APPLYING KEYWORD DRIVEN TESTING TO VALIDATE VEHICLE SOFTWARE

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The Changing Automotive Landscape

“In the next decade, the automotive industry will face a magnitude of change that has not been seen in a century. This change will be driven primarily by four mutually reinforcing trends, i.e., autonomous, connected, electric, and shared (ACES) vehicles...”

Source: Automotive software and electronics 2030, McKinsey & Company

- Software Standardization (e.g. Autosar) enables the separation from Hardware and Software. As result, Hardware is becoming a commodity i.e. **Software is the most important added value to the final product**
- Surge in Complexity of Software Functions (i.e. Energy Domain)
- Increasing Safety Criticality of Software Functions
- Higher demand for faster and cost effective Verification & Validation Processes
Thermal Management System Overview: Hybrid (PHEV), Electric (BEV) Vehicles

Heating and Cooling Vehicle System in Electric Vehicles

Source: Klimatisierung und Thermomanagement IAV Automotive Engineering
AUTOMATED VIRTUAL DRIVING CYCLES:
PROJECT GOAL AND OBJECTIVES
Project Goal and Objectives

- Shift In-Vehicle Tests to a Test Rig (reduction of the number of vehicle prototypes)
- Raise Productivity in terms of Test Cases
- Customer Focus on Specifying and not on Implementing Tests
- Provide an efficient Software Validation Process based on Customer Skill Set (good Knowledge on In-Vehicle Software Validation)
- Improve Communication within the Test Team
- Drive cross functional cooperation within the Organization
THERMAL MANAGEMENT TEST RIG: OVERVIEW
Test Rig: System HiL

Actual Plant
including all cooling circuit components, heat exchangers, HVAC, pipe, compressor, actuators / sensors

Simulation Modules:
Front- & HVAC Air Modules

Wiring harness <-> Actuators / Sensors Test Bench

CAN: „HIL, Customer-PC, Operator-PC <-> Ipetronik Simulation Modules“

Hybrid-CAN: „HIL -> Interface to Calibration Interface -> Automation-PC“

USB (VAS5163): Automation-PC <-> Diagnostic Connector HIL

LWL „HIL <-> Automation-PC (ControlDeskNG)“

MPI-Bus „Operator-PC (Ipemtion) <-> Test Rig-PLC“

POD-Interface (XCP-on-Ethernet): „TME-ECU <-> VX1131“
TEST REQUIREMENTS:
VEHICLE DRIVING CYCLES AND
EXPECTED SYSTEM RESPONSE
# Test Specification

## Branch Point

- **Cooler Simulation**
- **Hil Simulation Model**
- **Environment conditions, Fan Speed, Evaporator T**
- **Actual Plant**
- **Thermal Models**
- **Vehicle State**
- **Charging: AC/DC Power (KW)**
- **Idling:**
- **Misc**

## Driving Cycle

- **Driving: v(t)**
- **Charging: AC/DC Power (KW)**
- **Idling:**
- **Misc**

## Vehicle Model

- **Energy Losses (V)**
  - Max Charging Power, Charging Current, Lost Power (V)

## Test Specification Table

<table>
<thead>
<tr>
<th>TC-Goal</th>
<th>Expected Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## User Conference on Advanced Automated Testing

**MICRONOVA**

Software and Systems

**ETSI**

The Standards People

**TKI Automotive**
KEYWORD-DRIVEN TEST TOOL: TEST CASE GENERATOR
Workflow without Test Case Generator

Test cases are implemented manually, according to Test Specifications

Problems:
- Data Maintenance necessary in Several Places
- Slow, error-prone manual Implementation
- High Variance in Implementation
Automatic Generation of Test Cases

Test Specification
Precondition:
10. Ignition on

Action:
20. Stop Sending 'FRA::ESP_21'
30. Wait for DTC '40004' active 20s

Postcondition:
40. Ignition off

Expected Result:
30. Check DTC '40004' active

Operation Mapping
String from Testspec → EXAM Operation

„Ignition on“ → Switch_ignition_on
„Klemme 15 an“ → Switch_ignition_on
„Stop Sending %1“ → Stop_sending
„Wait for DTC %1 %2 %3“ → DTC_wait

Sequence Diagram
Generated, executable TestCase
USE CASE: PULL-DOWN
### Pull-Down: SPEC

