Special Edition
Predicting Human Behavior

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Interviews with:

Diego Minen
VI-grade

Hans-Peter Schöner
insight from outside
This issue of our magazine gives an overview of current research topics that deal with different aspects of Human-Centered Mobility relating to our research environment Drive.LAB, e.g. Driving Simulator and Human-Interactions, Pedestrians in the Loop, Human-System Integration Framework and ADAS/AD systems from a safety perspective and others.

We are particularly proud of having distinguished two experts sharing their view: Dr. Hans-Peter Schöner, CEO of „Insight from Outside” talks about future mobility and Diego Minen from VI-grade shares experiences around the present and future of Driving Simulators. Please enjoy reading!
Towards Human-like Autonomous Driving

BERNHARD BRANDSTÄTTER, Head of Department Energy Efficiency and Human Centered Systems

Imagine that you are approaching a crossing without traffic lights and at the same time another car from a different direction appears. Humans in this situation take advantage of many information within a fraction of a second: own speed, speed of the other car, eventually available traffic signs – and the awareness of the other driver. The same holds for country roads: when you recognize that a driver in an approaching car on the other lane is distracted by searching a station on his radio or by manipulating the temperature regulation – you would take special care!

As soon as automated driving comes into play in a complex scenario with mixed automated and non-automated vehicles – trust and, as a consequence, acceptance of systems will be the key to create substantial and sustainable market penetration of autonomous driving.

For creating trust and acceptance a human centric approach will not be enough, since this might lead to correct actions and decisions in a technical sense, but does not consider the human expectation.

This might lead to mistrust the technical system. (Referring the example with the crossing above, where your car could do some completely unexpected but still safe and feasible manoeuvres, would you keep your ADAS system turned on?)

Therefore, at VIRTUAL VEHICLE we focus our research on helping our costumers to create HUMAN-LIKE systems, which are systems whose behaviour is understandable and traceable.

The VIRTUAL VEHICLE simulation environment for developing human-like systems

VIRTUAL VEHICLE is currently expanding its simulation environment towards the possibility to simulate new developments for automated driving in a complex environment taking into account the awareness of the driver and other drivers and pedestrians (Fig. 1).
VIRTUAL VEHICLE’s Drive.LAB as enabler for human-like systems

The VIRTUAL VEHICLE Drive.LAB is a laboratory comprising a driving simulator designed for assessing drivers in a complex mixed-traffic driving scenario with other cars, road users and pedestrians. This dedicated driving simulator can be linked to other driving simulators, to pedestrians that are brought into the loop via augmented or virtual reality (see article “Pedestrians in the Loop” in this issue) and can be connected to the VIRTUAL VEHICLE autonomous driving demonstrator car to close the loop to reality in a seamless way.

Methodological set-up for developing human-like systems

The human centric needs for safety and comfort in a setting, in which drivers will be confronted with other tasks than simply driving the car (working, relaxing or being entertained) will be addressed in accepted systems only via trust (Fig. 2). Human-like systems will be key to create trust and acceptance. Tutoring the driver towards context- and situation-based interaction with automated systems is another central building block.

Three elements have been established by VIRTUAL VEHICLE to enable human-like system development, which are implemented in Drive.LAB (Fig. 3):

1. The Driver Digital Twin: human behavioural models that serve as the basis for all control actions in the loop (these models are continuously updated and enhanced according to measurements in the Drive.LAB)

2. Fluid Interaction: considering environmental information (weather, road condition, other vehicles, awareness and state of other drivers and pedestrians), own vehicle state and own state as a driver. Fluid interaction finds situation dependent the best possible way to warn the driver or bring him back into the control loop.

The fluid interface, like a fluid, surrounds the driver and continuously adapts to his psychophysical “envelope”.

It is a multisensory, omnipresent and

![Human-centered Driving Simulation for AD in mixed scenarios](image)

Figure 2: Drive.LAB is intended to address human-centered needs like safety and comfort, while creating trust and acceptance even in complex traffic scenarios. The tutoring of drivers to interact with automation is another feature that is offered by Drive.LAB.

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1 i.e. vehicles with or without ADAS functionality in complex scenario, like cities, crossings, open-spaces etc.
omnidirectional system that constantly monitors the driver, his activities and attentional levels to update a driver “digital twin” model. In turn, the updates in the model are used to generate and select the proper sensor modality, timing and location to issue signals and communicate naturally with the driver. The characteristics of a fluid interface enable the implementation of three functions: (i) sustained monitoring of driver, passengers and environment, including V2V and V2X communications; (ii) control management, including transitions of control (take over and hand back) across different levels of automation; (iii) tutoring of native manual drivers towards increasing automation levels.

