

Dynamic Test Scheduling in Hardware In the Loop Simulation of Commercial Vehicles

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ABSTRACT

Modern day commercial vehicles use Electronic Control Units that are complex. Integration testing of these Control Units as one control system has many challenges. Many of these challenges are met by driving Integration test activities towards automation, based on Hardware In the Loop (HIL) simulation. The simulation scenarios consist of functional tests designed with the aim of replicating real world tests that are performed in an actual vehicle. However, most of the HIL simulators used these days in industry have functional tests which are assumed to be independent and are executed in a sequence pre-determined by a Test engineer. We demonstrate that the assumption of test independence doesn't hold well in many simulation scenarios. Integration test process efficiency can be shown to be improved by dynamically scheduling functional tests while simulation is running instead of a pre-determined sequence. We propose two solutions to for the dynamic test scheduling problem. One solution is to model the integration test process as a state machine. The second proposed solution is functionally similar to a state machine but its implementation is derived from logic design. The dynamic test scheduler was implemented in a software module and integrated to the HIL simulator. It acts like a Test engineer, virtually driving the vehicle in simulation and dynamically scheduling the tests based on states of the vehicle dynamic control system.

INDEX TERMS: Dynamic scheduling, Hardware In the Loop simulation (HIL), Integration testing, State machines

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I. INTRODUCTION

Modern day commercial vehicles are controlled by various Electronic Control Units (ECU). They are not only tested as single units, but also by networking them in Controlled Area Network bus (CAN) to form a complete electrical control system. This is achieved using Hardware In the Loop (HIL) simulation.

Hardware In the Loop simulation has become a standard methodology in Verification and Validation of ECU's in automotive industry [1]. In HIL (Figure 1) a dynamic model of the environment (vehicle, other hardware, road and driver behavior) surrounding the hardware under test is developed. This model is compiled and downloaded from a Host PC to hardware capable of executing the model in real time. This real time hardware uses IO boards that are interfaced to the ECU's. They receive sensor signals from the dynamic model after a digital to analog conversion by the IO boards. Actuator signals generated by the ECU's are received by the IO hardware which is then converted to numerical values for the dynamic model.

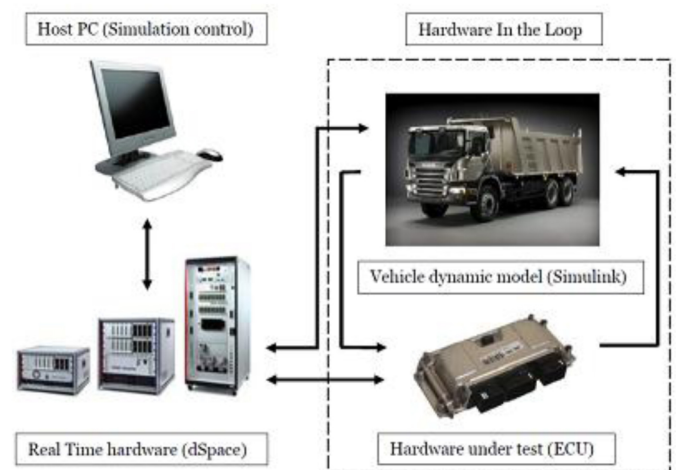


Fig. 1. Hardware In the Loop simulation

Testing functionality of the electrical system begins by defining functional tests. An example would be testing cruise

control activation. Executing each test is made possible by parameterizing variables in the vehicle dynamic model and externally controlling them.

HIL based Verification and Validation (V&V) is moving towards automation. This is because of the complexity of electrical control systems is increasing and manual V&V is time consuming. In an automated test environment, a Test Engineer develops test scripts to implement functional tests. These test scripts load the vehicle model to the real time processor, command execution of the vehicle model, control parameterized variables, and observe the electrical system response. This is compared to the expected response to decide if a functional test passed or failed. Tests are designed to remain independent of each other. Scheduling of tests is done by the Test Engineer, which is a difficult task owing to their large number and possible combinations. Hence, the normal practice is to execute tests in a pre-defined sequence. Functional tests are executed in HIL simulation as shown (Figure 2).

