or dynamically assign vehicle lanes at crossings based on the actual requirements while human traffic participants need clear rules and more space to account for their increased reaction times. The problem to be solved with this prototype was a system trying to integrate human traffic participants (manually driven vehicles or pedestrians) in an intelligent way to account for their weaknesses.

The idea was, that platoons of fully automated vehicles automatically split up to generate buffer zones around human elements. The problem was illustrated at an urban crossing. For instance, a platoon of multiple automated vehicles might open only a little space to allow crossing of another automated vehicle, but a human driver would need a much larger gap or even demands the crossing traffic to stop. Thus an intelligent system will have to know in advance which type of vehicle is approaching as well as details on the actual target to plan for the optimal throughput. As the idea of automatically opening platoons to account for human traffic participants reminded us of the biblical character Moses, we decided to call our system "Magnetic Moses". A prototype of the idea was built in form of a miniature urban crossing and the video was produced using stop-motion technique.

Dagstuhl Towers

This prototype was inspired by automated parking garages and is based around the idea, that entire rooms in future buildings could be automatically mounted on automated vehicles so that users can decide on their own which "context" they want to use for traveling. We created the following scenario and build prototypes to simulate it (Figure 7).

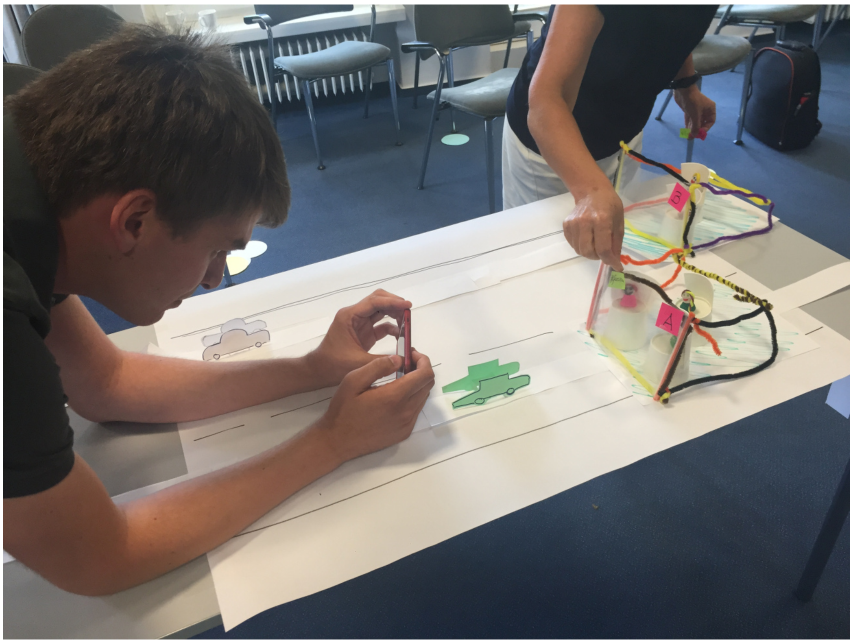

Figure 8 Two vehicles driving on a highway, revealing personal interests and personal details allows a matching algorithm to find similar people "on the road".

»Your mobile office room detaches from the office-building and drives you home, while you continue finishing your work. Your apartment only consists of one room. When needed, you call the mobile kitchen or dining room. If you want to spend some time outside, a mobile balcony can be attached. When you need some more space, the size of your apartment is increased by adding a mobile living room. The bathroom also does not need to be around all day. You just call it when you need to. Similarly, you only call your bedroom, when you are ready to sleep. You could even drive to work in your bedroom, enjoy sleep driving and start to work all refreshed.«

One of the benefits of this idea is the reduced amount of needed living space in dense areas, especially with an increasing population. In addition, having rooms on demand or as a "service" creates new business models. It could be possible to have rooms in different versions ranging from minimalistic to luxurious, depending on resources and needs. It could also enable people to save money by sharing owned rooms. On the other hand, various challenges were identified, for example: (A) How to realize the room attaching system? (B) Can the current infrastructure be changed to make room for automated mobile rooms? (C) Does it really save space in the city, when the unused rooms need to be stored somewhere?