3. AV Instructor: is used to evaluate the performance of self-driving vehicles with respect to driving style in simulated and real environments

This VVM edition comprises 3 articles emerging from the context of human-like autonomous driving:

1. Introduction of the possibilities and features of the dedicated driving simulator in the VIRTUAL VEHICLE Drive.LAB context.

2. How to bring pedestrians into the loop.

3. A human-system integration framework to effectively embed human considerations into complex technologies.

With DriveLAB and the accompanying methodology we offer our customers the best possibility to develop functions and systems for human-like automated driving.

ADAS systems and automated driving have the potential to reduce the number and severity of accidents dramatically especially, when drivers are trained to use these systems. DriveLAB offers the possibility to assess the ADAS/AD systems from a safety perspective via the VIRTUAL VEHICLE safety toolchain and human body models, which is described in the last article, where OSCCAR – an EU project, coordinated by VIRTUAL VEHICLE – is introduced.
Predicting Human Behavior

New Trends in Driving Simulators: The Out-of-the-loop Experience

PAOLO PRETTO, Key Researcher Human Factors & Driving Simulator

Driving simulators for research purposes are used in human factors research to monitor driver attention, behavior and performance, and in the automotive industry to design and evaluate new vehicles or new Advanced Driver Assistance Systems (ADAS). They are a tool that enables users to experience driving in a safe and controlled virtual environment.

Human-centered Driving Simulation

Typically, a driving simulator consists of a physical mockup, which includes the driving input commands (steering wheel and pedals), and a visualization system. The hardware configuration of these components ranges from affordable gaming-like desktop setups to complex installations consisting of, e.g., a 360-degree projection dome surrounding a real car and built on top of a moving system, often larger than a tennis court. The latter systems require dedicated IT and logistics infrastructures, with multi-million investments and high running costs. Nevertheless, this great technological investment is undertaken to provide higher fidelity, immersion and realism to the third and most important component of a driving simulator: the human driver. Indeed, the primary purpose of a driving simulator is to reproduce in a controlled virtual environment the same conditions that a driver would experience in the real world. Therefore, the simulator user is the measure of the effectiveness of the driving simulation, in which the driver’s perception and behavior are met.

Nowadays, simulators have well-established roles in the vehicle design process, from early
assessment of virtual prototypes to validation of production-ready solutions. Indeed, modern driving simulators allow designers and engineers to quickly implement virtual models and test them in highly realistic environments with selected drivers. The agility of this process, the standardization of the assessment procedures and the power of integrated software/hardware tools are surely key factors that explain the wide and successful adoption of driving simulator technology in industrial research.

The massive digitalization of industrial processes and the development of human-centered systems engineering are bridging the gap towards the design of usable, understandable, and natural Human-Machine Interfaces (HMI) which can be easily implemented and tested in driving simulators. Moreover, the development of ADAS is also being successfully tackled using driving simulators. However, the topic of Automated Driving (AD) is spreading in every sector of transportation technology and a question has raised:

Do we still need driving simulators in which users should be immersed, if vehicles are going to drive autonomously?

This seems a legitimate question if one considers that the driver will soon be OUT of the loop, while driving simulators have been designed to bring the driver IN the loop. The truth is that driving simulators are now more than ever necessary to put drivers and passengers in conditions that closely resemble the real road environment to evoke, measure, model and understand the complex relationship between humans, automated vehicles and road infrastructure.

New Driver Roles and Simulator Trends

A driving simulator conceived for research and development in the field of automated driving must consider the new roles that drivers are assuming. Indeed, with increasing level of automation drivers will be able to gradually phase-out control over the driving functions and transfer it to the automated vehicle. This trend will soon enable a variety of

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We will use our connected infrastructure to share information about drivers and passengers state and enable predictive safety in automated vehicles.

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Figure 1: The Drive.LAB simulator consists of real car cockpit complemented with a custom tilting platform, which provides acceleration cues for a higher immersion and realism. Moreover, the integration with a co-simulation framework enables the agile development of ADAS functions. The simulator can be linked to other driving simulators, to pedestrians that are brought into the loop via augmented or virtual reality and can be connected to an Automated Driving Demonstrator vehicle.
non-driving tasks that until now were simply not part of the driving experience. Moreover, safety-critical issues arise in transfer-of-control scenarios, where the automated system and the human driver need to effectively communicate to each other their intentions and actions.

