VERTICAL INTEGRATION OF SIMULATION ENVIRONMENTS & AUTOMATED TEST SUITE FOR VALIDATION OF JLR ADAS FEATURES

IPG APPLY AND INNOVATE 2018

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AGENDA

- INTRODUCTION
- INTEGRATED SIMULATION ENVIRONMENT
- HARDWARE-IN-THE-LOOP SOLUTION
- TEST VISUALISATION & INTERACTIVE CONTROL
- AUTOMATED TEST SUITE
- VALIDATION BENEFITS
- CONCLUSION
INTRODUCTION

THE FEATURES

• ADAPTIVE CRUISE CONTROL WITH QUEUE ASSIST
  - ACC only: 2000MY XK
  - Queue Assist: 2013MY Range Rover

• FORWARD COLLISION WARNING
  - 2000MY XK

• INTELLIGENT EMERGENCY BRAKING
  - 2008MY XF
  - High Speed & Mitigation only
INTRODUCTION
THE DEVELOPMENT APPROACH

CRUISE CONTROL MODULE

Raw Data → Object Detection → Object Classification → Controller (ACC/IEB/FCW)

DEVELOPMENT FOCUS: CONTROLLER SOFTWARE

Feature Requirements → System Functional Requirements → Subsystem Functional Requirements (SW) → Model Development

Vehicle Testing

Software Integration

Production Software

Hardware-in-the-Loop

Production Code

Software-in-the-Loop

Controller Models

Model-in-the-Loop / RCP

Functional Design Verification Tests + Unit tests (where applicable)
INTRODUCTION
THE NEED FOR VERTICAL INTEGRATION & AUTOMATION

Scenario

Constraints
• Resource
• Time

Complexities
• Vehicle Programmes
• Interfacing ECUs

Question

Effort

Coverage

Solution

Vertical Integration of Simulation Components

Test Automation

MiL
SiL
HiL
INTRODUCTION
THE SIMULATION FRAMEWORK GOALS

Goals
• Maximise Reuse
• Maximise Automation
• Maximise Flexibility
• Minimise Rework

Tool Chain
• CarMaker for Simulink
• Matlab
• Vector CANoe

The Simulation Framework Goals
• Vehicle Models
• Driver Models
• Sensor Model
• Relevant Plant and Controller Models
• Virtual World

System Under Test

Simulation Environment

Test Mechanism
• Test Cases
• Test Execution
• Test Evaluation
• Test Report

Test Visualisation & Control
• Customised Movie Animation
• Interactive Control Panel
INTEGRATED SIMULATION ENVIRONMENT
VEHICLE MODELS

- Base JLR Models from Virtual Hub
- Extended with:
  - Sensor Parameters
  - Vehicle Identification Parameters
  - Medium fidelity Plant/Controller Models
- Read Info-file Parameter blocks at simulink level to extract useful details.
INTEGRATED SIMULATION ENVIRONMENT

DRIVER MODELS

IPG Driver Models
(Standard Testing)

Logitech Racing Wheel
(Exploratory Testing)

Integration in Simulink
INTEGRATED SIMULATION ENVIRONMENT
SENSOR MODEL

- **Radar Object Classification Model**
  - Developed In-house
  - Based on:
    - CarMaker DA Sensor Object blocks
    - Read Info-file Parameter blocks
    - Read CM Dictionary Variable blocks
  - Classifies 5 important objects:
    - Front Moving, Front Stationary, Left, Right and Ahead
  - Adapts to vehicle type and number of traffic objects
  - Sustainable design
INTEGRATED SIMULATION ENVIRONMENT
RELEVANT PLANT & CONTROLLER MODELS

High Fidelity Models
- From relevant department / Supplier
- Representative & Comprehensive
- Computationally heavy
- Integration at Simulink Level
- Ex: ABS Hydraulics + ECU Model

Medium Fidelity Models
- Developed in-house
- Model of selected functions
- Computationally light
- Built on CM Dictionary Variables
- Integration at Simulink Level

Toggle at Simulink Level
Manually
INTEGRATED SIMULATION ENVIRONMENT
FINAL ARCHITECTURE
HARDWARE-IN-THE-LOOP SOLUTION
INITIAL APPROACH

Windows PC

CM4SL
- Simulation Environment
- Test Mechanism
- Test Visualisation

Network Simulation

Simulink
CAN Communication Blocks
- Object Data
- Vehicle Data

Vector VN1630A

System Under Test

No additional tool integration
Easy to maintain
Easy to Set up

Network simulation
Inconsistencies
No diagnostic command interface
HARDWARE-IN-THE-LOOP SOLUTION
CURRENT APPROACH

