Road to lab: validation of ADAS/AD functions in Automotive with real sensors

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Abstract: Road to lab: validation of ADAS/AD functions in Automotive with real sensors

Creating safe and robust automated driving systems for future vehicles is a complex task. Autonomous vehicles have hundreds of sensors that all need to work in concert within the car and with other smart vehicles in their surrounding environment. The software algorithms enabling autonomous driving features will ultimately need to synthesize all the information collected from these sensors to ensure the vehicle responds appropriately.

These algorithms require testing against millions of complex scenes covering a wide variety of driving scenarios. You need to be able to sign off on new ADAS and AV functionality confidently.

Keysight Technologies has introduced the Radar Scene Emulator (RSE) which tests the performance and response of radar-based ADAS/AD software against complex scenarios in a lab environment that includes near and far targets across a contiguous field of view (FOV).

The RSE provides a deterministic environment for in-lab testing of complex scenes that today can be tested only on the road, if at all. It enables accelerated learning of ADAS/AD algorithms by testing decisions earlier against complex, repeatable, high-density scenes, with objects either stationary or in motion.

1 Introduction

The introduction of advanced driver assistance systems (ADAS) in road vehicles, including the efforts for achieving fully automated driving (AD) play an important role in the goal to increase road safety.

Wide adoption of these systems depends on unshakable confidence in the minds of consumers, regulators and the insurance industry. In addition, they need to be reliable and affordable.

Vehicles are equipped with more and more complex sensors, providing a comprehensive view of the world to the ADAS or AD system. There are the line-of-sight sensors, which provide an immediate image of the world around the vehicle, like cameras, radar, and Lidar sensors. In addition, non-line-of sight sensors, like position information via GNSS and communication with other vehicles, infrastructure, or back-end systems (V2X) help navigate and understand critical situations earlier.

Ensuring safety as the primary goal means validating these systems thoroughly, against huge amounts of different situations that can occur on the road. Making them reliable also means they have to operate even in rare cases and are robust against component failures.

In the following sections, we will outline how this validation can be performed efficiently by testing at earlier stages in the lab, which will help achieve very high test coverage while keeping cost down.

2 The Test Gap

Algorithms in ADAS/AD systems need to be trained and tested to master all possible situations that can occur on the road within their intended functions. This means hundreds of millions of miles of driving to fully explore corner cases.

However, testing all possible conditions during road testing will lead to prohibitive cost. Also repeating situations in case of failures in many cases is not possible.

Therefore, massive simulation based testing is performed at earlier stages of the development cycle. With this, the algorithms that help drive a modern vehicle are tested against huge amounts of situations that can occur on the road.

On the downside, this method lacks realism, because the sensor models are not accurate enough, and the real-time behavior, especially on the communication buses in the vehicle, cannot be modeled exactly.

For validation of conventional vehicle systems like power train, brake and steering systems, hardware-in-the-loop (HIL) systems have been in use for many years, with an increasing fidelity of component models and driving dynamics. Vehicle HIL systems connect all electronic control units (ECU) in the vehicle with their respective communication busses, using models for the mechanical part of the vehicle. This allows validation of the system in an automated and repeatable way, covering many corner cases before even putting the vehicles on test tracks or open roads.

Using HIL systems for ADAS/AD testing has been limited by the fact that the many sensors mentioned before could not be fully included into these test systems. Replacing them by models has the same limitations like in software-only approaches.

Figure 1: The Test Gap

This is especially true for radar sensors. They are very important elements of the vehicle's perception system, being able to detect both distance and speed of objects.

The approach so far has been to use Radar Target Simulator (RTS) units, which are capable of simulating distance, radial speed, and RCS of individual objects. The primary use case for RTS is for validation and characterization of individual radar sensors. When used in an ADAS/AD HIL environment for including the radar sensor to the test system, there are specific limitations:

- Each RTS back-end will stimulate only a single object
- Each object is represented by a single echo. In the real world, there will be many echoes, which the sensor has to distinguish and associate with objects
- Lateral positioning or movement of an object requires either mechanically movable antenna heads, or multiplexing multiple antennas to the back-end. Simulating both horizontal (azimuth) and vertical (elevation) directions is almost impossible
- The cost of the RTS system prevents adding realistic amounts of echoes or objects to the test system

Figure 2: Today's reality with RTS

3 Radar Scene Emulator: Closing the gap

Addressing these limitations and providing means of realistically testing the ADAS/AD system was the challenge that Keysight accepted when discussing this with customers and industry partners.

With the help of advanced technology development by the renowned scientists in Keysight Labs, we have shrunk the elements needed for echo simulation to a single IC, which performs the basic function needed.