Therefore, a simulator must enable the study of the interactions between drivers, passengers, vehicles and road users. In line with this, it is foreseeable that the future development of driving simulators dedicated to AD research will focus more on enabling on-board connectivity, driver monitoring and interaction concepts and technologies. Driving simulators need to be re-conceived as living spaces where humans act out-of-the-loop, in connection with each other and using different technologies, and upgraded with multi-sensory interfaces that have yet to be designed. This perspective will have profound implications in the development of future simulator technology.

VIRTUAL VEHICLE Drive.LAB

Following the above-mentioned considerations, at VIRTUAL VEHICLE we have installed a new semi-static driving simulator, equipped with a high-end visualization system and a real car cockpit. We have customized the system for research purposes with additional hardware and software components. We have integrated an eye-tracker, physiological sensors and webcams for monitoring the driver state, active belts and active seat for somatosensory stimulation to provide quick acceleration onset cues to the driver, an accurate sound reproduction system, and several mounting points for installing displays in different positions inside the cockpit. Additionally, the simulator features a first-of-its-kind integration of the car cockpit on a tilting platform, which enables the accurate reproduction of inertial cues and vibrations for drivability and comfort studies, with no need for large motion systems. Overall, our system is designed to enable and test the design and development of ADAS and Human-Machine interfaces for traditional and AD scenarios.

With this most recent addition to our simulator fleet, at VIRTUAL VEHICLE we are building Drive.LAB, a laboratory where scientists can efficiently develop and test innovative concepts and tools to address the current and far beyond state-of-the-art mobility challenges. Drive.LAB sets us apart from other research organizations, featuring a unique combination of human factors expertise, simulation facilities and access to real road and vehicles data.

Moreover, Drive.LAB connected simulators will help our scientist to investigate, understand and shape the new foreseeable driver roles in hybrid mobility scenarios, from partial to full automation. Our research focuses on improving safety in automated vehicles, while enhancing passengers' comfort and the overall acceptance of automated vehicle technology.

To these purposes, we are currently designing multi-sensory Fluid HMI, capable of driver monitoring and tutoring, seamlessly supporting the transition between automation levels in a comfortable and safe way, according to human-centered design principles. We will use our connected infrastructure to share information about drivers and passengers state and enable Predictive Safety in automated vehicles. This vision aims at designing Human-like automated systems that, like human drivers, can predict a potential hazard and prevent the triggering of a critical situation, rather than detecting a danger that is already underway. We are also contributing to an ongoing European-funded project (DOMUS) to develop an integrated acoustic and thermal comfort model for drivers of electric and automated vehicles. With our studies we are measuring the impact of different cognitive aspects on the subjective impression of sound quality in the vehicle.

All Pictures show the new driving simulator of Drive.LAB at VIRTUAL VEHICLE in Graz. This tool was developed by VI-Grade within a strategic research cooperation.
Many testing procedures have been developed to ensure vehicle safety in common and extreme driving situations. However, these conventional testing procedures are insufficient for testing autonomous vehicles. They must handle unexpected scenarios with the same or less risk a human driver would take. Currently, safety related systems are not adequately tested, e.g. in collision avoidance scenarios with pedestrians. Examples are the change of pedestrian behaviour caused by interaction, environmental influences and personal aspects, which cannot be tested in real environments. VIRTUAL VEHICLE applies Virtual Reality and Augmented Reality techniques to incorporate real test-persons in a Pedestrian in the Loop Testing-framework.

Testing of autonomous vehicles for complex and uncertain environments has become one of the biggest challenges in the automotive industry. Automation and computational intelligence will increase abilities of the vehicle [1]. The environment perception and situation understanding will be covered, by computer algorithms. In addition to vehicle dynamics, the environmental states must be incorporated into the test [2].

In order to ensure safety, it is required to test the intelligent vehicle in a reasonable way. It is also necessary to have prediction mechanisms to infer the consequences of decisions correctly. Conventional testing procedures are insufficient to ensure safety of increasingly complex future assistance functions involving machine perception and cognition [3].

The vehicle must find in each situation a reasonable trade-off between safety and efficiency, which can lead to different levels of risk taking especially in motion planning. In classical driving situations a driver perceives the environment through to his sense
Aspects for a compromise in risk taking for motion planning of (autonomous) vehicles or unconsciously about the next suitable driving manoeuvre.

High Risk - High Responsibility

The same is true for a pedestrian, where the dynamics is different. The ability of pattern recognition helps to decode the causality of the situation and enables to infer future situations and reason about the consequences of the (planned) action \[4\]. More experienced and talented drivers can take more risky manoeuvres than untalented drivers. With higher risks, the probability for collisions will increase.

