Functional Testing of Automated Driving on Highways

Methodology and Test-Case Identification on the way towards approval

Holger Znamiec, TU Braunschweig – Institute of Automotive Engineering
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Highly automated Driving on highways, min. SAE-Level 3
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Highly automated Driving on highways, min. SAE-Level 3

addresses multidimensional environmental parameterspace

- Definition of relevant parameters
- Identification of representative parameter specifications
- Requirements on Test Process (Test Environments, Execution, Efficiency,...)

Qualification of the System in representative Test-Cases
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highly automated Driving on highways, min. SAE-Level 3
addresses multidimensional environmental parameterspace

- Definition of relevant parameters
- Identification of representative parameter specifications
- Requirements on Test Process (Test Environments, Execution, Efficiency,...)

Qualification of the System in representative Test-Cases
Basic Approaches

Qualification of the System in representative Test-Cases

I.) Scenario-Based Testing

II.) Black-Box-Testing

HAD[1] system

simulation

reality

test-case

behavior

[1]
Overall Methodology

Scenario Development

- HAD-System
- Use-Cases
- Base-Scenarios
- Generic Parameters

Test-Case Identification

- Information Base
- Specific Parameters
- Maneuvers
- Test-Cases

Test Procedure

- Test Specification
- Test Distribution and Execution
- Assessment and Evaluation
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- TEST SPECIFICATION
- TEST DISTRIBUTION AND EXECUTION
- ASSESSMENT AND EVALUATION

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Terminology

**USE-CASE**
Verbal description of one defined area of use of the function.

**BASE-SCENARIO**
Objective description of a use-case. Each Scenario is described by a set of generic parameters.

**MANEUVER**
In each scenario may exist different maneuvers. Constellations of traffic.

**TEST-CASE**
Concrete specific definition of the environmental behavior. Contains set of specific parameters.

- **APPROACHING AND MERGING.**
- **DRIVEWAY WITH TRAFFIC.**
- **FOLLOW-UP, CUT-INS OF OBJECT VEHICLES.**
- **LONGITUDINAL DISTANCES, VELOCITIES, LENGTHS...**
Scenario Description

<table>
<thead>
<tr>
<th>Base-Scenarios</th>
<th>Scenery elements</th>
<th>maneuvers</th>
<th>dynamic parameters</th>
<th>static parameters</th>
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<tr>
<td>driveway</td>
<td>ramps</td>
<td></td>
<td>traffic:</td>
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<td>driving lanes</td>
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<td>constructions</td>
<td>merging lanes</td>
<td></td>
<td>m</td>
<td></td>
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<td>Hazard. zones</td>
<td>...</td>
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Test-Case Identification

- Developed process for the specification of representative
- Test-cases towards approval of HAD-systems
- Extract the relevant specifications from different information bases
Test-Case Identification

INFORMATION BASE

ANALYSIS
Stat. and Dyn. Parameters, Maneuvers

RATING
Distributions, relevant characteristics

TEST-CASES

analysis of test-field

ENVIRONMENT INFORMATION BASE

analysis of real driving behavior

guidelines
Test-Case Identification

**Information Base**

**Analysis**

Stat. and Dyn. Parameters, Maneuvers

**Rating**

Distributions, relevant characteristics

**Test-Cases**

**Frequency** (2133)

**Length of acceleration lanes**

<table>
<thead>
<tr>
<th>Length in m</th>
<th>Frequency</th>
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<td>0-100</td>
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<td>100-200</td>
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<td>200-300</td>
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</tbody>
</table>
Test-Case Identification

**Information Base**

**Analysis**
Stat. and Dyn. Parameters, Maneuvers

**Rating**
Distributions, relevant characteristics

**Test-Cases**

---

**Distance in follow-ups on Target Lane in Driveway Scenarios**

- Median: ~30 m

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Test-Case Identification

**INFORMATION BASE**

Stat. and Dyn. Parameters, Maneuvers

**ANALYSIS**

**RATING**

Distributions,

**TEST-CASES**

Analysis of all function-relevant environmental parameters

Test-Case Catalog

### Test-Case Catalog

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Type</th>
<th>Rahmenbedingung</th>
<th>Beschreibung</th>
<th>Wert</th>
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<tr>
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<td>Sequenz Verkehr</td>
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- Assessment and Evaluation
Test-Case Assignment Tool

Test-Case Catalog

TEST-CASES

ASSIGNMENT

SIMULATION-FRAMEWORK

PROVING GROUND

PUBLIC ROAD, TEST FIELD

ASSESSMENT

+ Variation

[1]

[2]

+ Reference

[1]

[2]
Testmanager

Task:
- monitoring of real driven test-cases
- giving test instructions
- (controlling of object vehicles)

... for reproducible test executions

Maneuvers:
- merging
- lane changes
- overtaking

Usage:
- proving grounds

Instructions:
reduce speed!

\[ \Delta x \text{ [m]} \]

\[ v_{\text{target, object2}} \]

\[ v_{\text{object2}} \]

\[ x_{\text{object2}} \text{ [m]} \]

based on high-precise 360° lidar sensors, wlan communication

Object1

Object2

VuT

\[ v_{\text{object1}} \text{ [km/h]} \]

\[ x_{\text{object1}} \text{ [m]} \]

Object1

Object2

VuT

\[ v_{\text{object1}} \text{ [km/h]} \]

\[ x_{\text{object2}} \text{ [m]} \]
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... for reproducible test executions

Maneuvers:
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- lane changes
- overtaking

Usage:
- proving grounds
  instructions

$V_{target, object2}$
OK!

$V_{object1}$ [km/h]
$V_{object2}$ [km/h]
$X_{object1}$ [m]
$X_{object2}$ [m]
$\Delta x$ [m]

based on high-precise 360° lidar sensors,
wlan communication

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Task:
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Challenges of Testing
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Test-Case Identification

INFORMATION BASE → ANALYSIS → RATING → TEST-CASES

Analysis of all function-relevant environmental parameters.

Test-Case Catalog
Summary

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**Task:**
- monitoring of real driven test-cases
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based on high-precise 360° lidar sensors, wlan communication.
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