Using "Driver-in-the-Loop (DIL) with Sensor Fusion Test" to Reduce Costly Drive Tests for ADAS/AD Development Efforts.

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Executive Summary

As Automated Driver Assistance Systems (ADAS) and Autonomous Driving (AD) functionality gain adoption slowly yet surely, the jury remains on what type of testing is required automated Driver Assistance and more importantly, how much testing is required. With governmental and focus groups working together on this topic all over the world, OEMS and Tier 1s continue to develop and test ADAS and AD functionality primarily using Drive Tests and Miles on the Road as de facto test methods. In this white paper, VI-grade and Konrad Technologies (KT) discuss how driving simulators combined with sensor packages for ADAS/AD can be used together in a lab to robustly verify ADAS/AD functionality as a pre-step to ground truthing. Driver-in-the-Loop (DIL) with Sensor Fusion Test as a test methodology will also include driver reaction and human perception into the test for ADAS/AD functionality with the objective to replicate real world driving situations in a lab environment to possibly reduce costly and lengthy drive tests by possibly as much as 50%.

Abstract: DIL with Sensor Fusion Test

DIL with sensor fusion test is a test method that includes automotive sensors in the commonly used HIL test method for automotive ECU hardware and software functional test.
DIL with sensor fusion test enables the functional, regression and fault testing of ADAS and AD system and sub-system functionality in a lab environment before drive tests. Including the driver perception and behavior for real world driving scenarios validates the ADAS/AD functional performance closer to the real-world use case. This capability enables efficient optimization efforts for ADAS/AD functionality to reduce development cycles and meet regulatory standards in a safer work environment.

The Challenge: Efficiently Validating and Verifying ADAS/AD Functionality

As ADAS/AD functionality gain adoption slowly yet surely, the jury remains on what type of testing is required and more importantly, how much testing is required. As incremental steps to provide guidance and ensure safety for mass deployment, multiple goverment funded projects are underway in different parts of the world like the Pegasus Project in Germany and the TR68 effort in Singapore. Addendums to ISO 26262 have also introduced some insight on test requirements for the sensors involved.

With governmental and focus groups working together on this topic all over the world, OEMS and Tier 1s continue to race towards being the first to deploy a fully autonomous vehicle relying primarily on Drive Tests as de facto test methods. Expectations like multi million drive miles on road and forecasted calculations like 8.8 Billion Miles of Testing[1] possibly required for validating ADAS/AD functionality only serve to frame a growing challenge for OEMs to convince the general

public on the safety of using these advanced ADAS and AD functions and secure the next generation of revenue streams through these feature adoption.

Current Efforts: Drive Tests as Primary Method to Verify ADAS/AD Functionality

The current approach for ADAS/AD functional development and verification is to:

1. Identify a sensor package,
2. Develop the necessary software algorithm,
3. Perform limited software testing in the lab (typically with a HIL test rig), and
4. Perform drive tests in test vehicles.
5. Analyze drive test data and identify possible areas to improve software capability
6. Schedule a repeat drive test

The iterative data analysis and drive test is performed in a the loop until the ADAS/AD functionaltiy meets specifications.

This iterative development method is certainly functional and simultaneously offers an on-road validation and verification of ADAS/AD functionality. But it also inefficient, expensive, time consuming and results in longer development cycles due to extensive resource management needs.

The Solution: DIL with Sensor Fusion Test to validate and optimize ADAS/AD Functions

Driving simulators include human perception and behavior into the performance test for automotive features and functionalities. VI-grade driving simulators are used for extensive "virtual drive miles" to determine overall vehicle design performance and specific system or sub-system performance. The VI-grade Driver-in-Motion (DiM) 150 simulator offers a complete driver behavior and 9 degrees of vehicle movement to simulate a real-world drive situation while the Compact Driving Simulator (CDS) focuses on including driver behavior without the simulated vehicle movement.

Sensor Fusion HIL test is a test method first demonstrated by Konrad Technologies and our partners in the ADAS iiT consortium in 2015. It involves stimulating sensors in real-time according to driving scenarios for an ECU hardware-in-the loop test so that ECU-sensor communication can also be verified as part of the ECU performance and functional test. KT's radar, lidar, and camera simulators are used to simultaneously stimulate the sensors and their output are sent directly to the ECU for processing and necessary decisions/action.

DIL with Sensor Fusion Test combines the benefits of the technologies described above to offer a new level of test capability for ADAS/AD feature development and functional validation efforts.

Figure 1: below shows the KT radar simulator and a concept for the camera simulator being deployed for AEB and ACC test with the DiM150 at the VI-grade SimCenter in Udine, Italy.

VI-grade and KT Approach: DIL with Sensor Fusion Test to verify ADAS/AD functionality in the lab before drive tests.

Figure 2, below, shows the high-level architecture for a DIL with sensor fusion test application build by VI-grade and Konrad Technologies.
Key points are:

- The Driving Simulator Scene Generation software outputs object data streams that are sent to the radar and camera simulators from KT.
- The Camera and Radar Simulators stimulate the respective sensors in real-time according to the object data streams.
- The sensor outputs are connected to either an ECU or directly back to the driving simulator scenario models for real-time feedback and decision making as in drive tests.

