Federal Ministry of Education and Research

Cabinet Office

Joint research for automotive innovation

German-Japanese Research Cooperation on Connected and Automated Driving

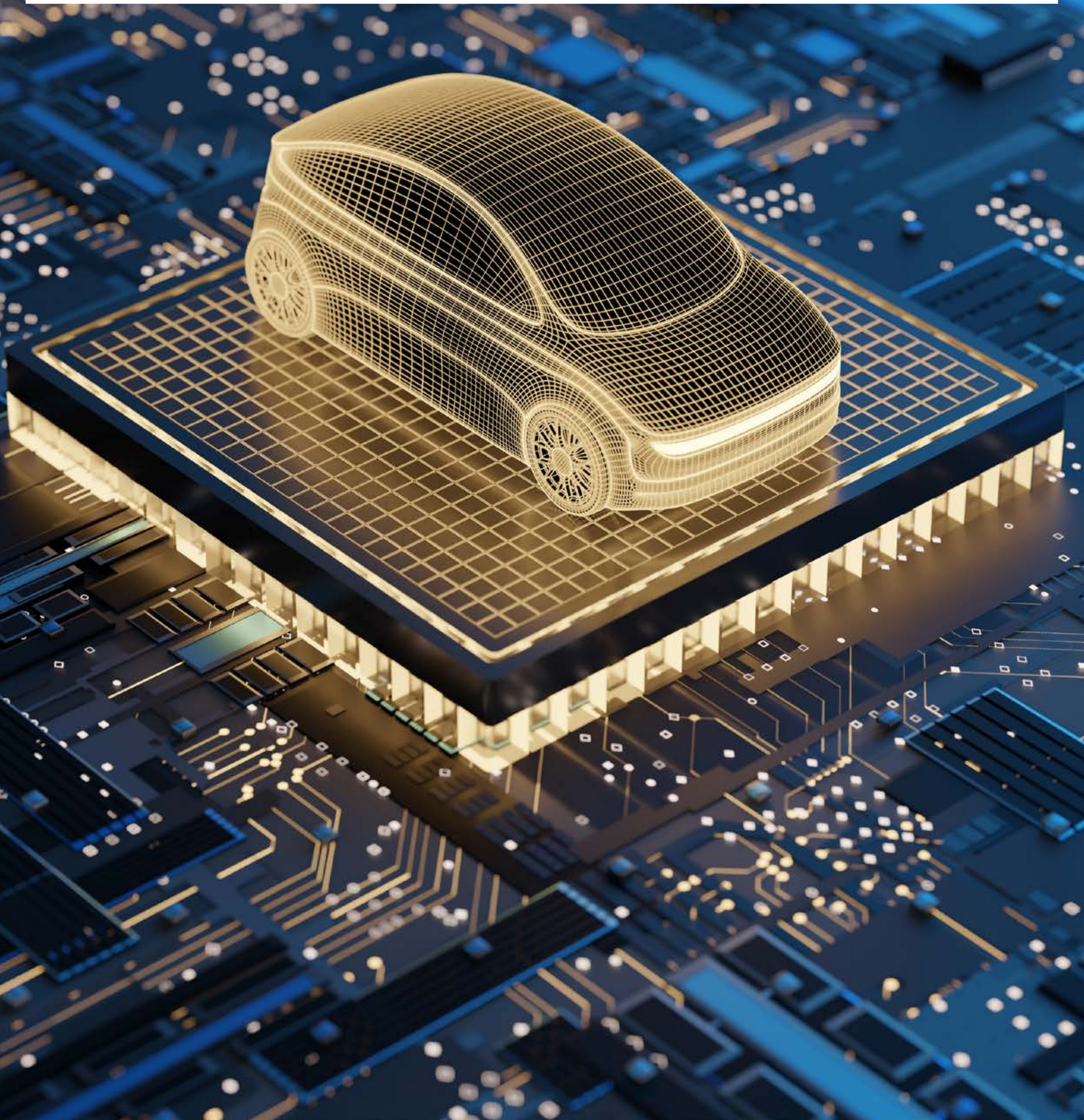


Table of contents

Introduction

Over the course of the past 50 years, Japan and Germany have enjoyed a close and prosperous collaboration supporting bilateral research activities in the field of science and technology. In 2017, the German Federal Ministry of Education and Research and the Japanese Cabinet Office started a new chapter in this successful partnership and initiated a bi-lateral research cooperation on automated and connected driving, realising the potential of scientific exchange and joint research activities in this technology field. Both, Germany and Japan, have a strong car industry that is an important pillar of each national economy. At the same time, both are facing similar challenges, especially in terms of demographic change and international competition. Hence, the main objective of this cooperation is to build on the commonalities and learn from ways in which each complements the other. Ultimately, automated and connected driving has the potential to contribute to safer traffic, reducing accidents and to provide new opportunities for the mobility of elderly or persons with reduced mobility capabilities.

