Database of relevant traffic scenarios for highly automated vehicles

Autonomous Vehicle Test & Development Symposium 2017

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## Goals and Work Contents of the PEGASUS Project

### Key Figures

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 Months Duration</td>
<td>January 1(^{st}), 2016 – June 30(^{th}), 2019</td>
</tr>
<tr>
<td>17 Partners</td>
<td>- OEM: Audi, BMW, Daimler, Opel, Volkswagen</td>
</tr>
<tr>
<td></td>
<td>- Tier 1: Automotive Distance Control, Bosch, Continental Teves</td>
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<tr>
<td></td>
<td>- Test Lab: TÜV SÜD</td>
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<td></td>
<td>- SME: fka, iMAR, IPG, QTronic, TraceTronic, VIRES</td>
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<tr>
<td></td>
<td>- Scientific institutes: DLR, TU Darmstadt</td>
</tr>
<tr>
<td>12 Subcontracts</td>
<td>- i.a. IFR, ika, OFFIS</td>
</tr>
<tr>
<td>Project Volume</td>
<td>- approx. 34.5 Mio. EUR</td>
</tr>
<tr>
<td></td>
<td>- Funding: 16.3 Mio. EUR</td>
</tr>
<tr>
<td>Personnel Deployment</td>
<td>- approx. 1,791 man-month or 149 man-years</td>
</tr>
</tbody>
</table>
## Current State of Development of HAD

### Prototypes
- Multitude of prototypes built by OEM with HAD-functionality
- Evidence, that HAD is technologically possible
- Partially tested in real traffic situations
- Test drives involve backup safety driver at all times

### Lab / Testing Ground
- Individual analyses to optimize prototypes
- Current test stands/ testing grounds do not provide enough test coverage for all HAD features currently in focus
- There is no procedure for adequate testing (particularly performance) of HAD-systems

### Products
- No release or introduction of variety of HAD features without sufficient assurance
Goals and Work Contents of the PEGASUS Project

Central Issues of the Project

What level of performance is expected of an automated vehicle? How can we verify that it achieves the desired performance consistently?

- Scenario Analysis & Quality Measures
  - What human capacity does the application require?
  - What about technical capacity?
  - Is it sufficiently accepted?
  - Which criteria and measures can be deducted from it?

- Implementation Process
  - Which tools, methods and processes are necessary?

- Testing
  - How can completeness of relevant test runs be ensured?
  - What do the criteria and measures for these test runs look like?
  - What can be tested in labs or in simulation? What must be tested on test grounds, what must be tested on the road?

- Reflection of Results & Embedding
  - Is the concept sustainable?
  - How does the process of embedding work?
### State of the Art

#### Currently available Methods and Tools

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Methods</th>
<th>DRIVER</th>
<th>VEHICLE</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field Operational Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controlled Field</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Dynamic Driving Simulator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **REAL**
  - Increase of Validity
  - Increase of Costs
- **VIRTUAL**

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State of the Art – Problem Definition

Challenges on Validation Methodology for HAD

- **No accepted evaluation framework** for ADAS is available balancing effectiveness, controllability and acceptance (<Level 3)

- **No evaluation methodology** available for **automated driving** (≥Level 3)

- **Safety impact** of automated driving is difficult to determine, no measurements possible

- Often **user related issues** are the limit of automated functions (e.g. take over, mixed mode)

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**Approach**

- **Database** of Relevant Traffic Scenarios
State of the Art

Circuit of relevant Scenarios

Database of Relevant Traffic Scenarios

Motivation

Extractions

E1

E2

generation of new constellations

criteria

critical test situations

critical real-world situations

R1

R2

R3

R4

R5

severity

Recording of situations & criteria

Real Traffic

Field Operational Tests

Test Track

Component Development

Hardware in-the-loop

Software in-the-loop

Dynamic Driving Simulator

Traffic Simulation

System Concept

Idea

Recording into the DB

Extracting from the DB

Test levels

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Relevance
“Which scenarios are relevant?”
- Differentiation between human behaviour leading to a critical situation (e.g. low distance to preceding vehicle) and critical scenarios due to traffic constellation (e.g. unstable behaviour of other vehicles)
- Consideration of exposure frequency (FOT, NDS) and potential accident severity
- Possibility to use expert knowledge for test case generation

