interACT

Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

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Foreword

Ms. Anna Schieben
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05.2017 – 12.2019

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01.2020 - 09.2020

The interACT project worked on the safe integration of automated vehicles into mixed traffic environments by designing, implementing and evaluating solutions for safe, cooperative and expectation-conforming interaction of the Automated Vehicles with both its on-board user and other road users.

With a total budget of 5.5 million Euros funding by the European Commission, eight partners from four European Countries worked together from 2017 to 2020 and joined their expertise to contribute to the vision of designing a cooperative interaction of Automated Vehicles with other road users in mixed traffic environments.

It is our great pleasure to present you the final interACT project results of the different work packages in this brochure.

Enjoy reading.

Table of Contents

The interACT project vision, objectives and technical approach

Project vision and objectives:

Road traffic will never be fully automated – think, for example, of cyclists, pedestrians or other non-equipped vehicles. Understanding how to develop the right cooperation strategy between all road users, including Automated Vehicles, is of high priority, in order to ensure successful deployment and acceptance of such Automated Vehicles by all road users. Thus, the vision of the interACT project is to enable the **safe integration of Automated Vehicles into mixed traffic environments by designing, implementing and evaluating solutions for safe, cooperative and expectation-conforming interaction** of the Automated Vehicle with both its on-board user and other road users.

Project techical approach:

To achieve the vision of the interACT project, the following technical approach was followed:

- **Research on psychological models of interaction** between different road users in mixed traffic situations by observing human-human interaction in real traffic. These are meant to help to design and select appropriate and safe interaction strategies for Automated Vehicles and evaluate the interACT solutions.

- **Development of methods and sensor algorithms for assessing the intentions and predicting the future behavior** of other traffic participants. These are used to improve the situation prediction of the Automated Vehicles.

- **Development of a novel Cooperation and Communication Planning Unit.** This unit enables the integrated and time-synchronised planning of Automated Vehicle's behaviour and explicit HMI (on-board and external) and is the core intelligence of the Automated Vehicle.

- **Research on a safety layer and fail-safe trajectory planning** using formal verification methods to ensure safety in mixed traffic environments and reduce certification costs.

- **Develop an integrated HMI and eHMI** design for the interaction of the on-board user, the Automated vehicles, and other road users to develop expectation-conforming behaviour of the Automated Vehicles.

- **Establish an evaluation methodology for assessing cooperation** for studying interaction of road user with Automated Vehicles and user acceptance.

Overview on project results

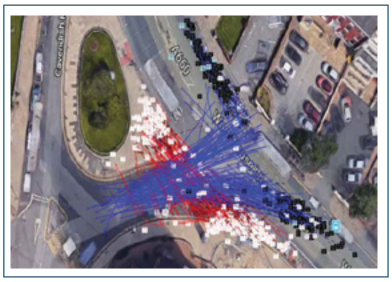
interACT objective

Achieve a safe, highly accepted and efficient integration of Automated Vehicles into mixed traffic environment

The results

Results - Evaluation methodologies

1. Evaluation criteria and methodologies derived for Automated vehicles **2.** interACT demonstrators evaluated in test-track studies, while eHMI/iHMI solutions were also evaluated using driving and pedestrian simulator **3.** Impact assessment carried out to understand the effects of the interACT solutions on safety, traffic flow, criticality, comfort, and acceptance



Results - Human interaction behaviour

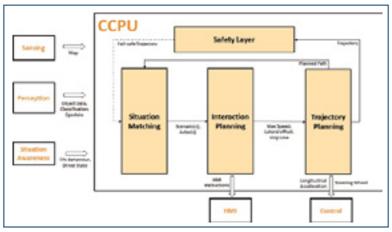
1. Definition of interaction terminology **2.** Several observation studies on human-human interaction in Greece, Germany and the UK **3.** Traffic participants tend to avoid conflicts; Interactions are more likely to occur when the vehicle is driving slowly; Pedestrians mostly focus on implicit vehicle cues rather than explicit communication

Results - HMI/eHMI

1. Two interaction strategies defined: intention-based & perception-based strategy for HMI/eHMI **2.** Two eHMI technologies developed and implemented: 360° Light Band & Directed Signal Lamp **3.** Two iHMI technologies: Light Band & Automation Display

Results - Intention recognition

1. Risk analysis framework for the prediction of traffic participants location **2.** Pedestrian intention prediction using the semantic map and behaviour models of other traffic participants **3.** Novel deep learning techniques, for classification of pedestrians' head orientation and hand waving gestures **4.** Hidden Markov model for vehicle maneuvers recognition and generation of intention-aware trajectory. **5.** Extended vehicle prediction trajectory via fusion of intention-based with typical motion-based



Results - Communication and Cooperation Planning Unit

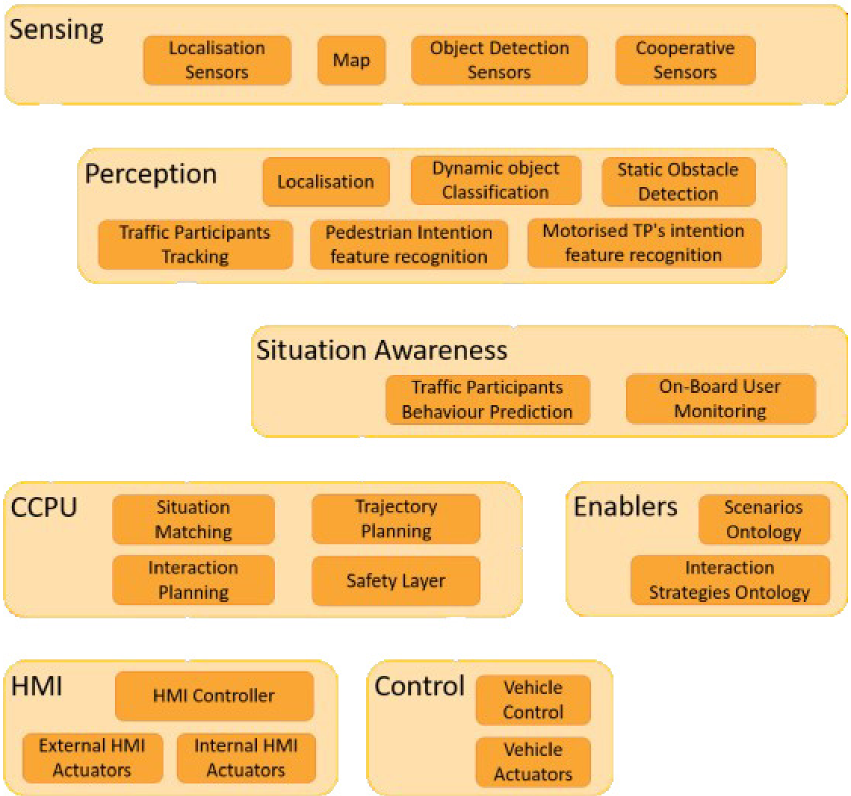
1. Recognition of traffic conflicts between Automated Vehicles and other traffic participants **2.** Implementation of reaction strategies according to the identified situation (future path constraints, candidate actors for HMI/eHMI interaction) **3.** Integration of internal and external HMI to enable human-like interaction **4.** Development of safety layer for emergency situations

interACT scenarios and system architecture

Objectives

In the beginning of the project, we focused on the selection of suitable use cases and scenarios for the interACT project. One essential task was to reduce the complexity of the traffic environment to a manageable number of relevant use cases and scenarios that an Automated Vehicle could be confronted with.