The general research objectives within the cooperation are the advancement of the safety and security of automated driving as well as the public acceptance of automated vehicles. This includes joint research and further development of trustworthy and high-performance electronic components and systems enabling automated and autonomous functions, and a secure communication. Furthermore, user-friendly operation and integration in traffic through advanced

Human Machine Interface as well as the research of socio-economic impacts and user acceptance are among the main topics of interest.

The research cooperation is being implemented under the current research frameworks of the German Federal Ministry of Research and Education and the Japanese Cross-ministerial Strategic Innovation Promotion Program – automated driving for universal services (SIP-adus) of the Cabinet Office. Each bi-national project of the research cooperation has a national funding project and a working plan in place that details the cooperation activities, which may include joint workshops, the exchange of young researchers, jointly planned complementary experiments, joint publications and the like.

A Steering Committee is the decision-making body and forum for exchange and discussion on governmental level. Members are representatives from the Cabinet Office and Ministry of Economics, Trade and Industry and from SIP-adus as well as the German Federal Ministry of Education and Research and the Federal Ministry of Economic Affairs and Climate Action. Researchers, industry experts and government representatives started a regular dialogue on cooperation topics in 2017. The four bi-national funding projects that have been started in 2019/20 based on those discussions are now reaching their conclusions. This brochure provides a report on their objectives and results. It demonstrates the relevance of international cooperation that promotes the development of close and trusting relationships in research that enable an enhancement of quality of research and its results by providing possibilities for new ideas and insights.

Meeting of representatives of BMBF, CAO, METI, SIP-adus, NEDO

Virtual validation for safe intelligent driving systems

Motivation

Connected and automated driving (CAD) requires the highest level of safety for the vehicles and their driving functions. Technological pre-requisites involve a comprehensive environmental perception based on redundant sensor systems and reliable wireless communication with control centres or other vehicles and traffic participants. Safety assurance is of major concern for the development and eventual homologation of automated and connected cars. The German-Japanese research cooperation VIVID focusses on scenario-based safety assurance through virtual verification and validation. It also strives to strengthen the exchange of know-how by means of joint research and development at a pre-competitive level with the goal of attaining global harmonisation and standardisation.

Objectives and Approaches

VIVID addresses the key question: "How can the safety of connected and automated driving functions be tested, measured, and assured?" Virtual test environments and drive tests on proving grounds and public roads are developed for lidar, radar, and camera sensors. Within virtual test environments the software, hardware components or even the vehicle and its behaviour can be tested. The methods include sensor reference data as well as sensor and environmental models embedded into holistic simulation tool chains. The project investigates how close to reality such simulations in a virtual environment are, and to what extent they can represent the complexity of field-operational tests. The cooperation delivers added value through commonalities, e.g., through convergence between models and interfaces, and complementary options, e.g., by supplementing the model portfolios by means of different expertise and approaches. The binding link between both consortia are six joint topical task teams (JT) on toolchain, scenario/environment data, sensors (camera, lidar, radar), and validation & verification framework and metrics.