The driver nevertheless has a responsibility within his decision making, which must be translated for autonomous vehicles into a machine understandable language. Safety generally has a higher priority than traffic flow, but it is also expected that the vehicle does not hinder other road users.

Currently, driving situations with pedestrians are often tested in observational statistical studies rather than in a randomized control experiment, due to safety reasons. This has an enormous impact on the development of motion planning strategies (conservative configuration) in autonomous vehicles and the usage for real scenarios (low generalizability, some aspects are not tested, i.e. intention, environmental aspects).

A randomized control experiment is proposed with the incorporation of virtual reality technologies (Fig. 1). The advantage is that real test persons can be incorporated in an experiment (Pedestrian in the loop). It is easily possible to change the virtual environments and to stimulate the perception of the test person. Deterministic mechanics of the human body (i.e. joint angles) can be measured with motion capture systems and walkable-platforms. Experiments with different persons offer new perspectives for the development of autonomous vehicles.

The movements and gestures of a test person acting like a pedestrian in a real environment are recorded (e.g. motion capture system) and the perception of the pedestrian is stimulated by virtual reality glasses (e.g. oncoming vehicle and buildings). The software of motion planning can be integrated in the virtual environment, so that safety critical

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**Figure 1:** The pedestrian in the loop framework offers the possibility to test existing algorithms for automated vehicles with real test persons. Central is the virtual environment, where a test person interacts with virtual reality glasses. Existing HIL/SIL/MIL test platforms can be integrated. A server coordinates the information exchange.
scenarios can be tested. The advantage of this approach is that interaction, real pedestrian behaviour, environmental influences and personal aspects can be incorporated into the test. The perception of the test person is stimulated by virtual reality glasses (e.g. oncoming vehicle and buildings).

**Key-facts of Pedestrians:**

- There is no absolute certainty in pedestrian movement prediction due to a lack of knowledge.
- Environmental understanding (especially in highly complex urban environments) and human behaviour are core challenges for automated vehicles.
- Many situation predictions for pedestrians might be plausible.
- Motion planning with pedestrians is a safety critical application; environmental influences, intention changes, perception, interaction and personal aspects are not directly testable in a randomized controlled experiment.
- Personal aspects, interaction, perception, intention changes and environmental influences on pedestrians must be tested.

VIRTUAL VEHICLE offers a new Pedestrian in the Loop technology. With Virtual Reality and Augmented Reality real pedestrian behaviour can be incorporated in a driving simulator. ■

**Reference**

This article is based on:


1. Which achievements in your area of responsibility are you most proud of?

During the last 15 years as Senior Manager at Daimler I defined new testing tools, verification methods and simulation environments, featuring essential traffic situations. One of the key methods I developed was the Coordinated Automatic Driving of several vehicles and self-driving crashable targets on proving grounds, in order to provide precise and repeatable testing situations. In 2012 I established Simulation Support for the development and testing of autonomous vehicle functions to verify vehicle behaviour in hundreds of traffic situations which could no longer be tested efficiently on the proving ground alone. Now the questions are how to verify and validate autonomous vehicle functions with the goal of a safer future traffic, accounting for Self Awareness and a Sense of Danger.

2. On the way to automated driving, what has been/is going to be the role of research, and the one of industry?

Research always has to tackle unsolved problems, invent and try out creative methods, and develop new tools. Industry has to pick the best of these results, and together with proven established methods provide robust, cost efficient and desirable products. Robust means: in industrial products, due to the large number of products, any conceivable problem will occur – so a solution must be found for all those problems. And since it must be cost efficient, you need to find and verify those solutions with effective methods.

3. What is the impact of automated driving on driving simulation technology?

Driving simulation technology is one of the many tools and methods to make automated driving more robust. In driving simulators with human drivers, the interaction of the driver with his environment can be studied. Although autonomous vehicles seem to drive without a human driver, there still are a lot of interactive situations: first, starting and ending the autonomous mode is quite important, especially under unconventional or extreme conditions. Second, autonomous vehicles will not be alone on the road, so the interaction of such vehicles with human driven vehicles is a further wide field of study.

4. What are the current and upcoming challenges for driving simulation? And the limits?

In the past, driving simulators focussed on single assistance functions, which were studied in very specific driving situations, mostly with only one other relevant interacting traffic participant. Autonomous driving needs to master the complete traffic – thus requiring to simulate all conceivable traffic situations with a large variation in behaviour of all traffic participants, including bicycles, motor bikes, pedestrians, and so on. And it needs to simulate the effect of vehicle sensors in those traffic situations, including faulty and erroneous signals. In many cases it is needed to abstract to only the relevant situations. Finding and defining these limits is one of the research questions.
5. How would you measure the performance of driving simulator and their validity for technological development?

