A Novel Approach to Integrate Human-in-the-Loop Testing in the Development Chain of Automated Driving on the Example of Automated Lane Change

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Agenda

- Project Introduction
- Automated Driving System Development Chain
- Automated Lane Change Function & HMI Concept
- Human-in-the-Loop Testing with Driving Simulator
- Results & Discussion
Project Introduction

- **Project goal**: implementation of virtual tools in the development process of automated driving systems
- The automated lane change (LC) function is used for demonstration purposes as system under test
- Industrial project in cooperation with Magna Steyr

Double V-Model for the development of Advanced Driver Assistance Systems (ADAS)
Automated Driving Function (ADF) Development Chain

- Functional concept
- System modeling
- HMI design
- Development test-scenarios
- Benchmark & human driver recording tests
- System parametrisation
- Survey on driver impressions over tested ADF (Validation)
- ADSG Tests with multiple test drivers
- ADSG adaption & ADF implementation

ADSG – Automated Driving Simulator Graz
Automated Lane Change Function & HMI Concept

• Lane change algorithm for decision making and trajectory planning based on dynamic traffic (Samiee, 2016)

• Parametrisation based on recorded natural test drives with multiple drivers

• HMI concept (Quinz, 2017)

Manual mode  Semi Automated mode  Automated mode
Human-in-the-Loop Testing

Driving Simulator Study

• Stationary driving simulator with full vehicle body, 360° surrounding view, acoustic and force-feedback simulation

• 20 test persons

Method

• Two-way test concepts: fixed manoeuvres and traffic flow scenario

• The fixed maneuvers evaluate driver acceptance with respect to the lane change starting point and its duration (focus function)

• The traffic flow test concept gives feedback about overall driver impression regarding usability and user friendliness (focus HMI)
Fixed Manoeuvres

- Four repeatable standard manoeuvres with fixed kinematic for all vehicles
- Every manoeuvre was driven three times by each test person:
  - Manual
  - Automated variant 1
  - Automated variant 2
- Questionnaire after each automated drive regarding:
  - Overall performance impression
  - LC initiation timing
  - LC duration
Traffic Flow Scenario

- Microscopic traffic flow simulation of a three-way highway with calibrated parameters from road measurements (PTV VISSIM)
- Simulated driving in “naturalistic” highway traffic
- Feedback about the overall driver impression of the LCA system
- Focus on HMI
- Three LCA modes:
  - Manual
  - Semi Automated
  - Automated
- Two-way questionnaire:
  - NASA Task Load Index
  - Specific questions regarding system understanding, safety and complexity and driving comfort
Fixed Manoeuvre Study Results

- Initiation timing (calculated over TTC) for most drivers under 15 s
- LC duration normally under 9 s
- No correlation between manual driving behaviour and rating of automated driving performance → “Driver vs. Passenger”

<table>
<thead>
<tr>
<th></th>
<th>Initialisation timing [s]</th>
<th>LC duration [s]</th>
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<tbody>
<tr>
<td>Mean value +/- standard deviation (N=20)</td>
<td>16,1 +/- 9,0</td>
<td>8,3 +/- 4,1</td>
</tr>
<tr>
<td>Mean value excl. outliers +/- standard deviation</td>
<td>11,1 +/- 2,8 (N=14, &lt;15s)</td>
<td>6,7 +/- 1,9 (N=15, &lt;9s)</td>
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Fixed Manoeuvre Study Results

Overall Score over all 4 Manoeuvres

- General impression: 6.09 (Variant 1), 6.69 (Variant 2)
- Initialisation timing: 5.75 (Variant 1), 6.58 (Variant 2)
- LC duration: 6.25 (Variant 1), 6.76 (Variant 2)

best rate 7
worst rate 1
Fixed Manoeuvre Study Results

Initialisation Timing

Rating Score

Manoeuvre 1  Manoeuvre 2  Manoeuvre 3  Manoeuvre 4

Variant 1  Variant 2

best rate 7
worst rate 1
Fixed Manoeuvre Study Results

**Lane Change Duration**

- **Manoeuvre 1**: 6.3 (Variant 1), 6.6 (Variant 2)
- **Manoeuvre 2**: 6.35 (Variant 1), 6.75 (Variant 2)
- **Manoeuvre 3**: 6.05 (Variant 1), 6.75 (Variant 2)
- **Manoeuvre 4**: 6.3 (Variant 1), 6.95 (Variant 2)

**Best rate**: 7
**Worst rate**: 1
Traffic Flow Scenario Results

NASA Task Load Index (TLX)

“...subjective, multidimensional assessment tool that rates perceived workload in order to assess a task or other aspects of performance” [Wikipedia]

- The questions were adjusted according to the driving task and different LCA modes in highway traffic

![NASA Task Load Index Chart](chart.png)
Traffic Flow Scenario Results

- Specific questions regarding system understanding, safety and complexity and driving comfort

![Graph showing comparison between manual, semi-automated, and automated systems in traffic flow scenario results.]

- Eases the LC manoeuvre
- Enhances the driving comfort
- Increases the feeling of safety
- Actions are easy to understand
- The familiarisation was easy

Totally disagree: 1
Totally agree: 7
Thank you for your attention
References