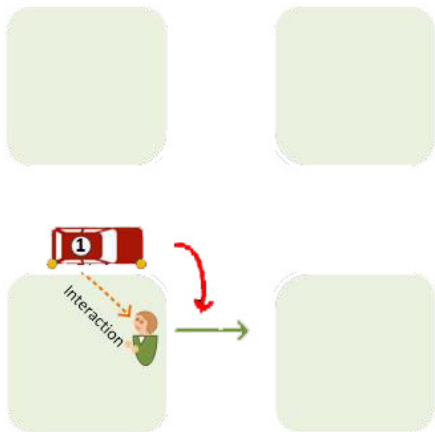
These use cases were used to extract the requirements that need to be satisfied by the interACT components and to propose the functional architecture to be used as basis for the development work. Technical and Human Factors requirements as well as legal, security, ethical and safety issues was taken into account. These actions resulted in the overall interACT system architecture and all interfaces between the software and hardware modules.



Technical approach

Regarding the use cases definition, we started with a common definition of relevant interACT use cases and scenarios among all industrial and academic consortium members. After that, use cases and scenarios have been selected using a step-wise process of intensive discussions within the consortium. Starting with some open brain-storming discussions the use cases were aggregated and rated by the partners against several criteria (such as relevance for safety, need for interaction behavior etc.) to agree on the most relevant ones.

Regarding the system architecture, requirements were collected and categorized by the consortium. As a next step, these categories were assigned to functional blocks. As a final step, the functional blocks were decomposed into components.



Main results

The consortium defined four "must-have" use cases that were of highest relevance. These use cases had to be covered by research and technical developments in all technical WPs and evaluated and demonstrated in the interACT demonstrator vehicles and simulators at the end of the project. These are the "must-have" use cases: **1)** React to crossing non-motorised traffic participants (TP) at crossings without traffic light, **2)** React to an ambiguous situation at an unsignalised intersection, **3)** React to non-motorised TP at a parking space, **4)** React to vehicles at a parking space.

A total of 101 requirements have been collected, categorised in General (9.9%), Operational (32.67%), Perception (22.77%), Human-Factor related (30.69%) and Actuation (3.96%) requirements. These five categories of requirements were then assigned seven functional blocks, namely Sensing, Perception, Situation Awareness, Communication and Cooperation Planning Unit, HMI, Control and Enablers. The functional blocks were decomposed into components which define the technical architecture of the interACT project.

Objectives

Understanding human-human interactions in current traffic is a first step to identify potential communication strategies for expectation-conforming encounters with automated vehicles. Our goal was to observe real traffic to identify potential factors influencing interactions, map the sequences of events and quantify the occurrence of events in interactions. Furthermore, we aimed to model observed interactions to quantify the effects of traffic encounters. To enable automated vehicles to correctly identify interaction demanding situations with pedestrians, we aimed to enhance path prediction algorithms and intention recognition capabilities.

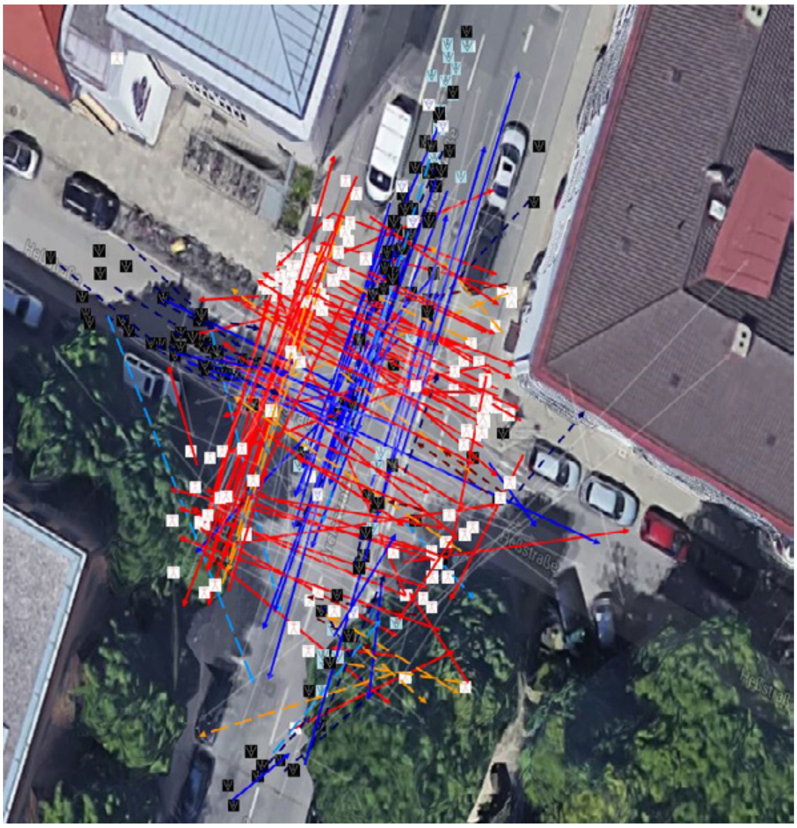


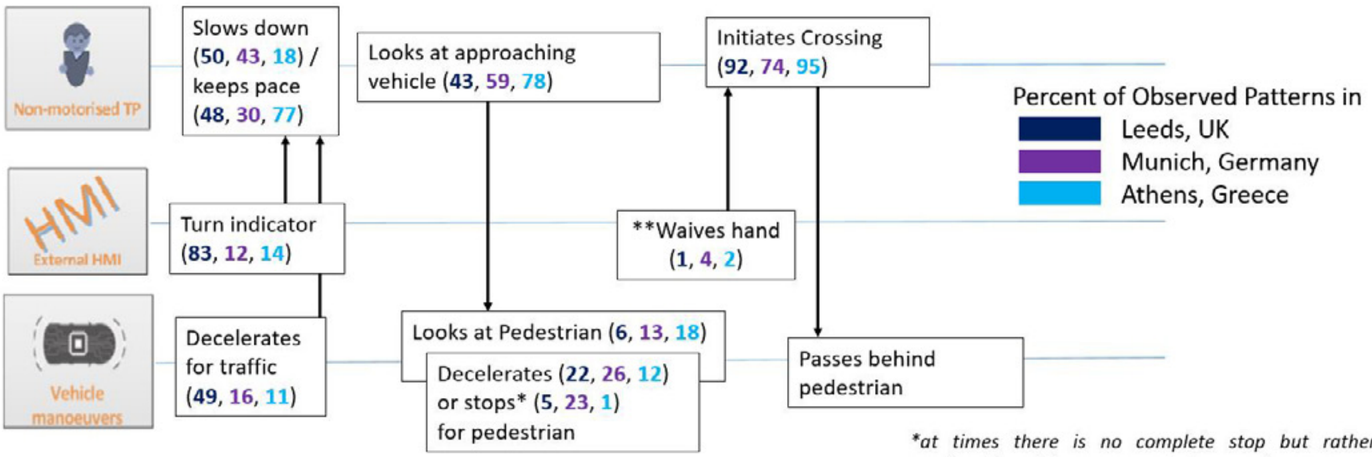
Figure 1: Manual observations from an intersection in Munich

Technical approach

An observation study was planned, designed and conducted in three countries: Athens (Greece), Leeds (UK) and Munich (Germany). To cover all of the four interACT scenarios, two locations per country –a busy intersection and a shared space scenario –were chosen as observation sites.