Connecting Car

"Speed Dating" or building social relationships seemed to be a very interesting topic for many seminar participants as second group built such a prototype without knowing from each other. It seems the use case fits well to the automated driving scenario – people can build up social connections like in any other social network, but with the advantage that they can "meet" in reality as they share the same location while still enjoy being a safe space (the own vehicle, Figure 8).

5.3 Methods

Driver-In-The-Loop

One break-out group dealt with the question how to deal with drivers completely "out of the loop", and how to maintain/recover situation awareness for such drivers? A major problem recently emerging is the question, how to deal with drivers that combine multiple level 2 features (according to the SAE levels of automation) and (mis)use as a level 3 automated driving system? Also in this case, initial ideas brought us back to the three levels of vehicle control that could allow to customize an automated vehicle's behavior. Different levels and tasks thus will offer different ways of how to get driver back into the control loop.

Trust in Vehicle Technology

First discussions about the topic revealed a great diversity between participants' understanding of trust and the related concepts, thus it was clear that definitions and potential approaches have to be shaped first. People might trust automation either correspondingly to a systems actual capabilities (appropriate trust) or otherwise will face distrust (systems are not used because of a lack of trust) or overtrust (expectations in a system exceed its actual capabilities.). It quickly became clear, that it cannot be the aim to just increase trust in automated vehicle technology but to find the right balance for each individual. A problem often present in complex automated systems is, that people often do not exactly know about system boundaries. It must be a main target that people actually know in which tasks systems perform good, and in which not. As trust can properly be increased by presenting why-and-how information, a large part of the break out group was to find out which information should be presented to drivers and to what extent. To bring an example, a vehicle emerging a traffic situation with an unpredictable object (like a deer) next to the road section ahead could communicate to the driver that this object has been detected. This could be communicated in different ways, for instance by informing the driver auditory, highlighting the object in a head-up display, by reducing the speed or by a combination of multiple cues. But if the same situation will happen more often, a driver might already trust the system enough that not all of this cues are necessary or become even annoying. Thus optimal trust calibration can only be possible if the amount of feedback steadily varies with respect to the operator.

Taking this into account, we decided to define a framework being capable of representing the whole spectrum of potential driving tasks, that can be split into the three levels operational (low level operations like lateral or longitudinal control), tactical (driving in a platoon of vehicles or overtaking others), and strategical (navigation, etc.) vehicle control (see Figure 9).

The main idea was, that vehicle tasks can be explained to the driver by presenting information concerning each of these levels, and that the amount of information presented might be reduced and shifted from lower levels (for a novice user, the system can explain all details of a maneuver on the operational level) to higher levels (high experienced drivers might be presented only information in the tactical or strategical level as they are well aware of their low-level implications). This idea was then mapped to trust related factors, such as perception, understanding, prediction and adaption. To illustrate the concept, we decided to map all relevant operations of a typical overtaking maneuver into the framework. The idea was further developed after the Dagstuhl Seminar and published in a Work-in-Progress paper to be presented at the AutomotiveUI 2016 conference.