- Simulate echo distance at ranges between ~1.5 to 300 m
- Modulate doppler to achieve radial speed simulation up to ±400 kph
- Control the echo strength to accommodate for the distance range and material properties of simulated echoes

Based on this element, which we call the miniature RTS (or mRTS), it is possible to setup arrays of mRTS, which are placed like a screen around the radar sensor, covering its full field of view in horizontal and vertical directions.

The whole array is placed inside an anechoic chamber, so the sensor will not be disturbed by influences inside the lab.

With this setup, and the ability to control each of the mRTS in real-time, the limitations from above can be overcome:

- The number of objects simulated is only limited by the resolution of the radar sensor and the amount of mRTS in the array
- Depending on the size and distance of an object, it will be represented by multiple echoes
- Lateral movement of an object in simulation leads to “moving” of the echo from one mRTS to the neighboring one, similar to the pixels on a screen.
- With the physical shrinking to a single IC comes a significant cost advantage.

Due to this analogy to the pixels on a screen we also use the nickname “rixel” (from radar pixel) for the mRTS elements. As we move from simulating individual objects to “rendering” of complex scenes, the resulting test system is called the Radar Scene Emulator.

Figure 3: Scene Emulation with an array of mRTS

The following two figures show a sketch on the impact of object distance vs. number of echoes graphically.

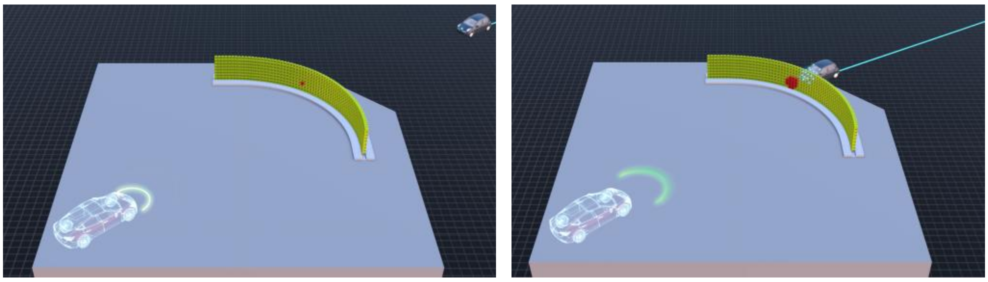

Figure 4: Emulation of a closer object: Multiple Echoes

Figure 5: Keysight AD1012A Radar Scene Emulator

4 Rendering the scene

Using this technology in a HIL system means connecting the radar sensor, which is placed inside the anechoic chamber of the RSE, with the communication and power I/Os of the HIL system. Depending on the vehicle's E/E architecture, the information from the radar sensor is then passed to the sensor fusion blocks and decision making algorithms either in different ECUs or to a central computing instance. From there, actuator outputs that operate brakes, steering and power train are read in by the HIL system's I/O lines, and processed by the physical model of the Ego vehicle. This is moving inside the simulated world, which consists of streets, buildings, traffic signs and other static objects, as well as simulated moving objects like other vehicles, pedestrians, or bicycles.

From there, using ray tracing techniques tuned to the radar's millimeter waves, information about the individual echoes in a scene relative to the radar sensor's position in the vehicle, is generated. This is processed by the RSE, which passes the data to the individual mRTS units. Each mRTS will receive the radar sensor's chirps by its RX antenna, modulate in real-time, and transmit the emulated echo back on its TX antenna. With this the loop closes and the circle starts over.

For the scene rendering, a number of commercially available simulation tools have already been integrated. They offer the 3D simulation of the world, static and dynamic traffic simulation, and integrate the physical model of the Ego vehicle. This ensures seamless connection with commercially available HIL systems, and an overall well integrated and consistent test setup.