To generate a holistic view of human-human intersections, four different methods were used to generate data:

- Manual observations using an HTML app to sequence the order of events that happened in an observed interaction
- Questionnaires to gain insights on how pedestrians perceived a previous interaction
- High Altitude Video recordings to verify the observed sequences and extract positional information using computer vision algorithms
- A stationary ground LiDAR providing positional information of observed road users



*at times there is no complete stop but rather a continuation of the movement at a very slow pace

**in some cases there was no hand waiving and the scenario played out comparably

Figure 2: Sequence of events and rate of occurrence of observed traffic encounters in Leeds, Athens and Munich

Further simulator studies were conducted to provide insights into the perception and decision making processes, which the quantitative models are based on.

Main results

The observation was conducted over several months in the end of 2017 resulting in overall:

- 900+ observation protocols
- 150+ completed questionnaires
- 100+ hours of videos and
- 20+ hours of LiDAR Data

Overall, occurrence and necessity of interactions was found to be highly depending on the individual traffic situation. A variety of influences, such as traffic density, time of day and specific traffic conditions (e.g. a bus arriving) had a high effect on traffic and thus the occurrence of interactions. Explicit communication (in the form of gestures, flashing headlights etc.) was observed very rarely. Most potential interaction-demanding situations were resolved beforehand by adjusting kinematic motion. This was consistent with pedestrians reporting to mostly rely on implicit cues, such as vehicle velocity and position. Cooperation, communication and thus interaction between human road users took place at low speeds, usually in congested traffic situations below 20 km/h. At higher speeds conflict avoidance was predominant, with pedestrians or drivers waiting for large enough inter-vehicle gaps without expecting the following vehicle to adapt.

Variable-drift diffusion models and threshold distribution models were developed, enabling the calculation of probability distributions of pedestrian crossing times when encountering automated vehicles. Furthermore, a long-term behavior prediction algorithm was developed. One further topic was the detection of further features to improve the performance of interaction models and enable an interaction between automated vehicles and pedestrians. Therefore, a head orientation estimation as well as a waving gesture recognition was developed.

Read more

Dietrich, A., Bengler, K., Evangelia, P., Nathanael, D., Ruenz, J., Wu, J. et al. "interACT D.2.1 Preliminary description of psychological models on human-human interaction in traffic." (2018)

Dietrich, A., Bengler, K., Markkula, G., Giles, O., Lee, Y. M., Pekkanen J., Madigan, R. & Merat, N. "interACT D.2.2 Final description of psychological models on human-human and human-automation interaction". (2019)

References

G. Markkula, R. Madigan, D. Nathanael, E. Portouli, Y. M. Lee, A. Dietrich, J. Billington, A. Schieben & N. Merat (2020) Defining interactions: a conceptual framework for understanding interactive behavior in human and automated road traffic, Theoretical Issues in Ergonomics Science

https://doi.org/10.1080/1463922X.2020.1736686

Lee, Y.M., Madigan, R., Giles, O., Garach-Morcillo, L., Markkula, G., Fox, C., Camara, F., Rothmueller, M., Vendelbo-Larsen, S.A., Rasmussen, P.H., Dietrich, A., Nathanael, D., Portouli, V., Schieben, A., & Merat, N. (2020) Road users rarely use explicit communication techniques when interacting in today's traffic: Implication for Automated Vehicles. Cognition, Technology and Work, 1-14

DOI: 10.1007/s10111-020-00635-y

Uttley, J., Lee, Y.M., Madigan, R., & Merat, N. (2020) Investigating Road user interactions in a shared space setting: understanding what means of communication are needed for future automated vehicles. Transportation Research Part F, 72, 32-46.

https://doi. org/10.1016/j.trf.2020.05.004

Intention recognition and behavior prediction of other traffic participants

Objectives

Interacting with other traffic participants in urban environments is an elaborated task of the AV that requires holistic planning and timely communication. To that end, predicting their motion (i.e. recognizing pedestrian crossing intention and vehicles' next maneuver), is not only important for safety in assisted and automated driving, but also beneficial for natural and smooth maneuvers and interaction of Automated Vehicles. This often requires a long prediction horizon, e.g., more than 3 seconds. In the interACT project one objective was to improve the prediction capability of the Automated Vehicle.

Technical approach

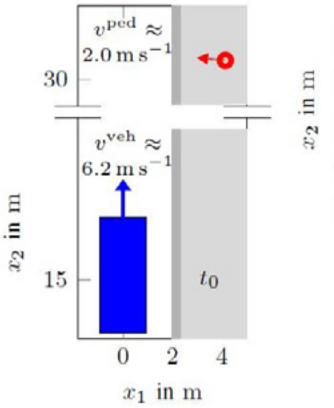
• Controlled Markov chains [1] were used to predict where the pedestrian will be and when, as well as the corresponding probabilities—a probabilistic spatiotemporal result.
• Pedestrians' intentions were estimated by incorporating the probability of colliding with other traffic participants (dynamic environments), their current dynamics, and topographic features of environments (semantic map).
• Model calibration was performed using recordings of real pedestrians [2] and considering different objective functions during optimization [1].
• In addition, for further improvement of the pedestrian intention recognition the head orientation as well as hand waving gestures of pedestrians were recognized through deep neural networks.
• Hidden Markov model was employed for probabilistic recognition of vehicle's maneuvers and generation of intention-aware map-conforming trajectory.
• Fusion of vehicle's intention-based trajectory with typical motion-based (short-term) trajectory to extend the prediction time horizon.

Main results

• Pedestrian Intention Recognition

Ability to perform frame-level action predictions, based on input video data, was demonstrated. Results have shown that as the pedestrian gets closer to road, the performance of our approach is further improved. Moreover, the abovementioned methods yielded more detailed probabilistic spatiotemporal predictions (see Figure 2).

