Verification & Validation approaches for Highly Automated Driving (HAD)

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Agenda

• Introduction & Overview – Visteon as Tier 1
• Agile & Scenario based Testing
• Driver in Loop Testing
• Vehicle Testing
• Test Classification & Acceptance Criteria
Introduction & Overview
Visteon as Tier 1 in ADAS & Autonomous Driving
Visteon in ADAS & Autonomous Driving

Failsafe Secure Centralized Computation

OPEN for algorithm developers

Artificial Intelligence in Autonomous Driving

DriveCore™ enables fast, controlled and secured algorithm development for autonomous driving
Visteon’s Autonomous Driving Platform

• DriveCore™ Studio: OPEN for Common Development

• DriveCore™ Compute: Modular Design with SoC Flexibility

• DriveCore™ Runtime: Safe Communication and Easy Integration in Vehicle
Visteon’s DriveCore™ Autonomous Driving Product

**Visteon Components**

- Development Environment
- Middleware
- Hardware Platform

**Visteon Offerings**

- **DriveCore™ Studio**
  - Cloud and PC-based tool for algorithm development:
    - Sensor data record/playback
    - Visualization, configuration, testing, comparison, validation and versioning
    - Simulated Environments; Eclipse IDE integration

- **DriveCore™ Runtime**
  - Middleware for high-frequency/low-latency communications:
    - Including APIs
    - Layer for sensor data and integration of algorithms
    - Framework for algorithms
    - Easy integration of 3rd party software and algorithms

- **DriveCore™ Compute**
  - Scalable computing hardware platform with ASIL compliance:
    - Multi SoC design & flexibility
    - From Level 2 to Level 4
    - Failsafe, fault tolerant scalable & modular computing
    - ASIL compliance
Agile & Scenario based Testing
Test Strategy & Process to the Lowest Level – V Model Approach

- **Code Review** (10% defects identified)
- **Static & Dynamic Code Analysis** (10% defects identified)
- **Unit Tests** (35% defects identified)
- **HW / SW integration tests** (10% defects identified)
- **System Verification & Validation** (35% defects identified)

**Test Process Flow**

1. **Start Iteration**
2. **Plan the requirement**
3. **Define the test strategy**
4. **Define the test environment**
5. **Review requirements**
6. **Iteration baseline**
7. **Test Architecture**
8. **Test Implementation**
9. **Execute and analyze the tests**
10. **Build the test reports**
11. **System test coverage**
12. **End Iteration**

- **Sub Systems from Skill**
- **System test coverage**
- **traceability**
Why Agile Verification over Classical V-model Process?

• V-Model requires all requirements in early phase of the development.

• ADAS / Autonomous Systems being complex, cannot cover all requirements at the early phase of development.

• Normal development time period of the product is approx. 3 yrs or more (End product deployment)

• Since having incremental requirements, it is not possible to execute verification at the end of the Product development.

• Tests to be planned based on Scenarios rather than focusing on millions of kms drive alone.

• Scenarios keeps on incrementing for testing hence continuous improvement of test suite and scenario based risk assessment (Monte-Carlo Analysis) to be performed.
Scenario Based Testing for Level 3 features (Case study: Highway Pilot)

Scenarios were generated based on following scenes:
1. Ramp Assistance
2. System Start Up (Autonomous driving start up)
3. Lane Keeping
4. Driving to main lane and out (joining and exiting highway)
5. Lane change
6. Road Maintenance scenarios
7. Congestion (Traffic situation in Highway)
8. Tunnel Driving
9. Exist & Entry to Highways
Different scenarios for operating conditions Driving on the Exit and Entry Ramp for Joining and exiting the Highways

1.a Merging of two entry Ramps on A highway
2.a Entry Ramp followed by Exit Ramp
3.a Parallel Exit Ramps

1.b Merging of two entry Ramps on A highway
2.b Entry Ramp followed by Exit Ramp
3.b Parallel Exit Ramps

1.a, 2.a, 3.a are a few of the real world scenarios for Ramp Driving which are implemented in the virtual environment in 1.b, 2.b and 3.b respectively.
Parameterization

- Requirements – Feature under test
- Scenario Strategy
- Create Scenarios
- Prioritize, Vary and Generate Combination of Parameters
- Range Conditions in a Scenario
- Identify Variable Parameters in Scenario
- Controllable Parameters
- All combinations identified and cross combinations applied
- Generated Multiple Situations
- Scenario based Test Execution for Every Single Combination
- Multiple Situations from same scenario for Test Runs
- Test Execution (Full / Regression)
Use Case

The automatic generation of the variations for the Test scenario Entry Ramp followed by an exit ramp can be explained using the images below:

- Day Time
- Dawn
- Dusk
- Night Time
- With Clouds
- With Snow
- With Rain Overcast
- With Rain and Fog

Above are a few variations generated automatically using the ASG concept wherein for the test scenario “Entry ramp followed by an exit ramp” the following parameters were varied for this example:

- Time of the day within a specified range
- Weather conditions like snow, rain with different intensities and combination of both
- Friction of the road within a specific range etc..

