Ko-HAF – Cooperative highly automated driving

Contents of the project and focus of research

Status: May 2017
Motivation:
Mobility challenge

- People injured and killed in individual mobility: **Reduction of the number of accidents**
- Economic losses due to traffic obstructions on German roads: **Increased efficiency**

In the future the average age of the population will increase: **Maintaining mobility**

Automation of driving functions is an answer to many issues of future mobility
Motivation
Motivation

- Mobility changes
- Automation of driving functions becomes a key technology
- Two directions of development can be expected
  - **Revolutionary** development approaches for autonomous driving
  - **Evolutionary** development on the basis of today’s partly automated driving functions
Project aim

Ko-HAF aims at the **highly automated driving of the second generation**, i.e.
- aversion from the task of driving
- at speeds of **up to 130 km/h**
- availability in extraordinary situations and in complex highway scenarios
- with a pleasant, anticipating way of driving
- and a further **increase of safety and traffic efficiency**
Challenges for high automation

German Law

Road Transport Law
- Section 1 of the German StVG

Liability Law
- Product Liability
- Drivers Liability (§18 StVG)
- Owners Liability (§7 StVG)

International Law

Vienna Convention on Road Traffic 1968
- Article 8 (5)
- Article 13 (1)

Uniform Provision for Type Approval of Vehicles
- ECE R 79 (Steering)
Challenges for high automation

- **Sensor technology and environment modelling**
  - It suddenly becomes necessary that the driver takes over (e.g. road marking ends, very complex course of the road at construction sites, ...)
  - At 130 km/h and a 10 seconds advance warning, a situation at a distance of over 350 m must be perceived in order to warn the driver that he will have to take over.
  - On-board environment sensors that will be available in the foreseeable future do not provide this capacity!!

- **Development of highly automated functions**
Challenges for high automation

Validating and securing

Accidents caused by conventional driving

Accidents by new automation risks

Proportion of accidents that can be avoided by automation

Challenges for high automation

Validating and securing

- How do we test highly automated driving?
- Securing expenses increase with increasing system complexity. Automated vehicles are very complex!
- How do we get a representative overview of possible hazardous situations (field tests, extended accident analyses)?
- How do we test technologies at their limits?
Challenges for high automation

Human
- What is the driver’s role?
- Integration and Validation of non driving related activities
- Concept and design of transitions
## Underlying data

<table>
<thead>
<tr>
<th>Project duration</th>
<th>Date</th>
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<tbody>
<tr>
<td>Specification and concept phase</td>
<td>05/2016</td>
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<tr>
<td>Development / implementation of the interaction</td>
<td>05/2017</td>
</tr>
<tr>
<td>the interaction between the safety server (back-end)</td>
<td></td>
</tr>
<tr>
<td>and the vehicle (front-end)</td>
<td>05/2017</td>
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<tr>
<td>Implementation of the Ko-HAF function for normal</td>
<td>02/2018</td>
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<td>and emergency operation</td>
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<tr>
<td>Trial phase</td>
<td>11/2018</td>
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<tr>
<td>Overall volume</td>
<td>36.3M€</td>
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<tr>
<td>Funds from the German Ministry for Economic Affairs</td>
<td>16.9M€</td>
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<tr>
<td>and Energy (BMWi)</td>
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# Project partners

<table>
<thead>
<tr>
<th>OEM</th>
<th>Suppliers</th>
<th>Small and medium-sized companies</th>
<th>Public institutions</th>
<th>Research organisations</th>
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<tr>
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<td><img src="image" alt="3D Mapping logo" /></td>
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</table>
Project structure

AP1 Detection & representation of the environment in the safety server

AP2 Localisation and static environment model

AP3 Cooperative driving and controllable automation

AP4 Function development for normal and emergency operation

AP5 Securing and trial testing

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AP1 – Objective

- Increase of the anticipation exceeding the range of sensors existing today by collective perception
- The prototypical back-end service “Safety Server” combines the heterogenous landscape of the test cars.
- Cars and external data sources provide more up-to-date data than ever before
- Precise maps thus become up-to-date maps
AP1 – Collective perception

Function development for normal and emergency operation relies on data from the safety server

Safety server as an additional sensor for localisation and static environment model

API1 Communication box

Layered map (partner-specific)

Alignment

Elements of the environment model

Layered map

Input memory for car data

Aggregation

Layered map

Parser

Open Drive

Reference map

3DM Capturing car

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Ko-HAF test cars

Ko-HAF - Cooperative highly automated driving
AP1 – Interim results: Test area defined, surveyed and Map created

Test track around Frankfurt

Reference Map XML / OpenDrive

Map elements

Map visualization created with QGIS: http://qgis.org/
AP1 – Interim results

- Specification of an exchange system independent from maps for a high-resolution geometry made
- Adequate message formats for transmission is available
- Specification of the data format in the server is available
- Implementation of the basic software in basic version available
- First test runs done and data processed in specified format
- First results of aggregators are available
- AP1 communication box built into vehicles and basic functionality implemented
AP2 – Objective

- Transmission of environment data to a central back-end
- High-precision localisation with a robust availability
- Fusion of the sensor-based environment model with back-end data
AP2 – Architecture

2.1 Interface
map data / server
adaptation software

Cross-AP and independent from partner-specific map formats
AP2 – Architecture

- **Plausibility check** of the back-end data with the vehicle sensor data
- **Geo-referencing** of the environment features and the back-end in case of deviations