Windows PC

CM4SL
- Simulation Environment
- Test Mechanism
- Test Visualisation

CANoe GUI
- Network Simulation Control & Visualisation
- FMU

FMI

CANoe RT
- Object Data
- Vehicle Data

Network Simulation

CH1: Object Data
CH2: Vehicle Data

System Under Test

Cruise Control Module (CCM)

Stable/Consistent network simulation
Tool optimisation
Diagnostic command interface

Requires additional Hardware/Software licenses
TEST VISUALISATION & INTERACTIVE CONTROL
CUSTOMISED IPG MOVIE ANIMATION

- ACC Cruise Icon
- ACC Set Speed
- Cluster Messages (ACC/FCW Status, Warnings…)
- Cluster Icons (ACC, FCW, EPB…)
- Vehicle Control & Target Object Info

Current Maneuver Info
TEST VISUALISATION & INTERACTIVE CONTROL
CUSTOMISED CM INSTRUMENTS

Cluster Messages (ACC/FCW Status, Warnings…)
Target Object Info

• Ignition Switch
• Steering Wheel Switches
• Terrain Mode Selector
• ECO On/Off Switch
• Driver Seatbelt and Door Manipulation
• ACC Status Icons

ACC Set Speed

Pressure Requests display
AUTOMATED TEST SUITE
AUTOMATED TEST CASES

Fault Injection

Control Switches/Knobs/HMI selections

Automatically Simulate
• Fault Injection
• User HMI Inputs

✔ Test conditions setup without manual intervention
AUTOMATED TEST SUITE
AUTOMATED TEST EXECUTION

Test Series with multiple test runs

Parameter Changes & Script Control:
- Vary CM Dictionary variables
- Manipulate Matlab workspace
- Trigger Matlab commands/scripts

Test Variations to manipulate:
- Vehicle variables
- Road & Traffic variables
- Maneuver variables
AUTOMATED TEST SUITE
AUTOMATED TEST EVALUATION

Thought Process

Start CM TestRun

Mon 0

Criteria 1

Pass

Mon 1

Criteria 2

Pass

Mon n

Criteria n

Pass/Fail

Criteria 1 Fail

Criteria 2 Fail

Print Overall Test Outcome

Print Criteria Pass/Fail Information

Check expected results & Print outcome

Implementation

Manuever

Real-time Expressions
Eval, first(), TestLog(), ManJump...

CM Dictionary Variables
Car.v, Car.ax, Steer.WhlAng...

Example
The following command turns the result status to red (bad), if the roll angle exceeded 3 degrees:
Eval mfirst(Car.Roll)>3*pi/180 ? TestLog("bad","Roll angle limit exceeded")

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Bespoke Matlab GUI Tool to setup/edit criteria intuitively
VALIDATION BENEFITS
REAL VS VIRTUAL WORLD COMPARISON 1

Functional Design Verification Tests: ACC with Queue Assist, No of Test cases: 100+

Real World Validation

Virtual Validation

CarMaker for Simulink Test Report

Result Summary

Overall Results

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests passed:</td>
<td>92</td>
<td>83.3%</td>
</tr>
<tr>
<td>Tests skipped:</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Tests with warning:</td>
<td>4</td>
<td>3.3%</td>
</tr>
<tr>
<td>Tests failed:</td>
<td>7</td>
<td>6.8%</td>
</tr>
<tr>
<td>Tests with error:</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Tests not executed:</td>
<td>0</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
VALIDATION BENEFITS
REAL VS VIRTUAL WORLD COMPARISON 2

System design assessment:
- System design had to be assessed owing to new functional changes.
- Actuator Subsystem Software update was needed.
- 756 variations planned to be assessed
  - 21 different gradients
  - 6 different load conditions
  - 3 different calibration settings
  - 2 different system settings
- All combinations assessed in simulation initially, prior to the Software delivery.
- Simulation results provided confidence in the system design.
- No of variations reduced for vehicle testing based on simulation results.
CONCLUSION

✓ End to end solution for simulation and test automation based on IPG CarMaker.

✓ Consistent simulation and validation mechanism across MiL, SiL & HiL levels.

✓ Cost-effective and easy to set-up HiL solution for Component-level verification.

✓ Ability to set-up test criteria, intuitively, without any need for manual programming.

✓ Significant reduction in validation and maintenance efforts.
THANK YOU

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