Figure 3. A typical scene where a pedestrian intends to cross



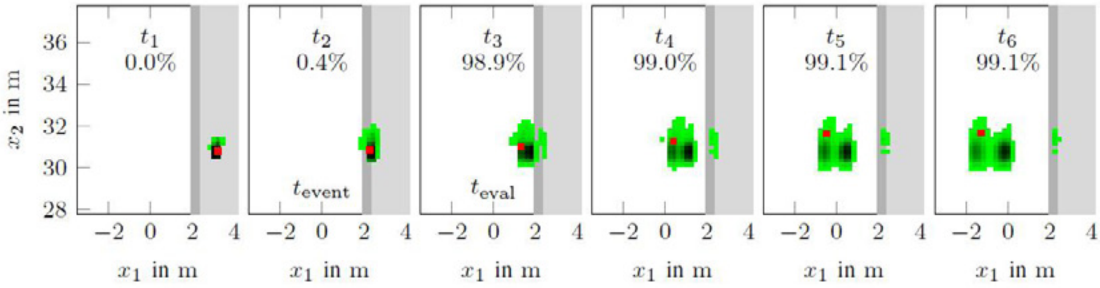


Figure 4. Probabilistic spatiotemporal prediction results (green cells are predicted future positions of the pedestrian, darker color means higher probability) for 6 time steps (up to 3 seconds). The ground truth position is denoted by red points

The suggested algorithms were incorporated into the interACT system enabling early and accurate detection of non-motorized traffic participants. System readiness, reaction and user-experience as a whole were extensively tested using real pedestrian-related scenarios, as part of WP6.

- **Vehicle Intention Recognition**

Simulation results demonstrated that the HMM enhanced trajectory prediction approach is able to predict driver intention to turn at least 3 seconds before the intersection entry, comparing favorably with the SoA. This enables a vehicle trajectory prediction considerably over 5 seconds as we can successfully use the map in the longer range while its accuracy in the short term is maintained by the kinematics-based trajectory fusion.

Integration in CRF demonstrator vehicle enabled to fine-tune model parameters using realistic scenarios, towards coordination between the Situation Awareness (intention-related) platform and the CCPU (decision and planning components).

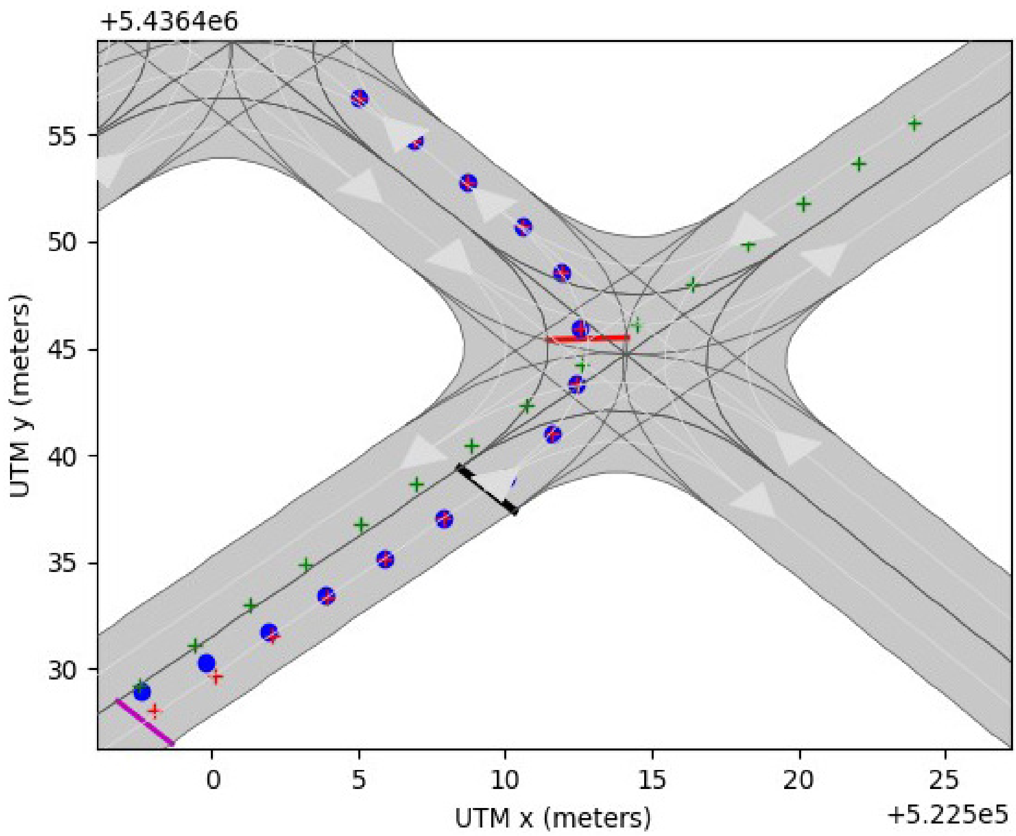


Figure 5. Simulation example: Vehicle trajectory prediction (blue) versus map-based trajectory (red) versus motion-model trajectory (green) in 4-leg intersection

References

[1] J. Wu, J. Ruenz and M. Althoff, "Calibration of Controlled Markov Chains for Predicting Pedestrian Crossing Behavior Using Multi-objective Genetic Algorithms," 2019 IEEE Intelligent Transportation Systems Conference (ITSC), Auckland, New Zealand, 2019, pp. 1032-1038

[2] J. F. P. Kooij, N. Schneider, F. Flohr, and D. M. Gavrila, "Contextbased pedestrian path prediction," in European Conference on Computer Vision. Springer, 2014, pp. 618–633.

Read more

Ruenz, J., Wu, J., Zhang, J., Cao, Y., Schürmann, B., Althoff, M., Drainakis, G., Portouli, E. "interACT D2.3 Sensors and algorithms incorporating the developed models to be integrated into the demonstrator" (2019)

Planning the automation behavior – the Cooperation and Communication Unit

Objectives

The Cooperation and Communication Unit (CCPU) is the AV intelligent core: taking into account the kinematics, the gestures and the anticipated behavior of all traffic participants (TPs), the CCPU develops an expectation-conforming, safe plan for the future motion of the AV. Goal of the CCPU is a behavior proposal for the AV, consisting of the decision to give or take way, resulting in the generation of stop lines in front of the vehicle, the minimal and maximal velocity and the decision about the information that should be communicated to surrounding traffic participants via the eHMI.