Car-local perception

- 2.1 Interface map data / server adaptation software
- 2.2 Autodiagnosis and integrity measure of localisation
- 2.3 Map evaluation new features
- 2.3 Fusion of static environment model

Back-end data + Sensor data = Fused environment model
AP2 – Architecture

- Support of the localisation through geo-referenced landmarks from the back-end
- Geo-referencing of the extracted environment features
- Autodiagnosis and integrity measure of the localisation
AP2 – Interim results

- **Data exchange**
  - **First data exchange between front end (AP2) and back end (AP1) has taken place**

- **Localisation**
  - **First round of referencing landmarks took place**
  - **First landmark-based localization has taken place**

- **Fusion**
  - **First fusion of digital card data and sensory perception has taken place**

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**Timeline: Erste Version Eigenlokalisation**
- 1.1.2017 - 5.17.2017
- 5.18.2017 - 2.28.2018

**Timeline: Erste Version Fusion**
- 1.1.2017 - 5.17.2017
- 5.18.2017 - 2.28.2018

**Timeline: Erste Version Up- und Download**
- 1.1.2017 - 5.17.2017
- 5.18.2017 - 2.28.2018

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- **Jan**, **Mrz**, **Mai**, **Heute**
AP3 – Objective

- Specifications of the test scenarios and aspects of the man-machine interaction
- Modelling the driver availability and vigilance
- Investigation of automation effects
- Transition concepts optimised for HAD
- Recommendations for methods and interaction concepts
AP3 – Central questions

- What is the driver’s role?
- For how long can the driver attend to non driving related activities?
- How long does it take until the driver can take over the driving in case of a sudden disturbance?
- The heterogeneity of the transitions is increasing – Does the system remain operable?

Ironies of automation

“Automated systems still are man-machine systems, for which both technical and human factors are important.”
(Bainbridge, 1983)

“... the irony that the more advanced a control system is, so the more crucial may be the contribution of the human operator.”
AP3 – Interim results

- Test scenarios, metrics and requirements for take-over concept defined
- Studies to non driving related activities and tired drivers largely completed (10+ simulator and real vehicle studies)
- Modeling of driver availability is currently the focus
AP4 – Objective

- Environment modelling and situation analysis
- Development of **highly automated driving functions**
- Anticipatory reaction to **danger points**
- Transition into a **minimal risk state**
AP4 – Function development

- Developing and testing HAD functions for normal operation

<table>
<thead>
<tr>
<th>Functions</th>
<th>Project partners</th>
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<tbody>
<tr>
<td>Exit automation</td>
<td>✔</td>
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<tr>
<td>Highway intersections</td>
<td>✔</td>
</tr>
<tr>
<td>Highway access and merging</td>
<td>✔</td>
</tr>
<tr>
<td>Roadworks</td>
<td>✔</td>
</tr>
<tr>
<td>Adjustable driving behaviour</td>
<td>✔</td>
</tr>
</tbody>
</table>

- Interim results:
  - A catalogue of scenarios defined
  - Vehicle setup and function development started
AP4 – Danger points

- **Tactical / immediate approach** → safety manoeuver
  - Braking
  - Steering
- **Strategic reaction** on the basis of server data → anticipatory manoeuver
  - Reducing speed
  - Changing lanes
  - Increasing distance
  - Informing the driver
AP4 – Vehicle setup and safe operation

- Conversion of **serial cars to HAD cars**
- Concepts for measures for attaining the **risk-minimal state** in your own car
  - What is a risk-minimal state?
  - How do I attain the risk-minimal state?
- **Cooperative measures** on the basis of server data
  - Notifying other vehicles of a take-over command
- **Safety concept** for test operation on public roads
  - Emergency off in case of malfunctions
  - Overriding of the system by the driver
AP5 – Objective

- Test methods for testing automated driving functions
- Setup of virtual trial test environment (HW/SW)
- Setup of test tools for reality trials
- Trial testing new highly automated driving functions
AP5 – Procedure

- Test process and specification
- Methods for generating safety statements

Interface between the virtual and the real test

Virtual tests and trials

Joint trial testing in a secluded test area

Joint trial testing in a public test area

Setup test equipment and facilities in test area
AP5 – Interim results

- **Initial catalogue of scenarios and tests completed**
- **Initial testing methods developed**
  - Approach: minimization of driving tests in public environment
  - Strategy: combination of virtual and real testing
  - Goal: High level of automation by XiL
- **Requirements for the test track and test devices defined**
- **The preparation of a public test field completed**

<table>
<thead>
<tr>
<th>#</th>
<th>Scenario</th>
<th>Skizze</th>
<th>Beschreibung</th>
<th>Ausgangssituation</th>
<th>Endsituation</th>
<th>Szene/Elemente</th>
<th>Ausgangssituation</th>
<th>Endsituation</th>
</tr>
</thead>
</table>
Conclusion / Expected innovations

- **Collective perception** by means of a communication among the vehicles and the safety server (back-end) → extended perception of the environment
- **Collection of data** in the vehicle including auto-localisation and interaction with the safety server
- **Gapless transition** between normal operation and active safety functions and between different automation levels
- **Transfer into the safe state** (emergency operation), e.g. in case of a driver blackout (no reaction to the take-over command)
- **Experimental joint trial testing** of the HAD functions on highways in mixed public traffic
- **Development of test and evaluation methods** for highly automated systems
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Thank you very much for your attention!

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