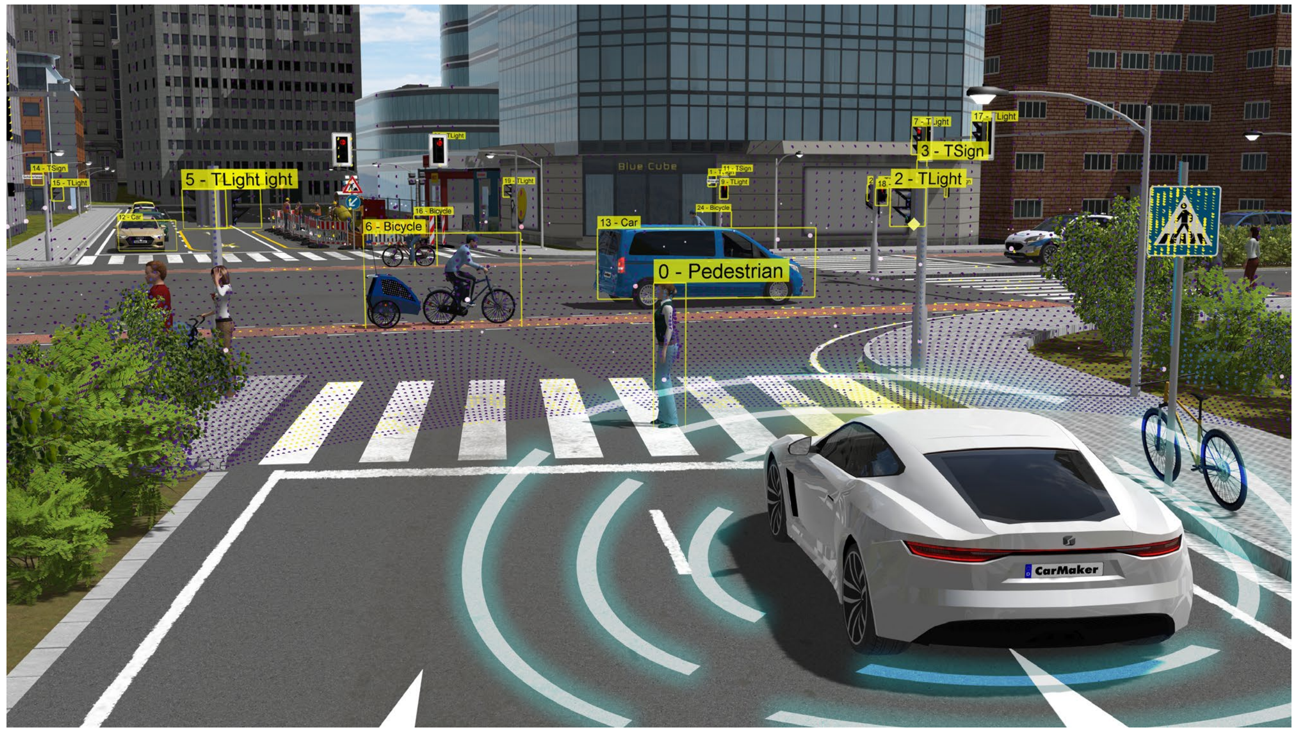

Test and Validation of Multi-Sensor Systems

Raphael Pfeffer, Prasanna Kannan, IPG Automotive GmbH

We spoke to Raphael Pfeffer, manager of the "Innovation Management" team, and to Prasanna Kannan, senior engineer from the "Test Systems & Engineering" team, about a new modular test platform that enables virtual testing and validation of radar sensors. As a result, advanced driver assistance systems (ADAS) and highly automated driving functions can be validated at a faster pace.

The number of sensors and the amount of data that are processed inside the decision-making units of ADAS-enabled vehicles are constantly rising. What are the consequences of this development?

