The robot driver in a co-simulated test environment: Supporting integrated development processes in the field of Real Driving Emissions

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Introduction

- Private company founded in 1983
- First products:
  - Valves for supra conductors: pressure control of liquid helium at 8 K
  - Valves for exhaust emission analyser: vacuum pressure regulator at 200 °C
- 1985: 1st AUTOPILOT system AP500 sold to BMW: Climatic chamber

- World-wide customer base
- More than 1000 robot systems sold world-wide
- Wide product range of robot systems

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Content

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➢ Development Challenge: RDE

➢ Co-simulated test environment with CarMaker & Stähle DriverModule

➢ Conclusion
Motivation

**RDE**

*great variability – many interactions*

- Weather
- Elevation
- Route
- Traffic
- Traffic signals
- No reference
- Vehicle & Drivetrain
- Driver behavior

Picture: Welt.de
Picture: Auto Bild
Picture: fotocommunity.de
Picture: haeusler-automobil-gmbh.de
Picture: faces.ch
Motivation

Detailed examination in testbed environments

Enabling Frontloading by combining hardware with simulation

- RDE test
  - random

- Testbed
  - reproducible

- Influences
  - transparent

- Measurements
  - in detail

Source: AVL
Development Challenge: RDE

Application of Stähle DriverModule
Development Challenge: RDE

Application of Stähle DriverModule

- Same „vehicle input generator“
- Correlation between test bench configurations
- Same behaviour & performance & features
- Elimination of multiple and redundant development processes
- No incompatibilities from Vehicle to SIL

Human drivestyles
Repeatable
Precise
Development Challenge: RDE

Repeatability and Analysis

Virtual Integration

RDE Reference-Cycle

VKM RDE Methodology Toolbox

Methodical adjustments to existing development procedures are necessary

Addressing RDE in early development phases with Co-Simulation Toolchain in the office & at the testbed

Modular Methodology Toolbox for various RDE Use Cases
Co-simulated test environment

Use Case

- RDE Testing on **EiL-testbed** with **CarMaker & Stähle DriverModule**

**Approach:**
Vehicle speed profile for virtual driver on digitalized road geometry

- Detailed focus on **Repeatability & Analysis** of virtual driver behaviour
  - Different drive style settings & strategies
  - Different shifting behaviour & strategies
  - Test repeatability
Co-simulated test environment
Repeatability – 3 ROBOT runs on chassis dyno

Pictures: Courtesy of IPEK, AUDI
Co-simulated test environment
Comparability – human drivers + Autopilot

Pictures: Courtesy of IPEK, AUDI
Co-simulated test environment
Testbed setup & Scenario

Input Driverparameter with Autopilot GUI

Realtime System: Real Driving Simulation Module

Soll Motorlast
Sollstellung Drosselklappe

Gemessenes Moment

Soll Motordrehzahl

Fahrermodell
Gewünschte Fahrgeschwindigkeit

Pedale & Lenkrad

Fahrzeuggeschwindigkeit

Widerstände & Informationen

3D-Umgebungsmodell

Signale
Verkehrsschilder & Objekte
Straße & Umgebung

Testbed-Setup

CarMaker Testbed
Stähle DriverModule
AVL PUMA Automation System
Co-simulated test environment
Testbed setup & Scenario

VKM commuter route profile
- Driving profile representative for ordinary commuter driving
- Consisting of all speed types regarding RDE

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Rural</th>
<th>Motorway</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Ø Speed (km/h)</td>
<td>23,1</td>
<td>67,7</td>
<td>113,1</td>
<td>32,4</td>
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<td>Trip share (%)</td>
<td>59,87</td>
<td>22,21</td>
<td>17,92</td>
<td>100</td>
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<tr>
<td>Distance (km)</td>
<td>7,24</td>
<td>2,69</td>
<td>2,17</td>
<td>12,1</td>
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</tbody>
</table>
Results

Observed behavior in RDE tests: Acceleration to ~ 50 km/h

- Different drivers, same maneuver
- Characteristic, pulsative increase in pedal activity
- Interrupted by shifting which leads to variances
- Two types of behavior
  - Quasi-constant pedal position after increase
  - Continuous increase in pedal position
Results

Stähle DriverModule integration with CarMaker Testbed

- Investigation of 2 different drive style settings (Driver 1 & Driver 2) at EiL-testbed

<table>
<thead>
<tr>
<th>Driver</th>
<th>RMSSE</th>
<th>ASCR</th>
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<tbody>
<tr>
<td>Driver 1</td>
<td>0.72</td>
<td>-3.22</td>
</tr>
<tr>
<td>Driver 2</td>
<td>0.70</td>
<td>-2.75</td>
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</table>
Conclusion

➢ RDE: great variability – many interactions

➢ Frontloading with automatable and reproducible tests on XiL-Testbeds with RDE Methodology Toolbox

➢ Successful implementation of CarMaker Testbed with Stähle DriverModule on PUMA EiL-Testbed

➢ Testbed setup shows great potential regarding RDE testing

   ➢ Detailed focus on Driver Influence:
     ➢ Repeatable driver behavior on testbed
     ➢ Precise driver behavior
     ➢ Different strategies in driving style realizable
Thank you for your kind attention!