Innovations and Perspectives

Virtual methods enable multiple, efficient, and reproducible test capabilities along with real test drives to ensure the safety and quality of CAD. They

Virtual Validation

Acronym
CAD VIVID

Joint Project Duration
01.10.2020 until 31.03.2023

Partners in Germany
- Thuringian Center of Innovation in Mobility at Technical University Ilmenau
- ADC Automotive Distance Control Systems GmbH
- AVL Deutschland GmbH
- Blickfeld GmbH
- German Aerospace Center (DLR)
- IPG Automotive GmbH
- University of Applied Sciences Kempten
- Karlsruhe Institute of Technology
- Mercedes-Benz AG
- Technical University Darmstadt
- Fraunhofer AISEC

Partners in Japan
- Toyota Motor Corporation
- Honda Motor Co., Ltd.
- Nissan Motor Co., Ltd.
- Kanagawa Institute of Technology
- BIPROGY Inc.
- SOKEN, INC.
- Mitsubishi Precision Company
- SOLIZE Corp.
- Sony Semiconductor Solutions Corp.
- DENSO Corp.
- PIONEER Corp.
- Deloitte

Budget of German Project
EUR 4.67 million,
BMBF funding: EUR 3.68 million

Research in virtual test environment

Breakout workshop of VIVID project at SIP-adus Workshop 2022 in Kyoto

are expected to become the method-of-choice in upcoming safety standards.

Results and benefits of bi-national cooperation

The Japanese DIVP® and the German VIVALDI sister projects in the VIVID cooperation contribute to a harmonised virtual validation framework and global standardisation. Based on the DIVP® safety assurance strategy, each element along the simulation toolchain is based upon expert knowledge. As of today, it has already been possible to standardise camera perception interfaces. A joint format has been identified for scenarios and environmental models, including material properties, and radar model interfaces have been accepted for the OpenX standard family by ASAM (Association for Standardization of Automation and Measuring Systems).

Major achievements have become a reality thanks to intense cooperation in the framework of the six JTs mentioned above. Each JT collaborates and exchanges technical solutions via regular meetings. For instance, the toolchain established with the DIVP® environmental model could be successfully injected into the VIVALDI radar simulator. The re-processing of sensor data allows for a reconstruction, analysis, and future mitigation of adverse effects in a controlled and safe environment. In the JT on scenarios and environment data, selected sensing weakness scenarios including random lights, rain or fog, and backscattering were investigated successfully. Activities are in progress to examine common formats and structures for a smooth exchange of such scenarios. A common material database is under construction, in combination with a proposal for integrating OpenMaterial into the OpenX standard family. The three JTs sensor teams succeeded in exchanging mutual data between the DIVP® environmental model and the VIVALDI sensor models, ready for interface standardisation.

Especially with respect to cameras, the connectivity between DIVP® data, based on a physical model architecture converted to OSI (Open Systems Interconnection Model) format, and the VIVALDI platform, based on a behavioural model architecture, could be verified. With respect to radar sensor modelling, raytracing data of scenario-specific propagation models could be successfully exchanged between DIVP® and VIVID. Within the JT on validation and verification framework and metrics, a mutual understanding of the processes and methodologies involved, aiming at de-facto standardisation, has been reached. The next steps will focus on defining and disseminating a consistent automated driving safety assurance standard, that is, the VIVID standard. Further activities will address the critical issue of metrics for the validation of the underlying models and the entire simulation toolchain. Connecting to other major global R&D activities on safety assurance of CAD will eventually provide the maximum of benefit.

In spite of the COVID-19 pandemic, the vibrant VIVID cooperation included two international in-person conferences in 2022, namely the safe CAD-DJ symposium held in June in Berlin, and the SIP-adus conference and breakout workshop in Kyoto in October, each of which was attended by about 20 participants from each of the invited partner projects. The animated discussions of major regional activities in the United States of America, the European Union and Japan made the advanced status reached by the VIVID consortium quite apparent , setting the scene for global safety assurance activities. Upcoming research will address cross-domain, technology-agnostic and adaptable sensor models including 5G/6G connectivity and data fusion, seamless exchangeability between toolchains and between virtual and real worlds, and quality metrics for data-driven modelling, in order to enable the global community to benefit from safe, clean, and efficient mobility by means of connected and automated driving in daily experience.

Trustworthy and secure autonomous vehicles

Motivation

Autonomous Driving and the ongoing digitalisation of vehicles and mobility concepts are not possible without a substantial increase in communication between the autonomous cars and other mobility entities (e.g., other cars, traffic lights, roadside units or more). Hence, increasing connectivity and progress in autonomous driving poses tremendous challenges for cybersecurity. These issues cannot be addressed solely on a national level due to complexity in global supply chains where actors and stakeholders have different trust models, security mechanisms and levels of information. Exchange, harmonisation and joint research in this field are therefore extremely important for both Germany and Japan.