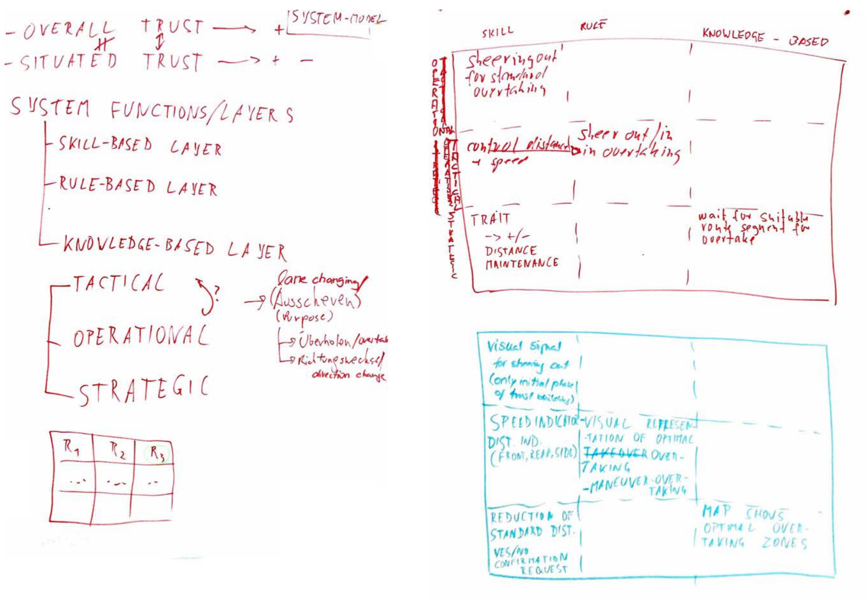

Figure 9 Mapping of vehicle tasks to different levels of vehicle control.

Simulation

A problem in automated driving research is the large variety of different research and data collection methods that make it hard to compare different studies, and challenging to collect similar data in different environments. Before we could start to discuss all the challenges with interdisciplinary participants, we needed to create a common terminology. For example, is a "simulation" referring to a driving simulator study with human participants, or a traffic simulation with simulated agents, or maybe even something different? After many discussions, we came to the conclusion, that we need to consider at least three dimensions when talking about driving research: "How artificial are the agents?", "How real is the environment?" and "How controlled are the scenarios?"

We created a multidimensional space that can be used to classify different user studies. The concept uses the three axes. "Environment" ranges from pure simulation, such as traffic simulations, to real environments, such as a public highway. "Scenarios" ranges from "controlled", like predefined driving tasks in driving simulator, to "natural", like free driving in open world driving simulation. The third axis is "Agents" and ranges from "human user" to "artificial agent". We tested our framework by classifying previous works and experiments as shown in Figure 10. On first sight, the dimension "Agent" seems to be binary. However, the intelligence of artificial agents can vary from very simple to complex or human-like in the context of the experiment. Other dimensions, such as "level of cognitive abstraction", "task complexity", etc. could be defined.

We learned that our framework helps to classify and discuss experiments among people from different disciplines. As a result, the framework can make research contributions more precise while allowing to answer research questions from different perspectives. Further, gaps in existing research can more easily be identified, leading to more synergistically connected research.

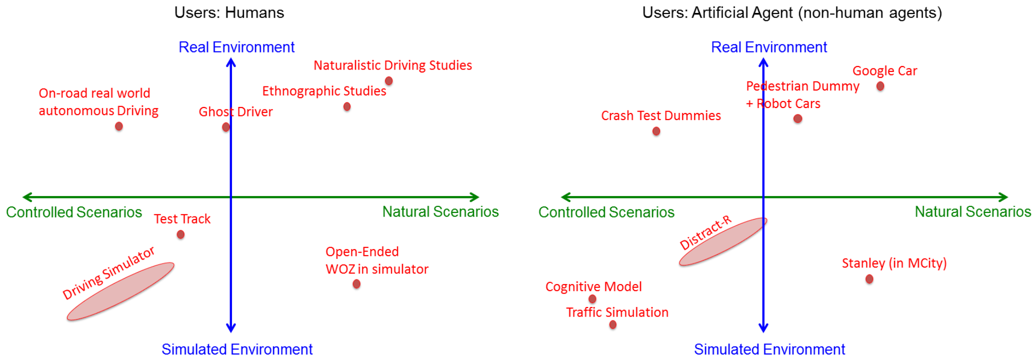

Figure 10 2D-view on the axes of the proposed framework with classified conducted research. Left: scenarios and environment for human agents. Right: scenarios and environment for non-human agents.

