Virtual Testing of Perception Systems

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In this interview, Martin Herrmann (Business Development Manager ADAS and Automated Driving) and Dr. Andreas Höfer (Team Lead Product Management Simulation Software) told us how CarMaker 10 supports the development of advanced driver assistance systems and autonomous driving functions using the Radar RSI sensor model as well as the new visualization tool MovieNX.

Which role does the perception of the environment play for autonomous driving functions?

Herrmann: Autonomous driving functions necessarily depend on reliable perception. Developing and testing these systems only with real test drives is difficult, especially because critical and challenging situations for environment perception are usually hard to find in reality. The nearly unlimited number of possible scenarios makes it crucial to test and validate with virtual test driving.

In the field of ADAS/AV, environment perception is one of the greatest challenges. For example, when unexpected behavior of other road users or difficult ambient conditions occur the functioning of the systems cannot be influenced in a negative way.

Which difficulties can arise in the development of autonomous driving functions?

Herrmann: In the real world, for example on the proving ground, testing such functions is challenging for a variety of reasons. Emulating real-world traffic requires a lot of effort and a large amount of material on the proving ground. Another important factor for perception is infrastructure, such as buildings and road markings. On the proving ground, you have to work with what you got. Aspects such as time of day or weather conditions as well cannot be reproduced at will. Some traffic situations that are required for validation can even be dangerous for involved persons and damage material. In addition, as soon as the sensor technology is modified or the vehicle sensors are rearranged, already recorded sensor data can only be reused to a limited extent.

Therefore, perception simulation is becoming increasingly important and has already become an indispensable element to validate autonomous driving functions. CarMaker is a great tool to simulate autonomous driving functions and can be used throughout the entire development process. Huge testing scopes in the field of MIL/SIL as well as continuous use up to HIL/VIL are possible here.

Simulation allows users to experiment with different sensor configurations or to test sensor concepts that are not yet available as a physical prototype. Also, the cost savings are remarkable: Simulation allows to carry out a lot of the conceptual preparations before real sensors are necessary.

CarMaker offers different sensor model classes for that purpose. Can you elaborate on that?

Höfer: There are three different sensor model classes in total. The so-called ideal sensor models output all relevant detected objects without considering effects that are specific to the respective technology and usually result in faulty information. This model class is used to test the driving function based on ideal environmental information, i.e. without the perception part. It can be used as a reference for the evaluation of object detection or sensor fusion as well.

The HiFi sensor models form the second model class. This class also outputs an object list but the information is enriched by technology-specific, physical effects and stochastic error models. It is used for overall testing of the assistance or driving function.

The third model class consists of Raw Signal Interfaces (RSI). They provide realistic input data for the perception algorithms of the sensor, including for example image data for the camera or point clouds for the lidar sensor. To generate the corresponding raw signals, this class considers detailed physical effects in signal propagation and the interaction with other objects.

The behavior of the sensor models and functions based on the information can be analyzed reproducibly in all conceivable traffic situations, on any route section and under various environmental conditions. All relevant sensor technologies, radar, lidar, camera and ultrasound, are available in CarMaker. It must be noted that all sensor models are high-performing and real-time capable.

Which impact does the use of RSIs have on scenario definition?

Herrmann: Depending on the level of detail of the sensor simulation, different levels of abstraction can be suitable for the geometric modeling of the environment. The basic sensor model classes do not need a very detailed environment because they represent geometric effects in an abstract way.

In contrast, the RSI requires a highly detailed 3D environment. For this kind of precise sensor simulation, ray tracing and rasterization methods are applied. These methods require an accordingly detailed environment as a basis for realistic sensor model behavior. Essentially, the setup or rather the level of detail of the 3D environment is as relevant as the sensor model itself. Sensor-specific material properties of the entire environment, including all road users, are also vital for the use of an RSI. This is used to calculate, amongst other things, how strongly a lidar beam is reflected.

However, you do not have to be a modeling expert to build the 3D environment: The object database in CarMaker comprises numerous models from vehicles to buildings and vegetation. The respective material properties are already defined for all models, making it very simple to place them in scenarios.

What impact does the use of RSIs have on the required hardware?

Herrmann: Their use requires high computing power, which is especially true for the graphics processing unit (GPU). As previously mentioned, a detailed model of the simulated environment is needed. Let's assume that we want to simulate a full autonomous vehicle equipped with 20 or more detailed sensor models which use a ray tracing method with high computational efforts. Only by deploying multiple GPUs and distributing the computational load, high speed and real-time capability can be assured.

To achieve a high throughput, however, it is not enough to speed up the individual virtual test runs. In this case, parallelization on the level of the test run allows for an almost linear scaling. The user can perform tests in parallel on a computer with multiple CPU or GPU cores, but he can also use a network of multiple computers or even entire computer clusters, locally or in the cloud.

Have there been any projects in the past to validate sensor models?

Höfer: Yes, indeed. In a cooperation with Magna Electronics we aimed at validating our ray tracing-based sensor model Radar RSI with measurements of a real radar sensor, including all relevant effects that a real radar sensor possesses.

The intention was to illustrate that the model is suitable for realistic modeling of real sensors. In the end, we were able to validate the model and to reach a very high level of maturity. Projects like this one are very exciting which is why this topic is certainly going to be around for a while.

Knowledge on the validity of models helps to design development processes on the basis of simulation-based system validation and homologation. For vehicle dynamics functions, for example an ESC, this is already common practice within CarMaker.

What new features does CarMaker 10 offer in this field?

Höfer: The most visible new feature is MovieNX, the successor of the well-known IPGMovie. It offers a completely new level of quality regarding visualization. Despite the quality, a high performance is achieved even in complex scenes. This is vital

Visualisation of the Lidar RSI point cloud

for the development of camera-based functions as it is increasingly based on simulation. We are cooperating very closely with our partner UNIGINE to develop MovieNX.

Moreover, we also continue to invest in all our sensor simulation technologies. For the Lidar RSI, we enhanced the interaction of the laser beam with the environment. The representation of different types of material and their impact on reflections are closer to reality than ever before.

We have also expanded the interaction model for the Ultrasonic RSI: Additional interaction points of the simulated acoustic wave with the environment are now taken into consideration. As a consequence, it enables an even more realistic simulation of the resulting acoustic pressure.

Are there any new features for scenario generation?

Höfer: Yes, in fact we also have a few highlights on this end. The road model was extended and can now reproduce detailed traffic islands and sidewalks. Together with the revised junction model which facilitates the modeling of highly elaborated junctions from the real world, the road model offers completely new possibilities. Extremely complex inner cities for example can be accommodated.

In addition, the traffic simulation on freeways and similar roads was extended to enable automated overtaking maneuvers. This reduces the modeling effort for freeway scenarios.

We also came up with some function extensions and new maneuver options for our driver model IPGDriver. Amongst other things, they aim at an extended compatibility with the ASAM standard OpenSCENARIO. This is a topic that we are currently working on intensely.

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