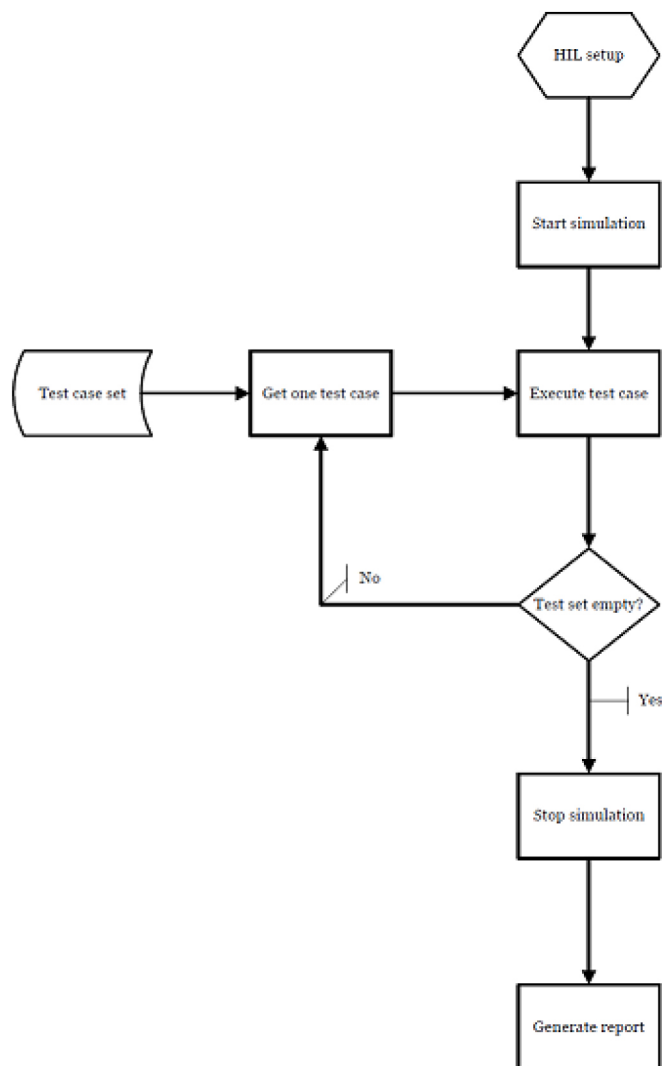


Fig. 2. Automated test process

To solve the test scheduling problem in Hardware In the Loop simulation, two solutions are proposed. Both the solutions exploit relationship between test case and state of the vehicle in a dynamic simulation environment. An example of such relationship is engaging cruise control only when vehicle speed is above 20 km/h. It can be proved that a test process that is sensitive to the simulation environment will be more realistic and hence efficient.

One solution is to model the test execution as a state machine. Tests are treated as states. Entry conditions for each state are defined using state variables of the dynamic model. When simulation is run, state variables of the dynamic model are sampled in real time. One sample of state variables trigger transition from one state to another in the state machine. When the state machine is in one state, test case corresponding to that state is selected and executed. A sequence of these transitions results in a test process evolving in time.

The second proposed solution is functionally similar to a state machine but its implementation is derived from logic design. Here, one sample of state variables is compared with entry conditions of each test case. Test cases whose entry conditions match with the current sample are selected for execution.

Both the solutions use Failure Mode Effective Analysis (FMEA) to resolve test selection conflicts, that is, situations where more than one test is selected. Results show that test execution using this approach is sensitive to the simulation environment and comparable to that of a real test drive scenario. An improvement in test efficiency both in Qualitative and Quantitative terms is also achieved. Test runs show how the new method of test execution allows faults to propagate from one test to another like in a real test drive.

II. DYNAMIC TEST SCHEDULING PROBLEM

A. Real Test Drive and Simulated Test Drive

Consider ten functional tests (TC1 to TC10) to be performed on a vehicle:

1. Central lock with key/remote
2. Seat belt warning
3. High beam with and without Ignition
4. Fuel level display
5. Low engine oil pressure warning
6. Hill hold feature
7. Retarder activation
8. Engage cruise control
9. Disengage cruise control