There are many other such parameters which can be automatically varied to cover the multidimensional space of the real scenarios.
Driver-in-Loop Testing

- Mimic real vehicle functionality and associated human factors
- High degree of realism of driving environment
- Immersive and realistic Driver-in-Loop (DIL) simulation experience
- Control the Car with steering wheels and pedals
- Provides better understanding of vehicle dynamics
- Vehicle control systems similar to ones on the real roads

Visteon Vehicle Simulator
Vehicle Testing Process (each iteration)

- **Sil Testing is finished**
  - System Integration is finished
  - No critical defects
  - Software is stable and backward compatible

- **Open Loop**
  - Open loop tests are done
  - No safety related defects present

- **Test Track/Proving Ground - Closed loop Testing**
  - Functional+ System testing is done
  - Less than 20% defects present (than lab environment)
  - No safety related defects + required closed loop mileage is achieved e.g. 1000kms
  - Defect Criticality Analysis is done for public road testing Go/NoGo decision

- **Public Road Testing - Closed loop**
  - Low/medium/High Speed test routes for each feature (low, moderate and high traffic situations)
  - Functional and System verification is done
  - Defects reported and tracked
  - No safety related defects + Required closed loop mileage is achieved e.g. 1000kms

- **Validation Release**
  - Test reports + Test results published
  - Defects are reported and tracked
  - Less than 2% non critical defects present (comparison with lab based test results)

- **SW Release to Customer**
  - Software is released
  - Release notes, results reports and defect lists Provided
**Verification & Validation Classification**

**Overview**

- **Level 0**: Safety, Standards & Regulations (Validation level)
  - This level tests the hazardous events which are independent of a feature and must be tested on each iteration.

- **Level 1**: Driver comfort, Ride Quality and Requirements gaps / analysis (Validation level)
  - This level is focused on testing the quality and comfort of the ride for driver & passengers (Comfort functions).

- **Level 2**: Customer Requirements (Verification level)
  - This level mainly checks customer requirements – functional, performance etc.

**Criteria**

- **Criteria 1**
- **Criteria 2**
- **Criteria 3**

**Function**

- **Function 1**
- **Function 2**
- **Function 3**

**Validation approach involves 3 levels starting from Level 0 and Level 1 which checks in the perspective of validation and executed based on standards and regulations and also internal expertise in Visteon. Level 2 is verification which mainly focus on the customer requirements.**

**Level 0 is also considered as the high priority tests which decides the system / software is good to be taken forward for further elaborated testing.**
**Verification & Validation**

- **Functional Tests** and calibration Tests.
- Mileage accumulation for agreed KPI's.
- Usage restriction for the software released to customer.

**Vehicle Calib Tests**

**Software-in Loop Tests**

**Hardware In loop Tests**

**Driver in Loop Tests**

**System Integration Tests**

**Software Detailed Design**

**Software Architecture Design**

**System Requirements**

**Stakeholders Requirements**

**DOORS**

**NextGen**

**Design Manager**

**Rhapsody**

**DOORS NextGen**

1. Diagnostic testing – DTS, Monaco, CANape, CANdiva
2. DTC Tests (ISO 14229)
3. Flash tests (the procedure and tool to be used by the customer)
4. Network tests (e.g., Jitter test, Bus sleep)
5. DV tests (e.g., Temperature, Humidity, Vibration)
6. Calibration checks
7. Stress tests (Scenario based over night Tests)
8. SOTIF related testing
9. Smoke test – (Drive cycle in highway to check HWC and TJC; city for Level 2 features.)
10. Production mode test – If and when planned
11. PPAP (Production pre-sample/burn-in test)
12. Tests related to cybersecurity

**HIL TESTS**

**SIL TESTS**

**TCL**

- TCL-1: 80% of the test cases at SIL are passed in regression Tests and can be recommended for HIL Tests
- TCL-2: No safety related defects.
- TCL-3: No feature blockers and Workload Defects.

**Development Tests**

**TCR**

- TCL-1: 95% of the test cases at SIL are passed in regression Tests and can be recommended for Vehicle Tests
- TCL-2: No safety related defects, No Stress related defects
- TCL-3: No feature blockers and Process/Integration Defects
- TCL-4: No feature blockers and Process/Integration Defects

**Tech confidence level based on the Quality of SW at each level of testing.**
Thank You!
&
Questions?