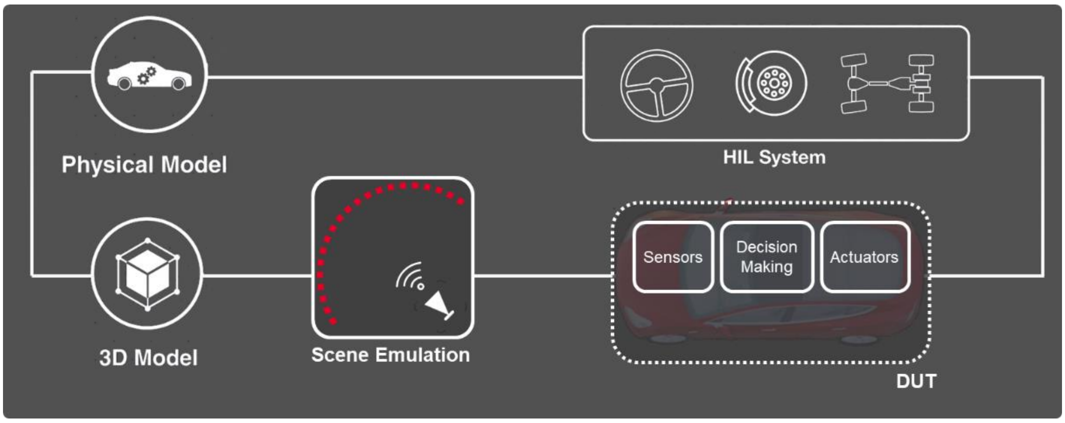

Figure 6 Closed Loop Operation

5 Combination with non-line-of-sight sensors

As discussed in the introduction, vehicles will also have to rely on non-line-of-sight information for safe driving.

This means determining the vehicle position on the map by using GNSS data, and receiving and sending out information on road conditions, hazardous events, or traffic signs.

Similar to the radar sensors, it is therefore necessary to include the real ECUs responsible for these tasks into the test.

Adding them to a HIL system means integrating GNSS stimulation and V2X capabilities both in hardware but also to the simulation. Both need to be synchronized with the movement of the ego vehicle in the simulated world and the simulated traffic.

With the recent acquisition of Nordsys, already long-term partner of Keysight for V2X test solutions, Keysight can now offer the complete test solution from physical connection using C-V2X or WiFi-based hardware all the way up to the application layer, to be included in the test system.

With this, the HIL simulation is enhanced by the communication behavior of the simulated traffic participants, completing the hardware setup to include telematic control units (TCU) or on-board units (OBU) in the test setup. V2X traffic emulation, GNSS emulation, and the radar sensor emulation together then complete a highly realistic setup.

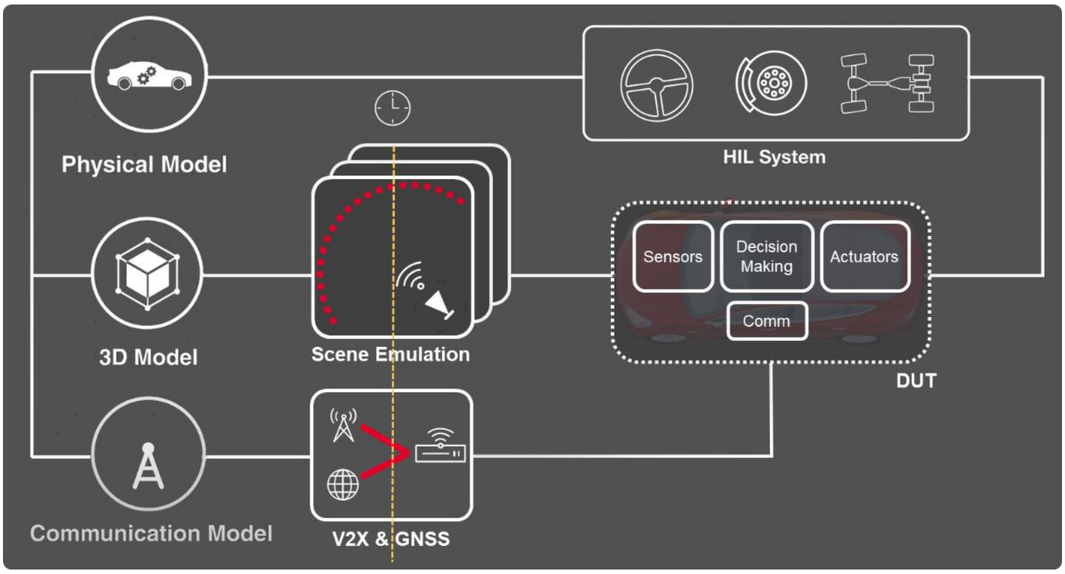

Figure 7: Full setup including GNSS and V2X

6 Conclusion and Summary

Being able to test ADAS/AD drive systems in the lab, using HIL systems, high-fidelity driving dynamics and models for the 3D world is an important step to bridge the gap between pure software based simulation and testing of complete vehicles on the road. Offering full test automation, 24/7 testing, repeatability of testing, and minimal test setup time, these systems will play an important role in the validation of ADAS and AD drive systems.

With highly realistic scene emulators and over-the-air testing of communication components, Keysight is offering a comprehensive line of solutions to help make ADAS/AD systems safe in less time and with less effort.