Validation of Complex Systems

EVoCS – Evolutionary Validation of Complex Systems

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Lead Partner: [Jaguar, Land Rover]

Partners: [QinetiQ, add2, University of Warwick]
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Validation of SoS Design

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EVoCS Project Overview

Part of UK Technology Programme (TSB Supported)
- Project size £10M Total 2006-2010

Partners: Jaguar Land-Rover, QinetiQ, add2, Warwick Univ

Objective: To maximise confidence in the design and implementation of complex automotive electrical systems through:

- Innovative techniques for the validation of the design at a System of Systems level
- Next Generation Platforms for the validation of the implementation at a Systems of Systems level
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Systems of Systems

Systems of Systems are a specific type of Complex System affecting many fields including biology, sociology, engineering and military

New systems are composed of a number of individual systems with their own levels of autonomy.

Significant properties are:

- Autonomy of elements
- Evolutionary development
- Heterogeneous elements
- Sharing of resources
- Geographic distribution
- Emergent behaviour
As systems become more complex it becomes harder to:

- Predict behaviour (Emergent properties)
- Verify complete system (state space explosion) or sub-parts in isolation
Late availability of vehicle level platforms

**Large Scale**

- Effort to model
- Understanding of interactions
- Scaling issues with formal methods

**Non-homogeneous nature of individual systems**

- Different levels of detail
- Different modelling techniques
- Different failure modes

Extent of re-validation when a change occurs in one system

**What properties/attributes to validate at an SoS level?**

Those that relate most strongly to Robustness
Robustness Study Conclusions

Significant issues are predominantly robustness related

Robustness concerns the resilience of a system to maintain an appropriate level of function during and after variations or disturbances

- More about ability to cope with variation rather than preventing it occurring
- Need to understand what are the important robustness parameters in a system
- Need guidance in techniques at a software, hardware & system level

Robustness problems are complex, interactive and emergent

- Not present during normal operation but under
- Transient conditions (initialisation, shut-down, race conditions, ....),
- Failures in other systems,
- Tolerance spread
- Unforeseen (ab)use cases
Robustness Study Conclusions

“Static” Analysis methods not effective at finding robustness issues

- FMEAs more suited to single point hard failures
- Potential robustness related issues too numerous for manual evaluation
- Level of detail is frequently not sufficient to be able to foresee specific issues even without time limitations

Need to model and test

- Selection of right robustness related attributes to model
- Ability to conduct modular testing
- Design of Experiments? – even with simulation still time limitations
  - Scalable, optimal search methods

Analysis

- Large sets of data (including field data)
- Not just looking for expected response but for a wider set of potentially undesirable results
Identify Key Robustness Parameters

- Variability Analysis
- Modular Dependability Case

Design of Experiment

- Robustness Testing DoE
  - e.g. Boundary + weighted Pseudo random
  - Scalable optimised search

Construct Test Artefacts (Models/Parts)

- Robustness Models
  - initialisation/shut down
  - Interaction (high level)

Advanced Physical Models

- Interaction (Detailed Level)

Conduct Test

- HIL/SIL
- Component/System
- Vehicle

- Automated testing
- Monitoring systems:
  - Machine vision
  - PIDs
  - BUS systems

Analysis

- Data Analysis Techniques
- Automated methods of analysis of large sets of data (including field data)
- Not just looking for expected response but for a wider set of potentially undesirable results

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System of System Design Validation

- Model Based Development Processes
- Enhanced Physical Modelling
- Interaction Modelling
- Design for Robustness
- Static Code Analysis Tools
- Formal Methods for Dependability
- Test case generation & coverage metrics
- Automated Model Based Testing
Interactions at SoS Level

Understanding System interactions vital for design of SoS

- Information typically spread across several specifications
- Large amount of interactions

Lack of analytical modelling techniques at SoS level to capture inter system interactions

- Conflict between detail and coverage
- Differing levels of detail known by integrator across systems

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Interactive model of Infotainment ECUs linked by “MOST” optical network used to improve initialisation robustness
Multiple refinements to check properties of detailed system

System Properties

Model check high level design satisfies system properties

MW state machine 1 \(\parallel\) \cdots \(\parallel\) MW state machine n

Stateflow 1 \(\subseteq\) Stateflow n

Stateflow-based refinement calculus + MALPORTE healthiness checking

Code 1 \(\subseteq\) Code n

Compositional model check of stateflow model satisfies high level design
Facilitates robustness testing at SIL & HIL through modeling of variability of physical parts (e.g. tolerance and wear-out & electrical conditions)

Pilot Study
Door Lock Mechanism in Dymola

Door Locking Module
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System of Systems Validation of Implementation

- Next Generation HIL Tests
- Flexible HIL Platform
- Platforms for full vehicle tests
- Test Automation
- HMI Simulation & Testing
- Machine Vision
- Validation of Manufacturing Systems
- Robustness Testing
- Low Voltage Testing
High flexibility under software control to support intersystem robustness testing

- Flexible Connectivity
- Flexible Signal Conditioning
- Flexible Signal Type
- Flexible Signal Direction
- Flexible Signal Disabling
- Flexible ground and reference selection
- Flexible Fault Insertion
Low Voltage Robustness Testing

Specification

Reality

Electronic “Rusty File”

Pseudo-random automated waveform generator

DUT
Plots showing coverage for 3 randomly variable parameters, V1, T1, T2

(a) 500 tests

(b) 5000 tests
Low Voltage Robustness Testing

Low Voltage Tester
Vehicle Battery Simulator

General Description

The vehicle battery simulator unit comprises a compact desktop unit for simulating battery and ground voltages commonly found in use applications when wiring to electronics systems.

The unit is typically used to allow the repeatable simulation of complex waveforms such as those seen in engine cranking and poor supply connection scenarios using a supplied GUI. An externally controlled slave mode is also available.

The ability to artificially create a voltage drop between the...
Automated Infotainment Testing

Fully automated robustness testing of Infotainment system initialisation

- Emulate expert functional testing to confirm that system (of systems) appears to be operating correctly

Key elements

- Pseudo random initialisation
- Stimulation of inputs: via electrical stimulation of touch screen and remote controls
- Monitoring and analysis of video and audio outputs
- Test Automation of manual test procedures
- Automated logging of diagnostics and MOST bus
Automated Infotainment Testing

Test Script

Precondition

...test

...post condition

Precondition

...test

...post condition

Precondition

...test

...post condition

Precondition

...test

...post condition

Precondition

...test

...post condition

Precondition

...test

...post condition

Control Parameters

Capture Data

Control Parameters

Capture Data

Vision Test

Trigger

Test Result

Test Result

Test Automation

scripts

Images (referenced to test)

HIL Tester

Electrical control of touch screen

CAN

Electrical control of touch screen

CAN

Pattern matching score = 99.9

Pattern matching score = 99.9

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- transient conditions (initialisation, shut-down, race conditions, ....),
- failures in other systems,
- tolerance spread
- unforeseen (ab)use cases

“Static” Analysis methods e.g. FMEAs not effective at finding robustness issues
Need to construct test artifacts (models/parts) and explore resilience at component, system and System of System level.
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