Objectives and Approaches

In the research project SAVE, technical and conceptual approaches to vehicle security for connected, automated vehicles are developed. Topics focus on 1) threat intelligence, 2) honeypots for vehicles, 3) platform and hardware security, and 4) security composition for complex automotive systems of systems. Through exchange between Japanese and German partners, the confidence in the developed systems and concepts shall be strengthened on an international level and outcomes shall be harmonized. This also strengthens the position of the industry partners involved in this project in standardisation efforts. Personal exchanges between academic and industrial researchers can identify potential for future collaborative approaches. Research results are discussed in frequent online and on-site workshops.

Innovations and Perspectives

Japanese partners in SAVE investigate how to monitor and analyse cyberattack vectors and develop honeypots that are specialised to automotive environments. Furthermore, they also conduct large scale studies on vehicular attack vectors and prevalence of vulnerabilities in the wild. German partners investigate security mechanisms like intrusion detection and prevention systems or hardware security mechanisms, as well as trust models that allow to quantify and reason with respect to trust relationships in complex automotive systems of systems.

Results and benefits of bi-national cooperation

Japanese partners investigated a design for a threat information sharing system for the automotive industries. Unlike IT systems, vehicles do not have a common architecture across OEMs, so there is a high probability that a certain threat for one vehicle may not be applicable to another. On the other hand, sharing analysed information will help identifying

Cybersecurity

Acronym
CAD SAVE

Joint Project Duration
01.11.2020 until 28.02.2023

Partners in Germany
- Infineon Technologies AG
- Ulm University
- DENSO AUTOMOTIVE Deutschland GmbH
- ESCRYPT GmbH Embedded Security
- Freie Universität Berlin
- Hochschule Karlsruhe – University of Applied Science
- Fraunhofer IEM
- Fraunhofer SIT
- Fraunhofer AISEC

Partners in Japan
- Toyota Motor Corporation
- Yokohama National University
- PwC Consulting
- NEDO

Budget of German Project
EUR 2.99 million
BMBF funding: EUR 2.23 million

threats that are commonly applicable for any vehicle. Japanese partners provided key features and method for the information sharing system, such as accumulation, utilisation, and collection.

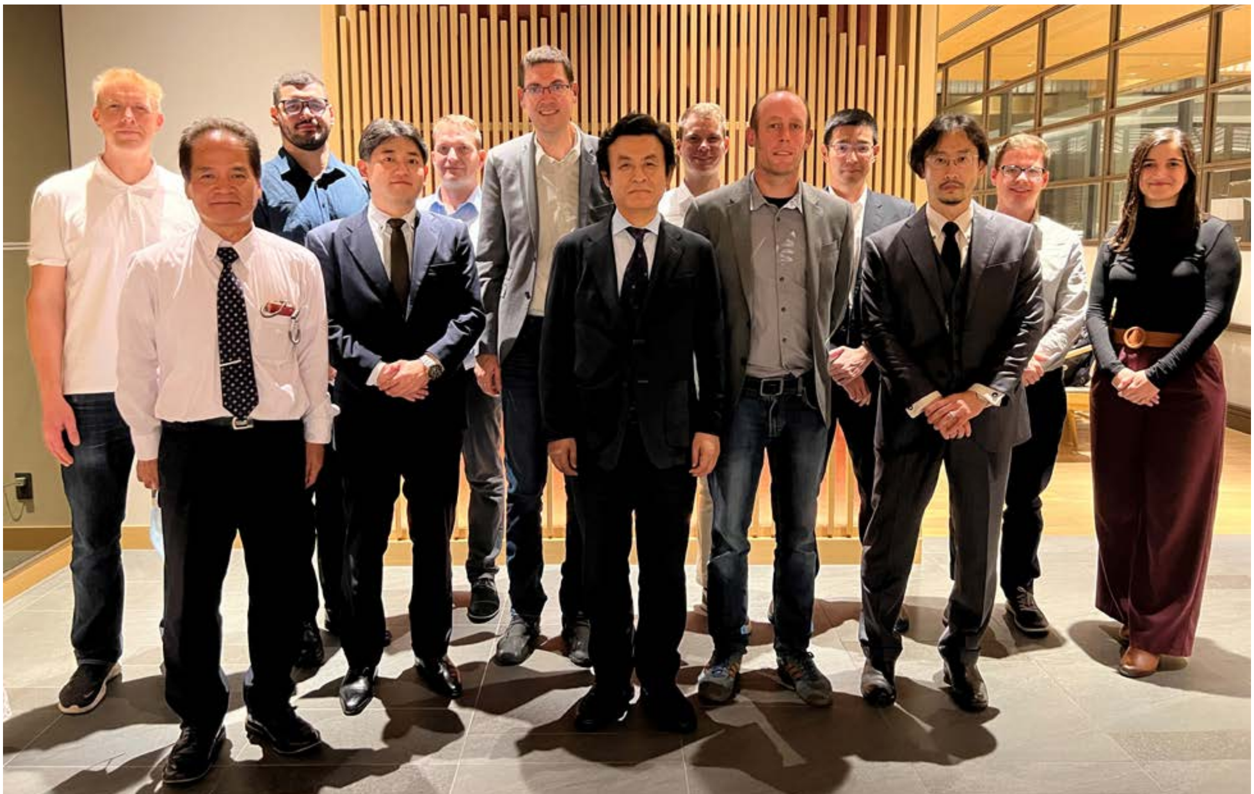
In addition, they demonstrated that proactive survey methodologies, honeypots and hacking contests, as e.g. Capture-the-Flag, to be good candidates for proactively collecting threat information in the automotive field. A vehicular honeypot was developed to monitor connected vehicles and devices. Methods for the developed vehicular honeypot can be applied for discovering potential targets by enabling an active search for devices and vehicles that have been accidentally exposed to the Internet. The sharing system could provide source information to an intrusion detection and prevention system, as investigated by German partners.