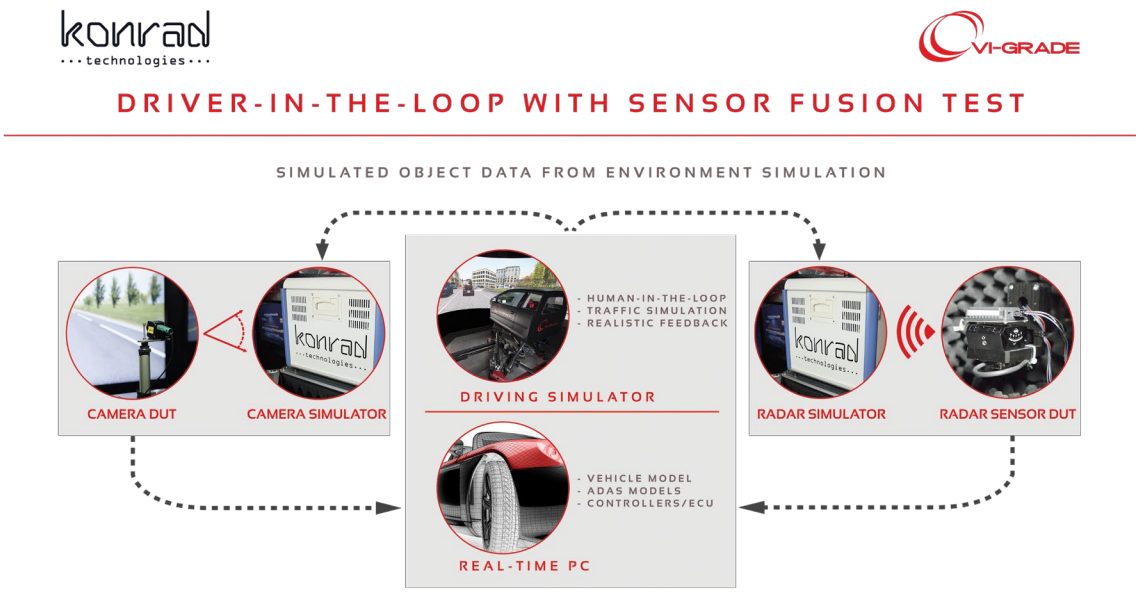

Figure 2: DIL with Sensor Fusion Test Top Level Architecture

Figure 3, below, shows the radar and camera simulators.The KT radar, camera, and lidar simulators are all designed with multiple bus options like CAN or Ethernet for linking to a realtime applicationon running the scenario model. The KT Vehicle Radar Test System (VRTS) enables object simulation and RF measurements with a single system to verify sensor performance and functionality for sensors with operating frequencies from 76GHz to 81GHz. It is built on the National Instruments VRTS platform for radar test and includes Konrad modules for connectivity and tests methodology for simulating one or multiple objects from 4m to 250m. It also includes capability to perform RF measurements like EIRP, operating bandwidth, also chirp analysis to name a few. With the PXI CAN module, the radar simulator has direct connectivity to the RT scene generation processor.

The Konrad Camera Simulator has options for Over The Air (OTA) or camera stream injection for analog and digital test capability of the camera module. It is also possible to have the camera conected to a separate ECU or processor for specific camera stream analysis like for example tracking lane marking algorithms or sub-system tests. For this demo, the VI-grade team used an internal VI-grade camera simulator as an example.

Figure 3: shows the radar and camera simulators connected to the DiM150.

Benefits and Positive Impacts from DIL with Sensor Fusion Test

DIL with Sensor Fusion offers several benefits for the ADAS/AD development process. Firstly, as a pre-step test for ground truthing, it enables drive tests to be planned for more rigorous level of evaluation. Secondly, it reliably tests and validates ADAS/AD functionality, including corner cases, in safe lab environment before a drive test to avoid preliminary driving that can be dangerous for the driver. Next, DIL with sensor fusion test allows for stress test and regression tests of ADAS/AD functionality to confirm a stable operational state before a drive test. Fourthly, this test method, includes driver reaction as part of ADAS/AD functional test which is a critical part of the overal ADAS/AD functional performance. The AEB Test is shown below.

Figure 4: Automated Emergency Braking (AEB) Test with DiM150 and Sensor Fusion Test. Notice the positive correlation between the red circles showing the objects detected by the radar sensor and the red car indicator on the UI cluster.

With these benefits, DIL with Sensor Fusion Test, is evolving R&D efforts for new and next generation ADAS/AD features, is a possibility for accomplishing automated 1B virtual drive miles to optimize ADAS/AD functionality, and is a key concept that can shorten the development V-cycle for ADAS/AD. Konrad Technologies and VI Grade continue to uncover new application areas where this capability can bring effective and efficient evaluation techniques for ADAS/AD functionality.

Sources

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