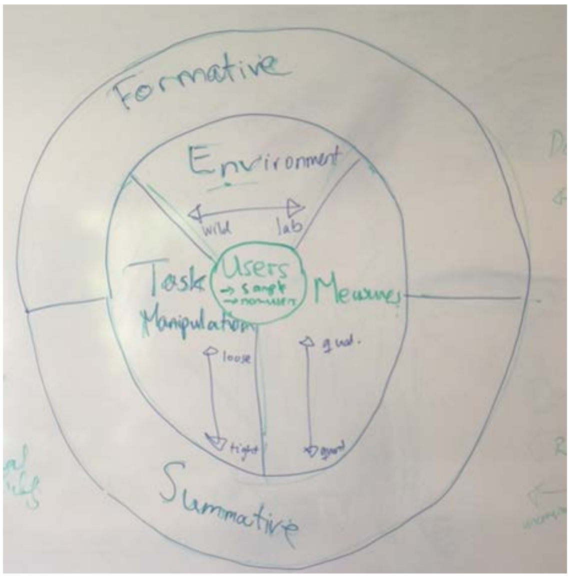

Figure 11 Possibility to categorize methods to find links between certain methods and the context of use of automated driving.

Methods in Automated Driving Research

Discussion about different methods revealed that there exist many methods. But which of them is the most appropriate in a given situation depends of several postulates: what do you mean by using the term "method", furthermore what is the current situation which involves as well as the context of use but moreover the design stage of what you want to explore (Figure 11).

In case of the research of automated driving concepts we need to think about what makes automated driving different but as well interesting to use and to develop certain methods. Therefor we have to categorize them to provide a focus, moreover the context of use for automated driving needs to be defined. The link between methods categories and the context of automated driving will reveal deeper insights into which methods are appropriate and where are still lacks. We therefore ask following research questions.

Research Questions

- What makes the evaluation of an automated driving experience different to any other interface (primary task) test?
  - What constitutes context of use?
  - What “new” methods are required when the traditional primary/secondary task distinctions break down?
- How can we develop new methods for uncovering unconscious/undreamed of requirements in this area?
- How can we combine highly diverse needs (emotional, performance) within methods?

6 Publications Inspired by the Dagstuhl Seminar 16262

The following list summarizes publications (as of November 14, 2016) inspired by the seminar.

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Participants

- Ignacio Alvarez
Intel Corporation – Portland, US
- Martin Baumann
Ulm University – Ulm, DE
- Susanne Boll
University of Oldenburg – Oldenburg, DE
- Linda Boyle
University of Washington – Seattle, US
- Nora Broy
BMW Group Research and Technology – Munich, DE
- Duncan Brumby
University College London – London, UK
- Gary Burnett
University of Nottingham – Nottingham, UK
- Lewis Chuang
Max Planck Institute for Biological Cybernetics – Tübingen, DE
- Frank Flemisch
German Aerospace Center (DLR), DE
- Anna-Katharina Frison
University of Applied Sciences Ingolstadt – Ingolstadt, DE
- Christian P. Janssen
Utrecht University – Utrecht, NL
- Jeon Myounghoon
Michigan Technological University – Houghton, US
- Wendy Ju
Stanford University – Stanford, US
- Andrew Kun
University of New Hampshire – Durham, US
- Andreas Löcken
University of Oldenburg, Germany
- Rod McCall
University of Luxembourg – Luxembourg City, LU
- Alexander Mirnig
University of Salzburg – Salzburg, AT
- Sebastian Osswald
Audi AG – Ingolstadt, DE
- Ingrid Pettersson
Volvo Cars & Chalmers University – Gothenburg, SE
- Bastian Pfleging
Ludwig-Maximilian-University (LMU) – Munich, DE
- Ioannis Politis
University of Cambridge – Cambridge, UK
- Benjamin Poppinga
Audi AG – Ingolstadt, DE
- Andreas Riener
University of Applied Sciences Ingolstadt – Ingolstadt, DE
- Maria Rimini-Doering
Robert Bosch GmbH – Renningen, DE
- Shadan Sadeghian Borojeni
OFFIS Oldenburg – Oldenburg, DE
- Albrecht Schmidt
Stuttgart University – Stuttgart, DE
- Steven Shladover
University of California at Berkeley – Berkeley, US
- Christine Sutter
Technical University Darmstadt – Darmstadt, DE
- Jacques Terken
Technical University of Eindhoven – Eindhoven, NL
- Mohan Trivedi
University of California – San Diego, US
- Philipp Wintersberger
University of Applied Sciences Ingolstadt – Ingolstadt, DE
- Jürgen Ziegler
University of Duisburg-Essen – Essen, DE