For the validity of a driving simulator the behaviour of a driver in the situation which is under evaluation needs to be identical or at least comparable to the behaviour in the real-world situation. Experts distinguish between absolute and relative validity, respectively. In order to validate a new type of simulation experiment, a comparison of driver behaviour in real world and in simulation should be performed, in order to understand the important conditions. This could be a typical task which can be done in a research simulator; industry could base their own experiments on such validated methods.

6. How do you see the standardization of driving simulators for homologation and validation purposes in automated driving technology?

The huge task of a virtual simulation world, which needs models for the behaviour of traffic participants, vehicle components, especially environment sensors, but also weather conditions and traffic situations, is only achievable if all community members are able to work towards standard interface definitions. Especially standardized traffic situations, which should be tested in simulation as part of homologation for automated vehicles, might be part of the validation procedure of autonomous vehicles, which are in discussion all over the world. However, this is still in the process of definition.

7. From an industry perspective, what are the (expected) benefits of automated driving?

I believe, that the benefits of automated driving should be primarily on the users’ side. A lot of human drivers are taking risks in many driving situations, which automated systems would never dare to take. This means, automated driving needs to be as cautious, careful and predictable as a good human driver. This needs a lot of technical investment in and development effort for autonomous vehicles. So, if you want to put it as a benefit of automated driving for the industry: the shared and autonomous driving of the future might need less vehicles per capita than we have nowadays, but with a significantly higher value of the single vehicle.

8. When are we going to see fully automated vehicles on the road?

There is a vision of the completely driverless automated vehicle, which can drive at any location under (almost) all weather conditions – this will surely take many more years, before we reach this robustness and cost efficiency. But vehicles, which provide full automation in specific limited situations (on the highway, especially under congested conditions, and in slow moving parking manoeuvres) with some kind of human supervision and rare need for interaction, shall be technically feasible within the next vehicle generation – and we will see it on the road as soon as legislation and homologation will allow this.

"Accurate and reproducible traffic situations can be generated through coordinated automated vehicles on the proving ground or through simulations in the driving simulator."

Dr. Hans-Peter Schöner, CEO of „Insight from Outside“ – Consulting, www.ifo-consulting.com and member of the Driving Simulation Association DSA. From 2014 until 2018 he was responsible for the development of testing methods, including driving simulation, at Daimler R&D in Sindelfingen.
Activities towards increased automation are often technology-centered: faster computers, improved sensors, enhanced deep learning algorithms etc. However, such complex technological systems are also user-intensive, i.e. they require the user to be an intimate part of the system, with the ultimate responsibility of taking safety-crucial decisions. Nevertheless, often these systems meet users who are less and less able and willing to learn, adapt and eventually take advantage of the innovations. The lack of trust, and the resulting misuse of those systems, is therefore a consequence of limited considerations for the human factors in the design and engineering processes.

To overcome this issue, VIRTUAL VEHICLE promotes and operates the integration of human considerations into the methodologies that are being developed to improve AD and ADAS technologies. In our human-centered approach, we assess humans’ characteristics and behavior in different (complex) driving scenarios to derive concrete specifications.
for the systems. We include scenarios that present concrete operational problems at different levels of complexity. For example, we analyze drivers' attentional drift when they are simultaneously engaged in multiple activities. In addition, we also include situations where multiple entities are involved, that is, the driver must interact not only with the vehicle, but also with the infrastructure and other road users. In this context, efficient and constantly updated flows of information, along with powerful models that capture the interactions between those entities, are being developed (see the articles from Pretto and Hartmann in this issue).

The execution and orchestration of these research activities requires the constant and active integration of cross-domain expertise, supported by Drive.LAB research infrastructure (see Pretto). The integration process spreads across five critical dimensions (AUTOS1): Artifacts, Users, Tasks, Organizations and Situations. In the followings, we provide a Systems Engineering description of those dimensions and show how we include them in our research activities.

Artifacts

The artifact is the result of the design process, the Automated Driving System for which SAE J3016 defines most entities. Within an expanded HSI framework other constraining factors that are not immediately in view of a “hard system perspective” become critical to define the artifact. The artifact does not exist in the thin air of a theoretically constructed ideal environment but is the intricacies of real usage and environmental conditions. Such conditions can be captured as scenarios (assessed using Drive.LAB) to reflect the users, their tasks (that might differ from driving-only), as well as their organizations and situations.