German partners designed an approach to develop trust models that reflect trust relationships in highly complex automotive systems-of-systems. The models are based on an advanced reasoning framework called Subjective Logic. They illustrated this approach on two use-cases, an in-vehicle architecture for a parking assist function and a cooperative intersection management. Currently, they are exploring how threat intelligence can be incorporated into these trust models to make them more accurate and more reactive when new attack vectors are discovered.

They also assessed the automotive attack surface and evaluated the feasibility of different Hardware Trust Anchors to design a novel secure Over-the-Air software update concept that is compliant to automotive standards and which uses a Trusted Platform Module 2.0 as Hardware Trust Anchor inside the vehicle. The Trusted Platform Module enforces system security policies and defends the concept against advanced cyberattacks. Currently, they are developing a proof-of-concept implementation for evaluation. SAVE participants of both countries are members of the Trusted Computing Group and will therefore introduce these results there, also.

Thanks to this collaborative effort, both sides are benefitting from direct insight into the work of the respective other country. For instance, Japanese and German partners are both working on different approaches for attack analysis and respective data collections that together provide a more holistic view on this topic. The project partners also envision that the trust models designed in SAVE can benefit from such threat intelligence gained in honeypots or through intrusion detection and prevention systems. In the remaining time of SAVE, it shall be explored how threat intelligence can be quantified through Subjective Logic and included into trust models. If successful, trust models could integrate many different parts of security and thus provide a holistic view on security of complex systems-of-systems.

Participants at workshop of SAVE project in Kyoto 2022



Naturalistic and safe interactions with autonomous cars

Motivation

Automated and connected driving is consistently being introduced to the market internationally. Thus, it is now necessary to develop innovative technologies that allow the operation of automated vehicles (AVs) beyond highway scenarios but also in less structured, complex mixed traffic involving other road users, i. e., non-automated vehicles, pedestrians, and cyclists in rural and urban areas. In order to facilitate and enable a holistic interaction concept, AVs must not only drive reliably, but must also communicate and cooperate with their drivers and other road users in a safe, efficient, and effective manner.

Objectives and Approaches

The objectives of this project are three-fold: First, innovative concepts of how AVs can interact and communicate with surrounding road users in complex mixed traffic situations are investigated and implemented. Second, the effect of drivers' training on how they interact with AVs is investigated. Third, different concepts for a safe and efficient interaction between driver and the automation in form of minimal risk manoeuvres and the transition of the driving task are evaluated. State of the art methods such as simulators for drivers, cyclists, and pedestrians or virtual reality, as well as regular collaboration between project partners, help ensure that the perspectives of all individuals using the road, both in rural and urban areas, are considered when it comes to the introduction of AVs.