Reference
“What is the reference for the capability of automated driving functions? How good is good enough?”
- Evaluation of human capability in a scenario. „How large is the amount of driver population, who can avoid an accident?” (accident data, driving simulator, traffic data)
### Data Sources - Examples

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Situation Description</th>
<th>Situation Relevance</th>
<th>Situation Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Traffic Data (NDS)</td>
<td>Complete (depending on sensor setup)</td>
<td>Frequency of scenarios</td>
<td>Examples for positive human performance</td>
</tr>
<tr>
<td>Field Operational Test</td>
<td>Complete (depending on sensor setup)</td>
<td>Frequency of scenarios (not representative)</td>
<td>Examples for positive human performance</td>
</tr>
<tr>
<td>FOT Data on ADAS</td>
<td>Complete (depending on sensor setup)</td>
<td>Indicator for frequency of scenarios with HAD</td>
<td>Examples for positive human performance</td>
</tr>
<tr>
<td>FOT/NDS Situations</td>
<td>Parameter combinations</td>
<td>None</td>
<td>Identification of positive human performance</td>
</tr>
<tr>
<td>Accident Data</td>
<td>Accident scenarios, but limited descript. (# of accident. participants)</td>
<td>Indicator for frequency of accident scenarios</td>
<td>Some examples for negative human performance</td>
</tr>
<tr>
<td>Proving Ground (Test Track)</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Driving Simulator Data</td>
<td>Parameter combinations (descript. limited to sim. quality)</td>
<td>None</td>
<td>Identification of human performance</td>
</tr>
<tr>
<td>Simulation</td>
<td>None</td>
<td>None</td>
<td>Identification of physical boundaries of situations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Identification of theoretical human performance</td>
</tr>
</tbody>
</table>
Bewertung der Hochautomatisierten Fahrfunktion (inkl. Mensch)

Testfälle

Test-Spezifikation

Automationsrisiken

Informationsquelle

Auswertung

konkrete Szenarien

Aggregation

Testfahrten

Testauswertung

Testdefinition

Test Cases

(Specific Scenarios)

OpenSCENARIO +Z

Selection using metric $M_{E/S/C}$

Test Specifications

OpenSCENARIO +X +Y

X: Parameter space

Y: Information on exposure and pass/fail-criteria on logical scenarios

Z: Relevant information for test performance (selection test environment etc.)

Measurement Data Scenarios

Scenario affiliation using metric $M_{Affiliation}$

Logical Szenarios

OpenSCENARIO +X

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Data Base Concept

Data Base + Data Process Chain

Data processing chain

Requirement definition and selection criteria

Use Case Definition
- Definition of functional scope of HAD
- Definition of scenario filter

Coverage of scenario information

Coverage of scenario information

Generation of common environment and traffic description
- Harmonization of signal names
- Transformation in common data format

Generation of deduced signal
- Format checks
- Indexing
- Formatting of information
- Assignment of access rights

Calculation of scenario affiliation
- Calculation of affiliation metrics to a specific scenario over time
- Usage of explicit rules and machine learning
- Extraction of scenario snippets

Scenario searching and clustering
- Scenario clustering
- Combined scenarios with frequencies
- User specific retrace on single scenarios

Test specification deduction
- Add information on Exposure for sections of the parameter space
- Add Pass/Fail criteria

Measurement Data Scenarios

Post processing of individual scenarios
- e.g. for individual case assessment, function development, etc.

Test Specifications

Exposed + Pass/Fail

Test Specification deduction

Data processing chain

External Data

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Database Concept

Technical Implementation - User Interface

The database for the validation of Advanced Driver Assistance Systems and Highly Automated Vehicles
Test and evaluation of highly automated vehicles requires new methods and tools for an efficient safety approval process.

Safety approval cannot be achieved for highly automated vehicles with available methods and tools within a limited time and budget. Therefore a new method is proposed: the circuit of relevant scenarios.

Today’s available methods and tools can be integrated in a circuit of relevant scenarios for safety approval and therefore increase the effectiveness of the new approach.

The central element of the circuit of relevant scenarios is a data base and an according data base processing toolchain, which is currently created in the research project PEGASUS.

The toolchain must be capable to include and use different data sources and therefore heterogenic data and data quality.

The proposed data base concept can realise an efficient and effective data processing in a common framework with a common tool chain.
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