We differentiate three types of scenarios (see Fig. 1):
- Problem Scenario
- Solution Scenario
- Opportunity Scenario


Users

The users, as defined in the SAE taxonomy, perform parts or all of the dynamic driving tasks in-real time and/or are the fallback for this task. This restricted view on the user sets aside some of the major enablers of automated driving that could make an ADS desirable. For example, currently excluded mobility participants could be included if the ADS is designed considering the specific user abilities. Other drivers may be able but unwilling to engage in the kind of necessary tasks because their motivation of buying the ADS contradicts them. The ADS as artifact is considered as part of a larger system and defines its required functionality.

Tasks

Tasks are defined in the SAE taxonomy primarily in the context of the dynamic driving task, specifically the lateral and longitudinal maneuvers as well as maneuver planning, the monitoring of the driving environment, signaling, and response initiation to specific events. The performance of these tasks shifts from the human to the automated driving system toward higher levels of automation. In turn, new tasks emerge for human operators who take on supervisory tasks and
Some of these new tasks may require knowledge and experience. For example, the basic functioning of automated driving systems requires familiarity with the timing and dynamics of transfers of control. In addition, human operators are expected to engage in non-driving tasks that in some cases may interfere with the driving-related tasks. After all, humans are primarily engaged in many life activities among which using an automated vehicle is just one.

Therefore, considering the larger context within which the automated driving is likely to occur will be critical to design automated vehicles appropriately. Also, in the spirit of human-systems integration, the tasks that a human operator of an automated driving vehicle should perform should not be primarily derived from the AD functions per se but vice versa. They should be both defined so that they are able to accommodate the desired trip experience but also the available technical constraints.

Organizations

The organizational dimension relates to the changed roles of the driver and the social issues that may result from the introduction of automated driving systems. For example, automated driving systems may share data with other entities that could allow to extract sensitive information about the human operator that they object to. Also, driving automation that relies on monitoring the human operator to infer appropriate driver state information such as fatigue or distraction could be at odds with the privacy and data protection interests of the human operator and cause non-acceptance or discomfort.

Finally, people may get used to automated driving systems and start responding in novel ways that are not envisioned or expectable otherwise. For example, pedestrians may take advantage of the presumed “overly-safe” performance of automated driving vehicles and force inappropriate maneuvers they would not attempt with human drivers.

Situations

At least two types of situations are relevant for automated driving systems. First, there are the concrete driving situations that the operator experiences while driving, including the events inside and outside of the vehicle. The situations inside the vehicle may demand the driver to communicate or interact with passengers or calling or texting. These vehicle usage situations may impact the operator’s readiness to engage in the tasks that need to be accomplished. Secondly, the ADS is designed for specific external situations in environments that are referred to as operational driving domains (ODD).

ODD include environmental situations such as weather conditions, vehicle speed, road maintenance, or road infrastructure conditions. The type and number of ODDs through which an ADS travels during a use scenario may impose significant requirements on the user. For example, entering or exiting an ODD may imply a different role and responsibilities for the human driver that need to be known. Therefore, the appropriate design of ODDs and their implication on user knowledge and responsibilities are an important aspect of ADS development.

An HSI framework for the Development of automated Driving Systems

The development of an ADS that is the result of an integration process between humans and technology starts with a close look at the five dimensions of the AUTOS framework described above. This perspective - with Drive.LAB as an enabling tool - is used to identify problem scenarios that are inspired by current mobility shortcomings or economic, operational, technical opportunities of AD. A multidisciplinary analysis of constraints and possibilities of each of the five AUTOS
dimensions results in the creation of solution scenarios that are the starting point of in the iterative HSI research process.

**Summary and Outlook**

The HSI framework introduced here represents a powerful and flexible tool to account for the complexity of technological and human-intensive mobility solutions. The early considerations of human factors in the development process becomes advantageous to define current mobility shortcomings, as well as possible enhancements, and to guide the implementations of actual artifacts and solutions. The consideration of specific user (dis)abilities may also extend the current adoption of ADAS and ADS.

Furthermore, with the possibility provided by increased automation of engaging in non-driving tasks, the simultaneous definition of AD functions and driver's tasks can accommodate both the desired trip experience and the technical constraints. The HSI framework also considers the implications for society and organizations, where dedicated policies will need to guarantee the appropriate protection and integrity of sensitive information and the safe behaviour of all road users, depending on the actual driving situations.