Driving Simulator at University of Tsukuba: A person attends to a non-driving related task while driving autonomously on a highway

Innovations and Perspectives

By working in a Japanese-German research collaboration, the presumably high influence of intercultural differences regarding the topics addressed above is investigated and considered. Therefore, this project benefits from methodological standards, a common understanding of usage scenarios, intercultural comparisons, and the identification of invariances for potential standardisation.

Results and benefits of bi-national cooperation

Throughout the project and even during the COVID-19-pandemic, Japanese and German researchers were able to benefit from the bi-national cooperation.

Human Factors

Acronym
CAD HF

Joint Project Duration
01.09.2019 until 31.08.2022

Partners in Germany
- Technical University of Munich
- University of Technology Chemnitz
- TU Dresden
- University Ulm
- German Aerospace Center (DLR)

Partners in Japan
- National Institute of Advanced Industrial Science and Technology (AIST)
- University of Tsukuba
- Keio University
- Kumamoto University
- The University of Tokyo
- Tokyoto Business Service Co.

Budget of German Project
EUR 2.03 million
BMBF funding: EUR 2.35 million

Driving Simulator at Ulm University: A person is driving manually while encountering a bottle-neck scenario in an urban area.

Participants at final project workshop of CAD HF project in Tokyo 2022

An exchange of knowledge and cultural and methodological insights was ensured in the form of regular workshops, meetings, seminars, webinars, joint experiments, publications, and educational activities. Coordinated between researchers, a multitude of experiments in driving-, bicycle-, and pedestrian simulators, virtual reality, online, or in real-traffic were conducted. Based on this, concrete conclusions about the interaction between the AV and the driver as well as with surrounding road users can be formulated on an international level.

Results indicate that scenarios in urban traffic reveal a high level of complexity. That is, a single vulnerable road user behaves differently than a group of vulnerable road users and the communication between the AVs – explicitly and implicitly – needs to be designed accordingly. Furthermore, adding to the complexity of urban traffic, heterogeneous behavior in human road users and different behaviour towards AVs as opposed to conventional vehicles was observed. Concrete recommendations regarding the design of external human-machine interfaces , the AVs' trajectories, and German and Japanese urban infrastructure are derived. To do so, study results from all partners are discussed, allowing a well-founded and extensive input at norming committees aiming to adapt an international standard of interaction concepts for AVs.

Japanese and German partners investigated the effect of driver education and training for operating an automated vehicle of SAE level 1–3. In so doing, a variety of learning facets were taken into consideration, e.g., the time between training sessions, the effectiveness of testing the drivers' knowledge, and the medium of knowledge transfer. Results demonstrate that general education and training about the automation can positively influence the drivers' driving performance, knowledge about the automation, and their attitudes with respect to the AV. That being said, however, the training needs to be of adequate content, length, and medium as well as consider the drivers' experience with AVs.

The interaction between AV and driver during transition phases was investigated from multiple perspectives: AVs capable of minimal risk manoeuvres to automatically reach a safe state, transitions only partly shifting the control to the driver, and including a monitoring phase prior to an intervention request. The results provide an extensive insight into current safety challenges and show that drivers are still an important factor. Even with minimal risk maneuvers, the risk of an accident or dangerous situation can only be reduced under a variety of specific conditions, e.g., providing enough time, choosing a driver friendly strategy, and supporting driver decisions and actions via a human-machine interface. Furthermore, in situations where the AV needs the driver to complete a subtask, an adequate transition design can improve the time for task fulfilment while not negatively affecting the user experience with the subtask. Additionally, the monitoring phase prior to an intervention request and use of an accordingly designed human-machine interface improved the drivers' driving performance and observational behaviour.

Pedestrian Simulator at German Aerospace Center (DLR): Simulating urban traffic scenarios in virtual reality.

Societal impacts assessment of autonomous driving

Motivation

Automated driving has the potential to change various dimensions of vehicle transportation systems, ranging from car ownership decisions to new mobility services and how they induce changes in traffic flow, reduce the ecological footprint of mobility or advance transportation equity. The impact of the future application of Connected and Automated Driving (CAD) on public acceptance, on the transport system and on the environment depends upon a number of factors. These include the adaptation and diffusion of CAD vehicles and mobility services as well as changes in individual mobility behaviour and transport demand as a whole.