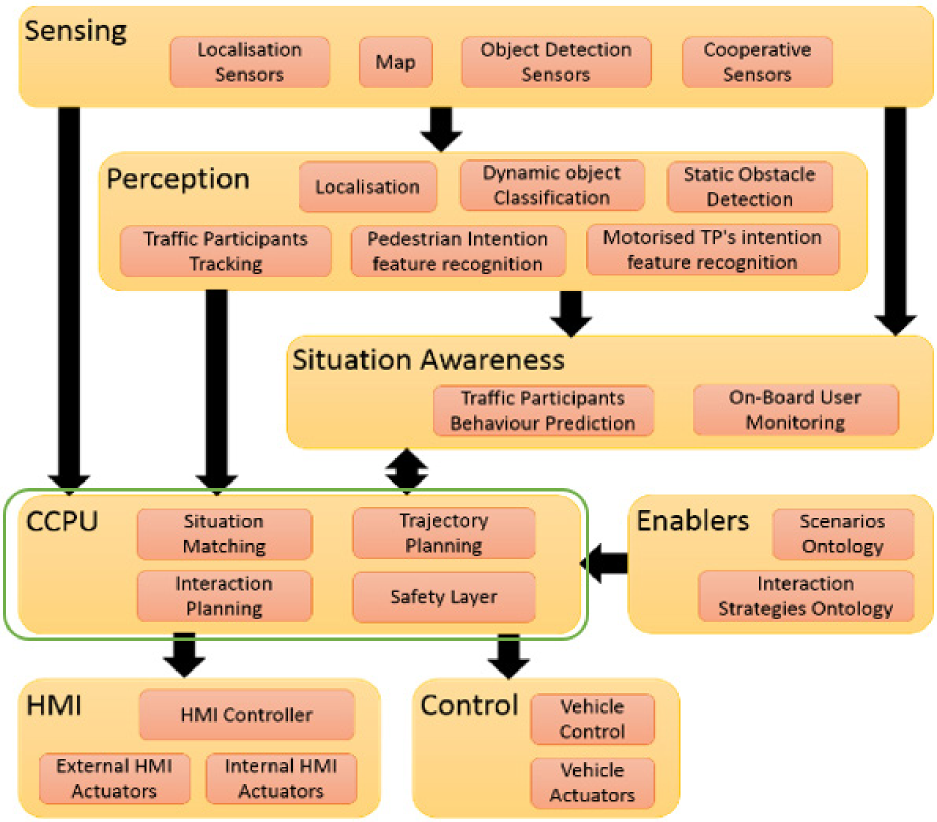


Figure 6. interACT system architecture and CCPU position in it.

Technical approach

A modular approach to software design was followed, where CCPU's core components were compartmentalized using virtualization. The main development included: rule-based traffic conflict identification incl. deadlock situation and non-collision courses, fuzzy rule-based AV desision making (stop line, speed constrains), long-term path planning using determenistic models, short-term trajectory planning using Model predictive control strategy and fail-safe trajectory calculation, based on motion prediction models. Supplementary, common messaging scheme (ROS) and map representation (CommonRoad) were employed, while enablers for digital scenarios (using Horn clause logic) and accompyning strategies (reactions to traffic scenarios) were built to support the core modules.

CCPU underwent technical evaluation both in a per-component basis and as an end-to-end system:

- Using simulated data (functional tests).
- With recorded datasets from the test track areas at BOSCH (Abstatt) and CRF (Orbassano).
- Deployment in the CRF prototype vehicle to evaluate interACT use-cases in protected environment (CRF Safety Centre, Orbassano).

Main results

CCPU results included:

• **Design of digital scenarios,** based on actors' kinematics and recognized pedestrian gestures creation featuring 25 traffic scenarios in 13 topologies.

• **Scenario Recognition and Interaction Planning in real-time** based on topology, AV ego state, situation awareness (intentions of other TPs).

✓Instructions for implicit and explicit communication with other TPs, according to the AV interaction strategy defined by the project (D4.2)

•AV **Trajectory Planning** & actuators handling (controlllers)

✓Low-speed (up to 15 km/hour) autonomous driving in a predefined path, including turns.

•Planning of **evasive trajectory** to minimize risk of collision with other TP if required **(Safety Layer)**

✓Automatic generation of critical scenarios for testing

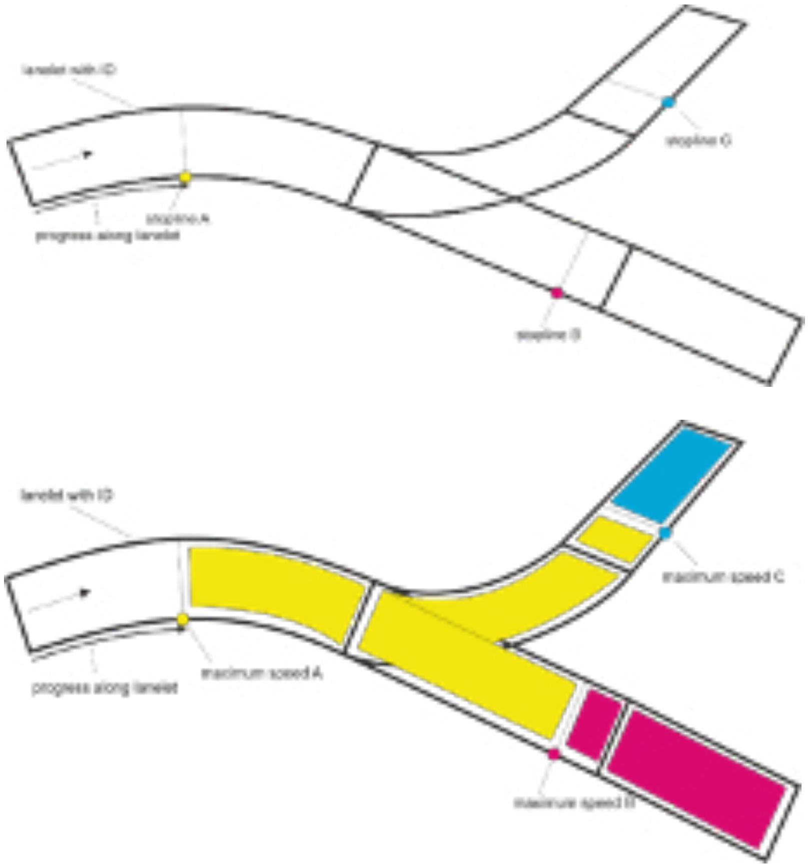


Figure 7. CCPU in action - generating constraints.

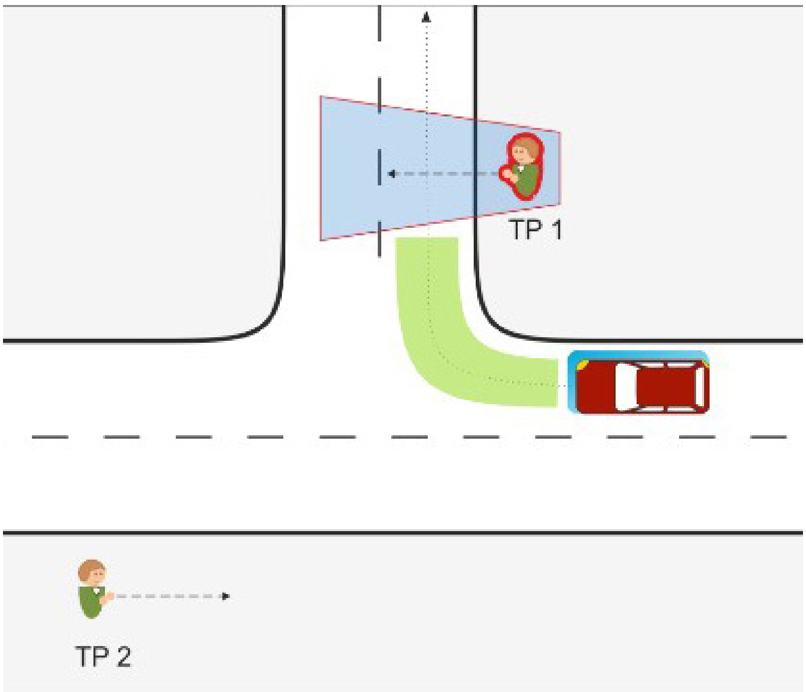


Figure 8. TP1 is identified as actor by the Situation Matching (SM), then the Interaction Planner generates AV speed constrains based on the currently planned trajectory and SM output, denoted in green.