#### Test Case Description

**Precondition:**
1. Execute Pre_DrivingCycle with the following input parameters 8 and VOKO
2. Set Environment Temperature = 40

**Action:**
30: Set sun radiation to 100 W/m²
40: Set Status Operation Mode to 6 (Ignition ON)
50: Turn Climate control on
60: Climate control set to Auto Mode
70: Set HVAC Fan to 0 level
80: Set climate control panel to MAX temperature
90: Check if StateOfCharge of the Battery = 100%
100: Start Measurement
110: Start Drive Mode, accelerate and keep speed to 32 Km/h
120: Start timer with input parameters (1800 s, "evaporator"), 180 s
130: Start Drive Mode and stay on idle 6 Km/h
140: Start timer with input parameters (900 s, "evaporator"), 180 s
150: Start Drive Mode, accelerate and keep speed to 60 Km/h
160: Start timer with input parameters (600 s, "evaporator"), 180 s

**Postcondition:**
170: Stop measurement
180: Set back initial conditions

**Expected Result:**
Pull-Down: DOORS Synchronizer

Please Confirm Synchronization

The following operations will be performed with the TestCases in EXAM:

- 0 will be deleted
- 0 will be updated
- 1 will be created

OK  Cancel
Pull-Down: Test Case Description

**Precondition:**
10: Execute Pre_DrivingCycle with the following input parameters 8 and VOKO
20: Set Environment Temperature = 40

**Action:**
30: Set sun radiation to 100 W/m²
40: Set Status Operation Mode to 6 (Ignition ON)
50: Turn Climate control on
60: Climate control set to Auto Mode
70: Set HVAC Fan to 0 level
80: Set climate control panel to MAX temperature
90: Check if StateOfCharge of the Battery = 100 %
100: Start Measurement
110: Start Drive Mode, accelerate and keep speed to 32 Km/h
120: Start timer with input parameters (1800 s, "evaporator", 180 s)
130: Start Drive Mode and stay on iddle 0 Km/h
140: Start timer with input parameters (900 s, "evaporator", 180 s)
150: Start Drive Mode, accelerate and keep speed to 60 Km/h
160: Start timer with input parameters (600 s, "evaporator", 180 s)

**Postcondition:**
170: Stop measurement
180: Set back initial conditions

**Expected Result:**
Pull-Down: Mapping

<table>
<thead>
<tr>
<th>Name</th>
<th>Column2</th>
</tr>
</thead>
<tbody>
<tr>
<td>UmgebungstemperaturEinstellen</td>
<td></td>
</tr>
<tr>
<td>SonnenstrahlungEinstellen</td>
<td></td>
</tr>
<tr>
<td>STOPmEinstellen</td>
<td></td>
</tr>
<tr>
<td>KBT_ON_OFF</td>
<td>Turn Climate control %1</td>
</tr>
<tr>
<td>ON_OFF</td>
<td></td>
</tr>
<tr>
<td>Expressions</td>
<td>Start Measurement</td>
</tr>
<tr>
<td>MessungStarten</td>
<td></td>
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<tr>
<td>Expressions</td>
<td></td>
</tr>
<tr>
<td>FzgStarten_FzgV_einstellen</td>
<td>Start Drive Mode, accelerate and keep speed to %1 Km/h</td>
</tr>
<tr>
<td>Placeholder</td>
<td>%1</td>
</tr>
<tr>
<td>DefaultValue</td>
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<tr>
<td>DefaultShortname</td>
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<tr>
<td>Unit</td>
<td></td>
</tr>
<tr>
<td>TV/RX</td>
<td></td>
</tr>
<tr>
<td>Expressions</td>
<td>Start Drive Mode and stay on idle %1 Km/h</td>
</tr>
</tbody>
</table>

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Pull-Down: Test Case Generation
Pull-Down: Test Case
CONCLUSIONS: ADDED VALUES
Key Take Aways

- Increasing SW Complexity drives the adoption of new Test Methods such as Keyword Driven Testing
- Provides an excellent Common Ground for cross functional Cooperation within the Organization
- The Usage of Test Case Generation sets the first Milestone for a well defined and structured Software Validation Process
- Automatic Test Case Generation raises Productivity and Quality Standards while reducing Time to Market
Thank you for your attention!

Q&A Time!

Time for Questions and hopefully also for some Answers...

Special Thanks to our Colleagues from Audi (EK-4, EE-I3) and dSPACE!!!