At VIRTUAL VEHICLE we believe that such a framework can effectively contribute to the development of a more efficient, safe and comfortable driving experience through a broader understanding, acceptance and trust of ADAS and ADS.
1. Which achievements in your area of responsibility are you most proud of?

Since kick off in 2006, VI-grade has been acting as pure software simulation company for the first three years. From 2009 on, we progressively converted it to successfully compete in the very challenging market of driving simulators, thus transforming our „full vehicle virtual simulation” into „full system hybrid simulation” including the human driver, in or out the loop. Currently most of the business of VI-grade is made around driving simulators turn-key solutions.

2. On the way to automated driving, what has been/is going to be the role of research, and the one of industry?

The two should work together intensively. The automated driving paradigm has been given for „resolved” already a few years ago. The more experience is collected from virtual and real scenarios, the more the problem looks to be much more complex than what has been thought. My opinion is that far more research is needed, the robotization quality is still primitive, little or zero is known about human adaptation, the entire infrastructure to host automated mobility is still far to be ready.

3. What is the impact of automated driving on driving simulation technology?

While until three or four of years ago about 1/4 of the requests for driving simulators was aimed to implement ADAS/AD scenarios, now the majority of all the installations require to have CAV (Connected Autonomous Vehicles) simulation available. This means to equip the simulators with the same or similar on-board sw and hw of the real CAVs, and to monitor their behavior in conjunction with vehicle traditional telemetry and with human acceptance/adaptation.

4. What are the current and upcoming challenges for driving simulation? And the limits?

There are several challenges. Perhaps the most difficult one is to increase the work space and improve the multisensorial perception without decreasing bandwidth and without increasing complexity and installation/usage cost. It appears evident that more and more non-expert drivers and normal passengers should go through the Driving Simulator experience for both vehicle, sensor and infrastructure optimal development.

5. How would you measure the performance of driving simulator and their validity for technological development?

That is simple: we have collected virtual-to-real telemetry and perception comparison on several projects. We need certainly more, however I think we are in the right direction with the experience accumulated so far, customer feedback is enthusiastic and every day a new application opportunity materializes, both in existing installations and with new prospects. We need more statistics for human impact to robotization, and we are working on it.
6. How do you see the standardization of driving simulators for homologation and validation purposes in automated driving technology?

This is a difficult question. Driving simulator architectures (sw, hw) are not standardized yet and I do not see that this could happen any time soon. It will much depend on when the public organisations will start considering the technology reliable from their perspective, and will be able to establish rules in terms of possible standard test and target performance, pretty much as they require for real cars. Once the technology is assessed at OEM and infrastructure level, then for example driver training on automated vehicles could be certified on driving simulators.

7. From an industry perspective, what are the (expected) benefits of automated driving?

I guess the answer for the currently visible horizon is simple: help at best or replace a distracted/tired/drunk/drugged human. It’s known that robot do a nice job for repeatable and boring task which tend to decrease human attention. But the transition to direct control must be straightforward, or cars could risk the trap of the B737M...can’t find instructions on how to quit the robot!

8. When are we going to see fully automated vehicles on the road?

On given short, connected, controlled and repeatable routes, soon; in generic slow traffic, maybe just in a few years; in a full messy, wild and fast traffic, I do not see yet when.

The human brain can still imagine scenario’s evolutions that are far more complex than those that sensors can algorithmically forecast. The problem is that to have full control of what could happen we should learn from a huge number of experiments. For this, simulation and driving simulators are rather becoming essential tools than just nice options.

“The human brain can still imagine scenario’s evolutions that are far more complex than those that sensors can algorithmically forecast.”

Diego Minen, Vice President Research & Development / CTO is Co-Founder of VI-grade and currently Technical Director and Chief Technical Officer, leading the Product Development.
The upcoming, interconnected generation of Highly Automated Vehicles (HAVs) has much to offer: New sitting postures through reclining and even rotating seats promise to convert HAVs into a place of relaxation and comfort. New seat positions though implicate challenges for the occupant safety and therefore call for new concepts of improved safety systems, such as “intelligent” seat belts and airbags. For the safety assessment of these new systems, the traditional crash test dummy also needs help from more biofidelic Human Body Models (HBMs).

Figure 1: OSCCAR’s strong international consortium, coordinated by VIRTUAL VEHICLE
Leading European OEMs like Daimler, Toyota Motors Europe, VolvoCars and Volkswagen and Tier1 suppliers Autoliv, Bosch and ZF join forces with the European and International research community in the EU H2020 project OSCCAR. Its goal is to pave the way for future safe and comfortable vehicle development using virtual development and assessment methods - making EU “Vision Zero” come a step closer!