Read more

Drakoulis, R., Drainakis, G., Portouli, E., Althoff, M., Magdici, S., Tango, F., Markowski, R. "interACT D3.1 Cooperation and Communication Planning Unit Concept" (2018)

Markowski, R., Lapoehn, S., Bolovinou, A., Drainakis, G., Drakoulis, R., Althoff, M., Klischat, M., Tango, F., Borello, G. "interACT D3.2 Cooperation and Communication Planning Unit prototype and accompanying report" (2019)

Weber F., Sorokin L., Schmidt E., Schieben A., Wilbrink M., Kettwich C., Dodiya J., Oehl M., Kaup M., Willrodt J., Lee Y., Madigan R., Markkula G., Romano R., Merat N. "interACT D4.2 Final interaction strategies for the interACT Automated Vehicles" (2019)

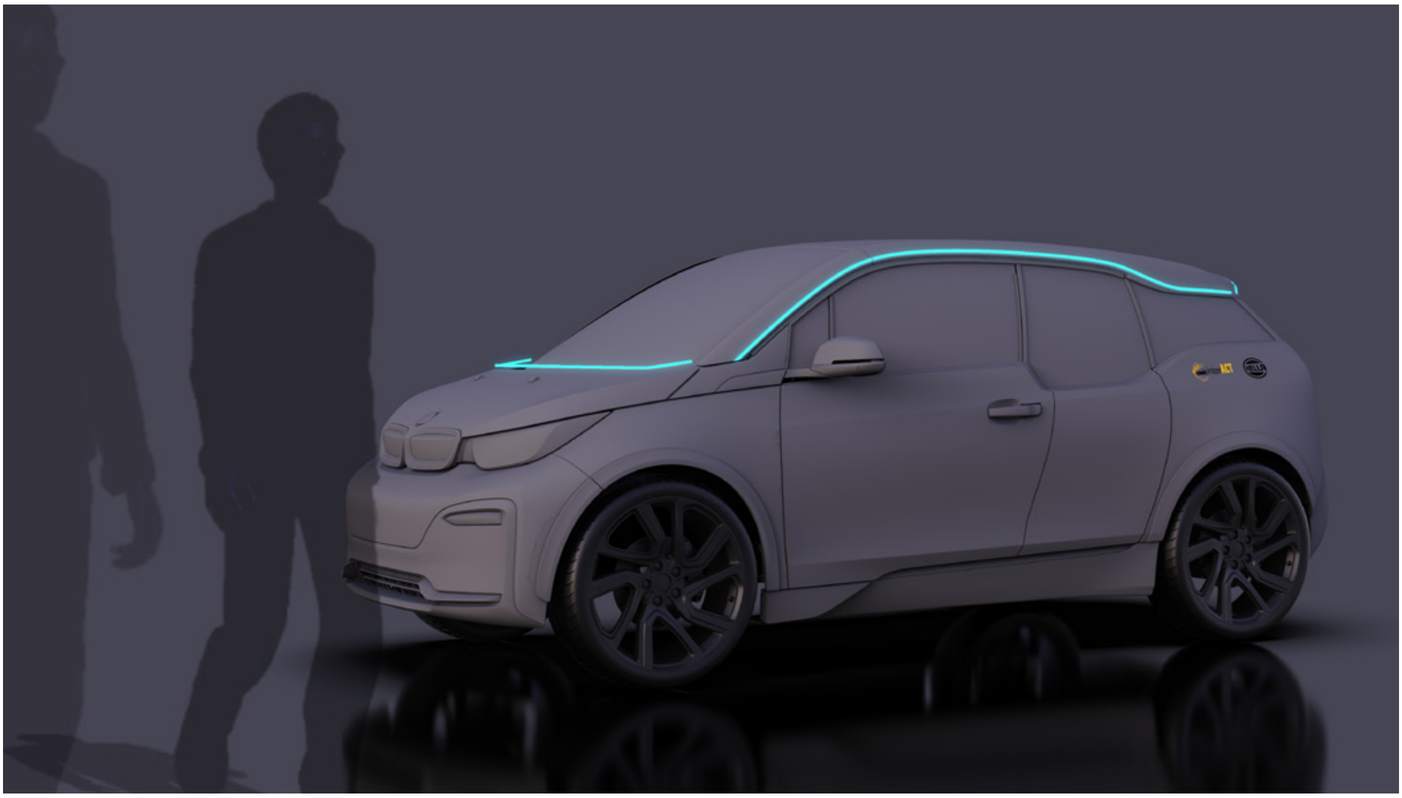


Figure 9. eHMI_1 = 360° Light Band

Objectives

To ensure clear, learnable and cooperative interaction between the Automated Vehicle and other traffic participants, as well as a smooth flow of all traffic, it is essential that there is good means of communication between all actors. Main objective was to substantially improve this communication and cooperation of the Automated Vehicle with its on-board user and surrounding traffic participants.

Technical Approach

In an interative design process we identified two important interaction strategies –the intention-based and the perception-based strategy and designed related messages. After the analysis of different interaction channels the visual channel was chosen as most promising one. interACT's HMI-development focused on technical components for visual transfer of messages, i.e. the technical implementation of new light-based exterior compo-

nents for the AV (eHMI) and on-board interfaces (iHMI). In several simulator and Virtual Reality studies with users we tested and refined the interaction strategies and the message design for the final implementation in the demonstrator vehicles.

Main results

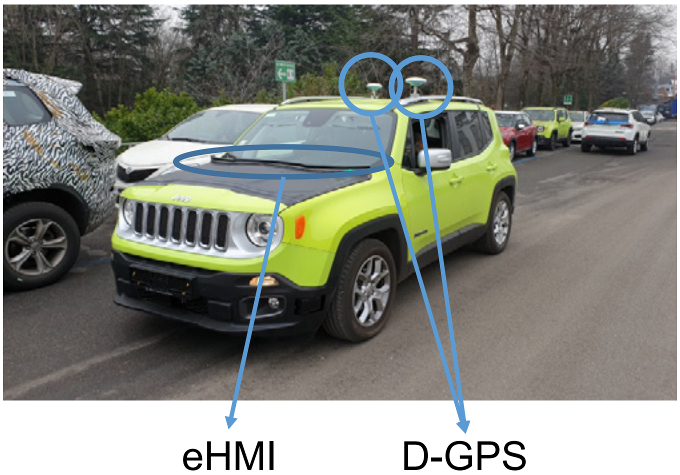
Final outputs are the interaction design strategies, the message design and the prototypes, which provide a visual communication system around the whole vehicle for communication with other traffic participants. In detail: Two eHMI technologies were selected, developed, implemented and integrated – a 360° LED Light Band and a so-called Directed Signal Lamp.

