Enhancing ADAS Validation with Automated Search for Critical Situations

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QTronic GmbH

Apply & Innovate Conference, Karlsruhe 2016
Virtual Validation for Automotive Development
Tools and Engineering

QTronic in: Berlin, Stuttgart, München

We help our customers to develop
• faster
• safer
• cost effective

With modern technologies for
• virtual ECUs
• virtual integration
• test and validation

20.09.2016
QTronic Presentation at Apply & Innovate Conference, Karlsruhe 2016
Motivation: ADAS Test and Validation

Interaction of
• Software
• Sensors
• Electronics
• Mechanics

Faults happen...
Important: Find all faults before release

Test and validation required in a large space of situations
Test and validation required in a large space of situations
### Assume
- 5 sampling points per parameter, such as acceleration 0..100% sampled at 0%, 25%, 50%, 75%, 100%
- Simulation time / scenario: 10 seconds
- An increasing number of parameters

<table>
<thead>
<tr>
<th></th>
<th>5 parameters</th>
<th>10 parameters</th>
<th>15 parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenarios</td>
<td>3.125</td>
<td>9.765.625</td>
<td>30.517.578.125</td>
</tr>
<tr>
<td>Simulation time</td>
<td>8.7 Hours</td>
<td>3 Years</td>
<td>9677 Years</td>
</tr>
</tbody>
</table>

### Conclusion
- Hand-defined scripts: high costs, poor coverage
- Exhaustive testing, Monte-Carlo search: do not scale either

*Can intelligent search methods better close the gap?*
Automated Search for Critical Situations

**Idea**
- intelligent generation of 1000s of differing test scenarios
- active attempt to:
  - maximize the state coverage
  - drive the system in “difficult” situations
- parallel simulation on cheap HW (PC)

**Benefit**
- high coverage
- low efforts for test specification
TestWeaver - Evolutionary Search Strategy

- controllable input
- component fault

inputs u

simulation

state space

reached state
alarm state

outputs y

TestWeaver

Change sub-optimal scenarios to generate worst-cases

Drive the system in states that were not covered before

Reactive generation
- Learn from past situations
- All cases can be reproduced

Software controllers
requirement monitoring

vehicle & traffic model

Test Report

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TestWeaver - Test Generation Strategy

Strategy
- Assess state
  - criticality
  - impact on coverage
- Learn from past situations
- Detect “hot spots”
- Search around “hot-spots”
Overview reports for all scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Gear A</th>
<th>Gear B</th>
<th>Clutch A</th>
<th>Clutch B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>neutral</td>
<td>ok</td>
<td>ok</td>
<td>sl7</td>
</tr>
<tr>
<td>2</td>
<td>neutral</td>
<td>ok</td>
<td>ok</td>
<td>sl6, sl2</td>
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<tr>
<td>3</td>
<td>neutral</td>
<td>ok</td>
<td>ok</td>
<td>sl10, sl12</td>
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<tr>
<td>4</td>
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<td>sl14</td>
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<tr>
<td>9</td>
<td>ok</td>
<td>sl10, sl12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Detailed reports for individual scenarios

Replay in simulation and debug
System State Coverage - Examples

Reached shifts in a 9-gear automatic transmission

after 2000 scenarios about 61000 shifts

Reached engine speed/torque states

after 2000 scenarios

Source code coverage is used in combination with operational state coverage
TestWeaver - Connections to ADAS Simulators

VTD  
www.vires.com

CarMaker  
www.ipg.de

PreScan  
www.tassinternational.com
Crosswind Stabilization for the 2009 S-Class

Active Body Control (ABC) for Crosswind Stabilization

- ABC-software exported from Simulink
- co-simulated with Mercedes-Benz in-house vehicle model
- TestWeaver controls the parameters for:
  - driver manoeuvres
  - wind and road profiles
- generated and analysed 100,000 driving scenarios, each 45 sec. within 3 weeks
  > 2 times faster than real-time

Details in: Klaus-Dieter Hilf et al:
Automated Simulation of Scenarios to Guide Development of a Crosswind Stabilization,
IFAC Symposium Advances in Automotive Control 2010, Munich, Germany
Validation for Bosch ESP® Stabilization Functions

Trailway Swing Mitigation and Crosswind Stabilization

- Bosch ESP®-software exported from Simulink
- Co-simulated with IPG CarMaker vehicle models
- TestWeaver controls the parameters for:
  - driver manoeuvres
  - road profiles
  - wind profiles

Details in:
Transmission Control Units (TCUs) for Automatic Transmissions AT/DCT

- virtual TCUs built with QTronic Silver
- co-simulated in Silver with accurate Mercedes-Benz vehicle models (FMUs)
- TestWeaver
  thousands of scenarios generated and analysed at every software release on several PCs in parallel

See for instance: Stefan Gloss, Milan Slezák, Andreas Patzer: Systematic Validation of over 200 Transmission Variants, in ATZ elektronik 4/2013
Enhancing ADAS Validation with Automated Search for Critical Situations

- Traditional test and validation methods do not scale with the increasing system complexity!
- The automation of search in large parameter / event spaces is a necessity!
- Methods for intelligent search dramatically increase test coverage already used in series development

**Benefit**

*Increased confidence in system correct functioning!*
*More problems found and corrected in time!*
What are virtual ECUs?
“Run on PC like in the car!” - via SiL or vPiL

- Virtual ECUs (vECUs) simulate ECU functionality on a PC.
- They are built using tools like Simulink and TargetLink.
- C code and libraries are generated from a function/module.
- CPU emulation (vPiL) and simulation (SiL) are possible.
- Virtual system test is performed in 10 min.
- Feedback to developers is provided.

ECU

vECU

virtual system test

in 10 min

feed-back to developers

Function / Module Developers
Simulink / TargetLink / C code

C code generation

C code, libs

build for PC

SiL

CPU emulation

vPiL

build for target CPU

hex

Developer’s PC

ECU

in 10 min

feed-back to developers
Silver: virtual ECUs, CAN & plant model simulation
BMW and ZF virtualize the TCU for the ZF 8HP 8-speed automatic transmission with Silver

OEM and supplier exchange compiled objects to build the vTCU

- ‘virtual HiL on a laptop’ for closed-loop system test
- pre-calibration with INCA or CANape
- debugging on C source level

**details in:** Rui Gaspar, B. Wiesner, G. Bauer: *Virtualizing the TCU of BMW’s 8 speed transmission*
10th Symposium Automotive Powertrain Control Systems, Berlin, September 2014
Virtual Powertrain Integration - Mercedes-Benz

**Drivability Calibration - Virtual Powertrain on PC**

- closed-loop simulation
  
  \[ \text{vECU} + \text{vPCU} + \text{plant models} \]

- full diesel engine vECU via chip simulation on PC - vPiL

- powertrain control vPCU via code compiled for PC - SiL


Software Development Process
Agile Development with Virtual ECUs

- software requirements
- functional specification
- detailed design

- verification
- system test
- integration test
- module implementation test

- acceptance test

...requires...

Good, validated specification

Good, validated implementation

Easy iteration at higher levels of system integration for every engineer on his PC

QTronic Presentation
vECUs - Mercedes-Benz Powertrain Calibration

View inside a diesel ECU

- vECU simulated with **QTronic Silver** via chip simulation
- SW modules and connections between them
- left supplier modules
- right OEM modules
- white HW interface modules

Customers 2016