OSCCAR, coordinated by VIRTUAL VEHICLE, unites more than 20 international partners and runs for 3 years since June 2018. The experts develop a novel simulation-based approach to safeguard occupants involved in future vehicle accidents. Future accident scenarios, new advanced occupant protection and the improvement of diverse, omnidirectional, biofidelic and robust Human Body Models (HBMs) are the cornerstones of the project. Its ambition is to pave the way for future virtual testing-based homologation, especially needed for the complexity of HAV capabilities.

Researching on advanced occupant protection

In order to provide a safe and comfortable vehicle interior for HAVs, new seat configurations need to be equipped with appropriate safety systems to maintain optimal passive safety for all occupants. OSCCAR will therefore develop and demonstrate advanced occupant protection principles. These need to be assessed with improved HBMs, considering gender and demographic factors as well as enhanced biofidelity. Furthermore, fully integrated assessment methods for complex test scenarios of the complete crash phase will be devised and applied. OSCCAR will also contribute to the harmonization of HBMs and injury criteria as well as the improvement and development of virtual testing standards. Eventually OSCCAR will develop a clear roadmap towards large scale implementation of virtual testing methods for advanced safety solutions, not only relevant in the automotive domain but also for two-wheelers, vulnerable road users (VRUs), or even in sports.
In a first step OSCCAR project analyses the limits of current occupant vehicle safety systems for HAVs. Deficits will be identified, and appropriate improvements of current systems will be suggested. For this application it is especially necessary to provide virtual tools and harmonized methods for the development and assessment of those advanced automated vehicle safety systems.

Current hardware-based testing methods and tools will no longer neither be sufficient to handle the high complexity of future accident scenarios, nor will it be possible to conduct the necessary number of tests in reality. Thus, improved virtual testing methods are necessary.

For where conventional physical crash test dummies cannot reliably be used, harmonized, enhanced HBMs suitable for complex testing will be developed. These models usually depict internal organs, bones and individual muscles and are able to represent the heterogeneity of the population also taking into consideration characteristics like gender, age and other demographic factors. Some even have an active and reactive muscle functionality for assessing the pre-crash phase. All that at feasible cost and hugely increased capability compared to crash test dummies, for a dedicated increase in safety for the individual.

An integrated toolchain will be developed that allows a continuous assessment and novel interior concepts in future accident scenarios using advanced HBM evaluation tools. This enables the development of advanced and adaptable protection for the diverse occupant population.

The OSCCAR project foresees to achieve advancements in the following important areas:

1. OSCCAR will provide simulation tools including advanced HBMs for the development and assessment of advanced automated vehicle safety systems

2. OSCCAR will lay the foundation for future harmonized virtual testing of advanced protection systems and the homologation of future sitting positions in the context of automatic driving

3. OSCCAR will generate an in-depth knowledge about future accident scenarios incl. a publicly available database

4. OSCCAR will develop advanced protection principles for new - automated vehicle enabled - innovative seating concepts

Due to its excellent partner consortium and collaboration with key players from industry and research from Europe, North America and Asia, OSCCAR is in the position to ensure global application of its results and achievements.

More Information:
www.osccarproject.eu

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New results about these research topics (and more) at the following international events:

- **12th Graz Symposium Virtual Vehicle - GSVF (May 7-8, Graz, Austria)**
  www.gsvf.at

- **Comfort Congress (August 29-30, Delft, The Netherlands)**
  “Measuring Holistic Comfort for Virtual Cabin Designs”
  www.icc2019.eu

- **Driving Simulation Conference (September 4-6, Strasbourg, France)**
  “Assessment of Acoustic Comfort in Electric Autonomous Vehicles”
  www.dsc2019.org

- **International Conference on Human Systems Integration (September 11-13, Biarritz, France)**
  “A Human-Systems Integration Framework Around the SAE Taxonomy for Automated Driving Systems”
  www.incose.org/hsi2019

- **World Usability Congress (October 16-17, Graz, Austria)**
  “Fluid: Shaping the Automated Driving Experience”
  www.worldusabilitycongress.com
HUMAN CENTERED DRIVING SIMULATOR

Tools:
- Safety Toolchain
- Human Body Models
- Acoustic & Holistic Comfort Models
- Driver Digital Twin

Features:
- Driver – Vehicle – Road Interactions
- Fluid Human-System Interface
- Connectivity with other simulators, real vehicles and pedestrians

Human-centered Approach for enhanced Usability and Understanding
Research & Development of Human-like Automated Driving
Increasing Safety, Comfort, Acceptance and Trust in Driving Automation