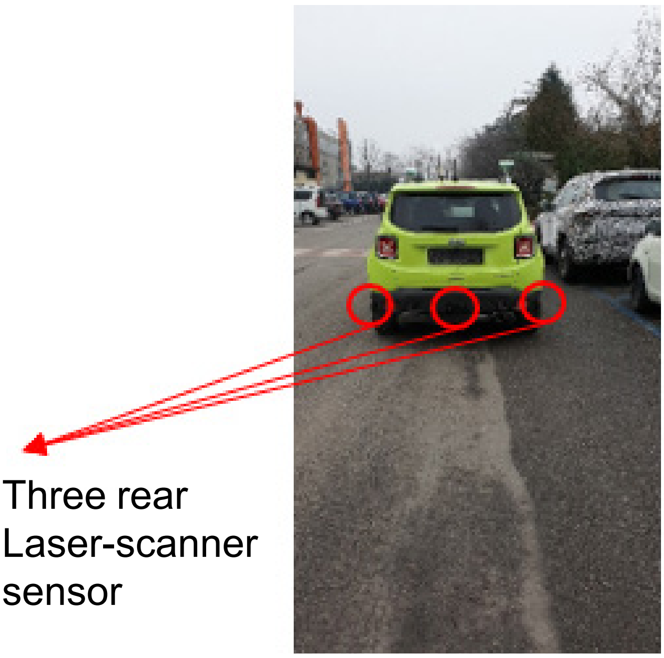
These devices put the project into a position to implement an intention-based or perception-based interaction strategy or a combination of both. In accordance with overall interaction strategies, two iHMI technologies were selected for the interACT project as well. The communication with the on-board user was established via a 360° Light Band and an Automation Display.

Read more

D Drakoulis, R., Drainakis, G., Portouli, E., Althoff, M., Magdici, S., Tango, F., Markowski, R. "interACT D3.1 Cooperation and Communication Planning Unit Concept" (2018)
Markowski, R., Lapoehn, S., Bolovinou, A., Drainakis, G., Drakoulis, R., Althoff, M., Klischat, M., Tango, F., Borello, G. "interACT D3.2 Cooperation and Communication Planning Unit prototype and accompanying report" (2019)
Weber F., Sorokin L., Schmidt E., Schieben A., Wilbrink M., Kettwich C., Dodiya J., Oehl M., Kaup M., Willrodt J., Lee Y., Madigan R., Markkula G., Romano R., Merat N. "interACT D4.2 Final interaction strategies for the interACT Automated Vehicles" (2019)

Vehicle overview





Objectives

After the development of the perception algorithms, the eHMI and iHMI modules, as well as the CCPU, we worked on the implementation and integration of all these components in two demonstrator vehicles by CRF and BMW, each focusing on different scenarios and use cases.

Technical Approach

The main activity was the integration of all components in the two demonstrator cars, including the technical testing and the validation of the sub-components, modules and then of the whole system, in order to verify that the functionality was according to the requirements defined at the beginning of the project. The preparation of these vehicles has been carried out through several integration workshops among the involved partners of interACT.

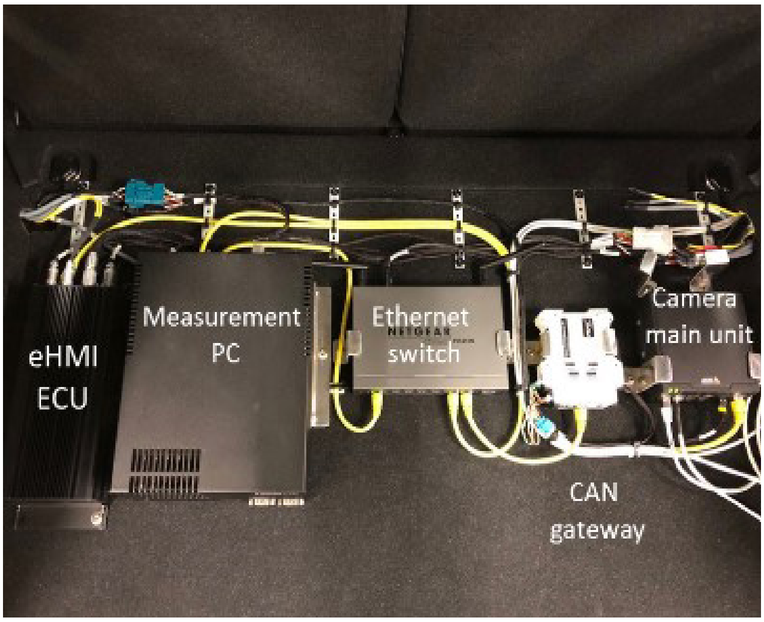
Main results

The main results are the two interACT vehicles, prepared

eHMI solution

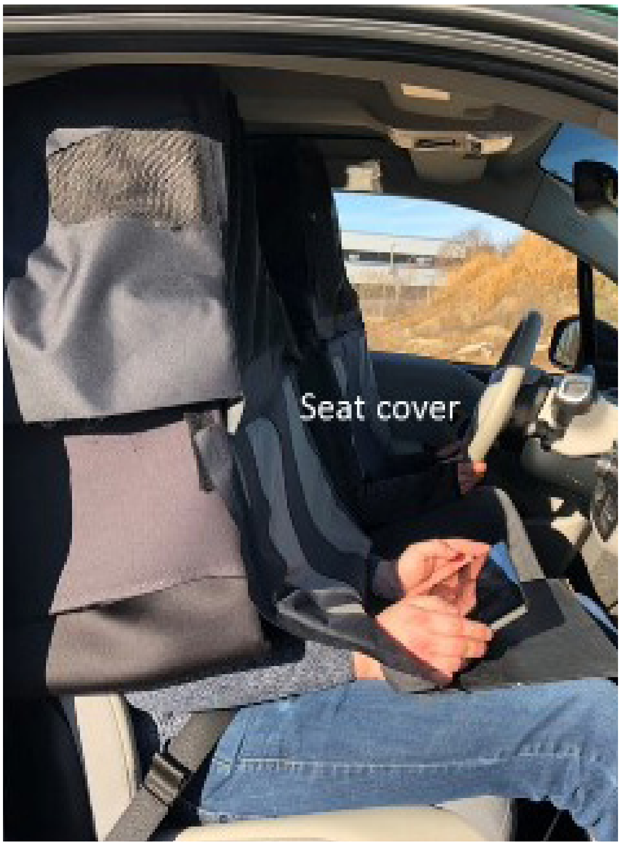
CCPU and PPU

and implemented by CRF and BMW. The following figures show the installation for the CRF vehicle. This automated vehicle is equipped with the full release of the Perception Platform Unit (PPU), as developed by BOSCH, the basic version of the external HMI (eHMI), as designed by HELLA, and finally the full version of the Cooperation and Communication Platform Unit (CCPU), as developed by the partners of WP3 in interACT project. The CRF vehicle is



focused on the parking scenario, in particular taking into account pedestrians and other vehicles (not autonomous) interacting with the Automated Vehicle (the CRF car). For these use-cases, where the CRF car is able to move autonomously, the PP include several sensors: 6 Laser-scanners, DGPS and advanced digital maps, front cameras.