Pfeffer: The need for testing and the validation effort for users, and accordingly for system developers, are increasing. This increase is caused by the numerous interactions between the systems installed in the vehicle. Additionally, many different existing technologies have to work together smoothly. Due to the high number of embedded systems that need to be considered, it is also referred to as a "system of systems". When we then start to think about future level 3+ systems, also referred to as automated driving, that do not have a driver anymore to serve as a fallback level for the system, there will be an even higher need for testing. The magnitude of required tests will not be comparable to the leap we made with "conventional" advanced driver assistance systems.

IPG Automotive is designing and developing a modular test platform in cooperation with Keysight Technologies and Nordsys that speeds up the validation of ADAS and highly automated driving functions. Why is that so important?

Pfeffer: There are a variety of sensors and various sensor technologies in the vehicle, such as camera, radar, lidar or ultrasound. But vehicles are different: There are plenty of distinct configurations and combinations that require flexible modeling in the test system. In addition, the focus is on the simulation environment which is why we need a realistic model of the surroundings. All characteristics of the sensors, such as the camera resolution, have to be modeled with sufficient detail. Only the interplay of the components, including a realistic simulation environment and the possibility to model all sensors in the test system, enables the development of this modular test platform and the creation of representative tests for highly automated driving functions.

What can customers achieve with this system that they can't do now?

Kannan: The open integration and test platform CarMaker allows them to test algorithms for autonomous driving functions with different levels of maturity. We can support the users from the beginning. When the algorithms are in the phase of prototyping or at the software stage, we can perform tests with model-in-the-loop or software-in-the-loop for example. Since the system is subject to continuous development until the series production status, we can test ECUs with our environment as well. Examples would be "over-the-air" (OTA) or "injection" technologies.

Pfeffer: Besides, the concept of the Autonomous Drive Emulation (ADE) platform enables OTA testing for all modeled components in the test environment. This applies to sensors operating within the line of sight, such as radar, camera and lidar sensors, but also to V2X systems that do not require a free line of sight. We are therefore able to test the entire event chain of the sensors individually as well as within their network. No compromises need to be made in modeling.

Can you describe the structure of the platform architecture?

Kannan: Our ADE architecture considers sensor emulation with the help of CarMaker sensor models in real time by using the hardware platform Xpack4. The camera can be emulated via the Video Interface Box X, which emulates the image sensor. The simulation of the radar sensor is performed with an OTA simulator.

Required additional input signals from the individual autonomous vehicle controllers, for example velocity of the vehicle or yaw and pitch, can in turn be processed via the CarMaker Xpack4 ecosystem. The signals from the actuators are introduced through the real-time hardware of the respective subsystems in the vehicle model. Xpack4 supports all necessary technologies, like CAN-FD, FlexRay or SOME/IP. This is very useful to emulate the vehicle body as close to reality as possible.

What are the benefits of this radar target simulator?

Pfeffer: The complete radar sensor can be thought of as a black box. No estimates are needed regarding the ECU, as they could lead to corrupted modeling for example. The integration of sensors into the test system is relatively easy because there is no need for an additional interface in the ECU. Through the direct connection of the environment simulation CarMaker with the Keysight hardware, the simulation of an unlimited number of targets and objects becomes possible without using a mechanical approach. That is much more compared to the performance of other test systems available on the market.

Which role does simulation play in this use case?

Kannan: To explain that, let's take a look at the principle of radar. In autonomous driving, radar is a key element. The radar sensor has many advantages in comparison to other sensors. It is therefore crucial to test it with the highest level of detail possible. Simulation plays an important role here: It is needed to emulate the environment perceived by the radar sensor in a way that the radar sensor can be tested well.

There are conventional methods to emulate the object list that the radar sensor perceives. But in this case, the test coverage is very low. Therefore, the OTA approach is a good option. It allows to test the entire signal processing chain in the radar ECU for example. The combination of a highly approximate simulation with the OTA approach would not be comparable to reality any more. That is why we accept the additional effort to model the environment with high precision, for example with realistic 3D models for other road users. Another approach we also use in the radar model is ray tracing. Ray tracing allows for excellent transfer of the radar characteristics that are transferred to the ECU via the OTA approach in the simulation.