Objectives and Approaches

The research cooperation on Socio-economic Impact Assessment focusses on two research tasks: 1) exploring, describing and modelling the diffusion of CAD vehicles and mobility services, and 2) understanding the factors that influence the perception, adoption or rejection of a CAD system. These issues are particularly relevant in the Japanese-German context due to the economic importance of the automotive industry in both countries. In the German-Japanese research cooperation, the various perspectives on the concept of “social acceptance” of automated driving are investigated and discussed against the background of cultural communalities and differences. In addition, suitable modelling tools are developed in order to support the successful market introduction of automated vehicles beyond vehicle-related technical issues.

Innovations and Perspectives

A deeper understanding of the social acceptance and diffusion of automated driving can reduce innovation risks, will inform socio-economic impact assessments, and may also influence the course of technical and scientific progress in the field of automated driving.

Results and benefits of bi-national cooperation

The framework conditions of the two transport systems in Germany and Japan were comprehensively compared regarding history of the transport system, transport infrastructure today, travel costs, and further criteria. Thus, for instance, similarities regarding the importance of the automotive industry and differences as the regulatory frameworks or travel mode choice in the Japanese and German transport systems were investigated. This comparison set the groundwork for understanding the context underpinning the introduction of vehicle automation in the two countries.

Socio-economic Impact Assessment

Acronym
CADIA

Joint Project Duration
01.09.2019 until 31.12.2022

Partners in Germany
- German Aerospace Center (DLR)
- Karlsruhe Institute of Technology
- RWTH Aachen
- BMW

Partners in Japan
- The University of Tokyo
- Doshisha University
- Kagawa University
- Nagoya University
- Nanzan University
- University of Tsukuba
- Kyoto University
- Tokyo University of Science

Budget of German Project
EUR 0.93 million
BMBF-funding: EUR 0.88 million

Participants of a CADIA Workshop in Kyoto 2022

An analysis of governance approaches and state actions in terms of three aspects – politics, polity, and policies – contributed significantly to achieving a better understanding of the role and relevance of political institutions in the development of automated vehicles in both countries.

A business analysis and prognosis regarding the German autonomous ride-hailing market indicate that future customer price levels of shared autonomous vehicle services in Germany may be about 0.60–0.65 EUR/km (about 90 yen/km). This is significantly lower than current cost of use for ride-hailing services, but may not be low enough to convince a considerable number of passengers to switch from their private car to shared autonomous vehicle services.

The social acceptance of CAD was investigated both conceptually and empirically. On the conceptual side, a definition of social acceptance was developed that attempts to capture the complexity of social processes that influence the adoption and diffusion of CAD. Empirical work focussed on the analysis of joint surveys in Japan and Germany, which were conducted within the cooperation. These surveys suggest that individual expectations in both countries when it comes to CAD are largely similar, but also show differences when it comes to the details. It was found that the “power words” in transport policy towards CAD have some things in common, but also reveal differences in Japan and Germany. In both countries, improved safety and the support of societal goals are generally cited when it comes to the introduction of automated driving. However, in Japan, de-regulation is more important than de-carbonisation, which is a supporting argument in Germany.

Comparable models were used to investigate the diffusion of CAD in both countries in 2050. The effects of CAD on car ownership are marginal and depend on the path through which automation enters the transport system. Private automated vehicles are likely to marginally increase car ownership rates, and shared services will also only minimally reduce car ownership rates. The diffusion model results for surveys conducted in Germany demonstrated an anticipated share of private automated vehicles of 40 % to 45 % in the 2050 car inventory. Travel demand model results imply slight increases of vehicle kilometres travelled of about 5 %, which might lead to further congestion.

The main results and findings of the research cooperation will be presented in a jointly composed book that is expected to be published early 2023. This book represents the result of the close cooperation and collaboration between Germany and Japan. Researchers from both countries developed a deep understanding of the transport systems in the two countries and the potential impact of CAD on these systems. Thanks to close interaction by means of virtual and physical meetings, conferences, and workshops, a wide range of ideas, approaches, and results surrounding the conducted research were discussed intensively. Meetings in Berlin and Kyoto contributed significantly to a better understanding of the research, but also to cultural and personal exchanges.

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