The following figures show the installation for the BMW vehicle. This vehicle is equipped with sensors and a fully working Cooperation and Communication Planning Unit (CCPU) as well as with HMI components that allows the vehicle to be driven automatically and to react to interaction demanding situations . The BMW demonstrator will be



driven manually. Therefore, the prototype is equipped with a seat cover to hide the driver of the car and to simulate an autonomous driving vehicle. Furthermore, a DGPS System is installed to get time synchronized information about the exact position of the vehicle and further vehicle parameters such as velocity and acceleration. Two cameras enable the monitoring of the surrounding and the interaction behavior of other traffic participants during the evaluation studies. The information of all components were transferred to an installed PC to log all vehicle and interaction data as well as video data for detailed analysis of the interaction patterns in the evaluation studies.

Objectives

The main objectives of WP6 were to define appropriate methodologies for the evaluation of AV interaction strategies, and to apply these methodologies to assess the impacts of the interACT communication solutions, in particular the eHMI and iHMI developed in WP4, and the safety layer developed in WP3.

Technical Approach

A multi-method approach was taken for this evaluation, as different methods have been shown to have different strengths and weaknesses. The demonstrator vehicles were evaluated using a mixture of test-track and real-world studies. These were complemented with pedestrian and driving simulator tests which allowed the evaluation of the eHMI and iHMI using a number of different scenarios. Threshold distribution models were used to test predictions about when the road user would start crossing the road in an accepted traffic gap, and what the impact of eHMI and deceleration would be on this timing. Finally, threat assessment models were used to evaluate the success of the interACT safety layer.

Main results

• Mathematical models show that the incorporation of the interACT safety layer means that the AV never causes an accident, no matter how other road users are moving. The fail-safe manoeuvres ensure the availability of safe actions, even in situations where vulnerable road users behave unexpectedly.

✓Based on this, we expect that the safety layer will also increase the comfort and trust of humans in AVs.

• The simulator and test-track studies show that when there is no eHMI present, participants are able to use kinematic information to make judgements about AV behaviour. There were no differences in crossing reaction times between no eHMI and eHMI conditions in the CRF test-track study, and mixed findings in the BMW real-world evaluation.

• However, results from the simulator studies also show that eHMIs could lead to changes in pedestrian crossing behaviour, including earlier crossings, shorter interaction times, and improved traffic flow.

• The visiblity of eHMI solutions, and their ability to relay consistent and reliable messages, are important design considerations to ensure positive user evaluations and road user safety.

• The inclusion of failure trials in both pedestrian and driving simulator studies show that the consequences of eHMI failure or miscommunication can be severe, and therefore public guidance around eHMI capability will be required. More studies around the potential negative effects of eHMIs should be conducted.

• A comparison of the results emerging using different methodologies suggests that simulator studies seem to be capturing more effects of eHMI than test-track or real-world studies. This may be linked to the visibility of the eHMI, and is something which should be further investigated in future studies.

Figure 11: (a) HIKER Pedestrian Simulator, University of Leeds; (b) CRF Test Track; (c) BMW Test Track

Increasing road safety

We evaluated the interACT solutions by using computer simulation to consider all possible manoeuvres currently conducted on the road by traffic participants to assess the safety of the interACT solutions for ensuring collision avoidance. We also investigated the perceived safety of surrounding road users, while they interacted with our AV, which incorporated eHMI, designed to communicate the intentions of the AV. Results suggest that both the presence of an eHMI and slightly exaggerated yielding decelerations may improve the subjective experience of AV safety for pedestrians. The interACT safety layer uses formal methods proving that the vehicle never causes an accident, no matter how vulnerable road users are moving. This has been realized by a set-based prediction of surrounding traffic participants and the generation of fail-safe maneuvers of the automated system. These fail-safe maneuvers ensure the availability of safe actions even if vulnerable road users behave unexpectedly.

Increasing user-acceptance and ease-of use of Automated Vehicles

The project considered road-based, human-human interactions, user requirements and expectations throughout the whole design process. We assessed the final interACT solutions, comparing them to Automated Vehicles without additional communication cues, considering the needs of both on-board users, and other traffic participants, especially Vulnerable Road Users. Based on the evaluation results, the eHMI solutions developed in interACT, and tested in a range of settings, were positively evaluated by participants, suggesting that the inclusion of eHMI could lead to increased acceptance of, and higher satisfaction for, AV interactions. The visibility of eHMI solutions, and their ability to relay consistent and reliable information, are important considerations in this context, to ensure both positive user evaluations and road user safety.

Improving validation procedures for Automated Vehicles

The interACT partners worked on a range of methodologies to test and assess cooperation strategies, and investigate safe interactions between an Automated Vehicle, the on-board user, and other road users, in order to help improve the validation procedures for Automated Vehicles. Further, the project provides novel, on-the-fly techniques for manoeuvre and trajectory planning, that reduce the need for exhaustive testing all possible road scenarios. In order to demonstrate that our on-the-fly techniques for manoeuvre and trajectory planning work, we have created several hundred realistic test scenarios.

This database is online available at https://commonroad.in.tum.de/. We have also used this database in a student competition, in which we received more than 20.000 submissions. Educating students about safe vehicle automation is believed to be another major contribution of interACT.

A detailed review of appropriate methodologies suggests that a combination of data collection techniques was required, and thus the project made use of pedestrian simulator, driving simulator, test-track, and real-world, wizard-of-oz studies. The studies also developed a number of new methods and measures, to capture crossing times and durations (see D6.2). Quantitative models of human-AV interactions at pedestrian crossings and vehicle intersections were used to develop simulations of the traffic flow efficiency impacts of the interACT solutions. These models can be used to capture the quality of the interactions between AVs and humans.

Raising awareness for the integration of Automated Vehicles in mixed traffic environments

During the project run time, interACT evaluated, demonstrated and disseminated its project results in two demonstrator vehicles, several research simulators and many dissemination events and conferences to raise awareness of the interACT solutions that were developed to allow the safe, cooperative and intuitive integration of Automated Vehicles in mixed traffic environments.

Supporting the leadership position of the European vehicle industry

The interACT project enables its industrial partners to fully exploit project findings, increasing the potential safety benefits, sales, and adoption of Automated Vehicles. With leading manufacturers such as BMW, BOSCH, CRF, and HELLA on board, the project ensures that results are integrated at a fast pace, allowing Europe to remain at the forefront of this type of research. For several technical developments the TRL level was increased in the three years of the interACT project. E.g. a new light component, the directed signal lamp, was developed as prototype and installed at the BMW demonstrator vehicle for the first time in the project and with this an important step on the product development path was made (TRL 2- TRL 6). Further, the Cooperation and Communication Planning Unit (CCPU) was developed from TRL level 2 to 5.

consortium

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

BOSCH
Invented for life

Technical University of Munich

UNIVERSITY OF LEEDS

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