Is it possible to integrate sensor models with different levels of maturity?

Kannan: Yes indeed. We offer an ideal, a functional and a component-based sensor model for all types of sensors. When talking about ideal sensors, we mean the object sensors in our simulation environment – they can be of interest for applications with a rapid prototyping approach for example.

In case the driving function needs to be tested immediately and with very exact data – ground truth data – the object sensor is the right choice. The next level is the HiFi sensor. In addition to the ground truth information, it can model radar phenomena such as false positives and false negatives. Effects like occlusion, which are caused by other objects such as a vehicle trim, are also included. We can also model this effect with the HiFi sensors. For more detailed modeling, we provide the radar RSI model. This model allows for component-based modeling which can be of interest for component developers.

One of the possibilities is to model the wave propagation model. With this model, the details of a 3D environment can also be perceived in the simulation, as you get different reflections from the wheels or the body for example. Multipath is also relevant for radar: You either get the direct reflection of a target vehicle or a multipath reflection, for example in cases where radar beams are reflected on the guardrail. These effects can also be modeled in the radar RSI model. The user can thus choose between the three sensor model types for radar applications. A combination, for example of an object sensor and a radar HiFi sensor, is also possible. In this case, the objects are reproduced according to the ground truth information but the radar cross-section is calculated in the radar HiFi sensor.

What are the advantages of being an open platform?

Kannan: The open platform is of great significance in the philosophy of IPG Automotive. If our clients want to integrate their own algorithms or models into the CarMaker environment, we offer the necessary interfaces as well as suitable software and hardware platforms. The Xpack4 platform enables specific requirements, such as the integration of external hardware into the platform.

Which technological limitations do other available sensor emulation applications have?

Kannan: One example in the current technologies, or rather in the emulation applications, would be the restbus approach. Here, the object list for radar is integrated into the signal processing chain at a very late stage, resulting in many systems not being tested at all. This represents a considerable disadvantage and limitation when testing the complete system. The very reverse is the OTA method that does test the entire system. It is striking that the available systems on the market can only simulate very few reflections and objects. But a radar sensor from the current generation can recognize hundreds of objects and reflections. We are not sticking to reality by emulating only a few objects.

Pfeffer: Another aspect is that when emulating sensors, proof is needed to show that the emulation is actually valid. Apart from the fact that the further one models these emulations, the more physical properties are reproduced, and the more the question of performance arises. At some point, the real-time capability of the model cannot be guaranteed anymore. These challenges are bypassed the moment you overlay the unit under test (UTT) OTA. Because all components are present physically, we can be sure that what the radar does matches its behavior in the physical vehicle. This is how validity of the behavior of the UUT is given.

Which challenges can be overcome on the customer end?

Pfeffer: Both OEMs and Tier1s can test and validate individual functions. The ADE platform also enables to test the interplay or the integration with other ECUs. Basically, the platform covers all options from the component HIL to the integration HIL.

Kannan: In addition, autonomous driving functions are being developed at a fast pace. We are just at the beginning of the “boom” and all these rapid developments need to be validated. Our emulation platform offers all tools necessary for that.

In your opinion, what potential does this platform have for future applications?

Pfeffer: Today, we are already aware that the effort involved in testing on the road with physical prototypes is no longer viable. Billions of test kilometers would be required for highly automated driving functions – that is not feasible from an economic point of view. Especially for higher functions such as automated driving in the city, meaning from level 3 onwards, the creation of complex test scenarios is necessary. A platform like the one we are presenting here can meet those demands and perform these test scenarios in a closed loop. This also allows for any level of complexity regarding the test environment. With this platform, we have the opportunity to bridge the gap between real tests and mere simulation in the domain of hardware-in-the-loop.

Thank you for taking the time and for this insightful interview.