Testing and validation in virtual test driving

Alexander Frings, Martin Herrmann, IPG Automotive GmbH

The importance of testing and validation in virtual test driving is growing as a result of an increasing number of ECU functions and a nearly unlimited quantity of possible scenarios. In this interview, Alexander Frings (Manager Product Management Engineering Services) and Martin Herrmann (Business Development Manager ADAS and Automated Driving) told us how new possibilities for scenario generation can contribute to the highest test coverage possible.

What exactly is "virtual validation" and why is it important?

Frings: Virtual validation is the final step of a preferably virtual development process that uses as few real components and systems as possible. The aims are a shorter time to market, better and safer products and saving costs in comparison to the conventional development process.

Vehicle simulation in different environments and under different circumstances ensures that all functions work correctly at all times. You have to make sure that what is simulated actually corresponds to the real world.

What options exist to recreate the real environment in the virtual world?

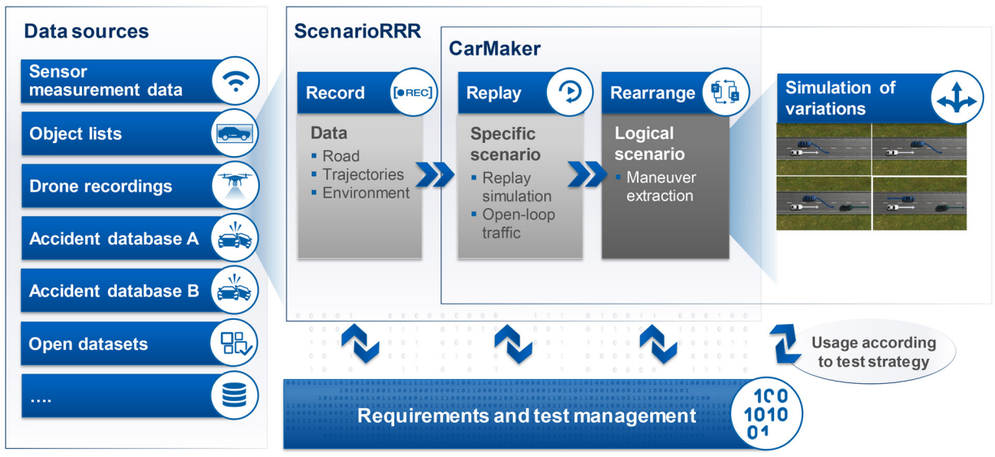
Frings: The first question of an engineer has to be: Where do we want to drive? It is always best to use a virtual road modeled after a real one. There is a high demand for the creation of road network models that do not require manual work in the Scenario Editor and do not need additional measurements. That is why in CarMaker 9, we have integrated the HERE HD Live Maps import into the Scenario Editor. These road maps are highly precise and available online. This new feature allows to create a virtual road network in the ROAD5 format from the online data provided by HERE.

However, the road network is only one component in the static part of a scenario. Scenarios also include the description of all dynamic road users and objects, such as other vehicles and pedestrians.

What role do scenarios play in virtual test driving?

Frings: Scenarios are essential. We want to ensure vehicle safety in all imaginable situations, so it is crucial to test a very large number of scenarios. Of course, we are aware that we will never be able to test all relevant scenarios and therefore never reach full test coverage. There will always be corner cases that we do not know about or that we did not expect.

Process and Solutions



Process ScenarioRRR

HD Live Maps Import

The more situations are analyzed and transformed into virtual test drives, the more critical scenarios can be tested. A high number of scenarios helps us to challenge developed driving functions.

To reduce uncertainty in virtual validation, we need to take advantage of all available test scenario sources. Some examples are derived test cases from specified system requirements, accident data bases, standardized and normed tests or records from field tests.

Can the method "ScenarioRRR" (Record, Replay, Rearrange) be applied?

Frings: Yes. This is a method that supports scenario generation from real sensor measurement data. First, the trajectories are used for a "Replay" scenario in the simulation. As soon as the traffic objects are modeled in the CarMaker test run, they can be adapted if necessary to allow for variation of the recorded scene. At Open House 2019, we presented how the conversion of road and trajectories and the parameter variation could look like in highway scenarios. For this year's Open House, we were looking for other freely available data sets to illustrate this method.

Amongst others, we encountered LevelXdata which is a collection of data sets from fka GmbH. The special feature of this data set is that drones measure a fixed point. The recordings can therefore capture a great number of objects.

Are there other possibilities to transfer real scenarios to the virtual world?

Herrmann: We have just started working on a service that transfers highly complex scenarios from the real world to simulation with our partner Scale AI. Scale AI specializes in labeling sensor data from autonomous vehicles. The annotations are typically used as ground truth by perception teams in the development of object detection and sensor fusion algorithms. But they are also an excellent basis for the generation of simulation scenarios for CarMaker with the ScenarioRRR method.

The client tests his vehicle fleet in the field and activates the data recording for example via an intervention by the driver when an error is detected in the system. All sensor data from the previous seconds are then recorded. At the end of the day, the raw sensor data are uploaded to the Scale AI platform where they are annotated: Dynamic objects, traffic signs, road markings etc. are labeled and classified. The abstracted data are then forwarded to the customer's perception team in form of an object list to train the detection algorithms. They are also sent to us because our job is to extract a CarMaker scenario with the described ScenarioRRR method and to prepare the data for variations. This scenario can then be made available to planning and function development teams in order to integrate it into their test catalogs.

You mentioned accident data bases. To what extend are they suitable sources?

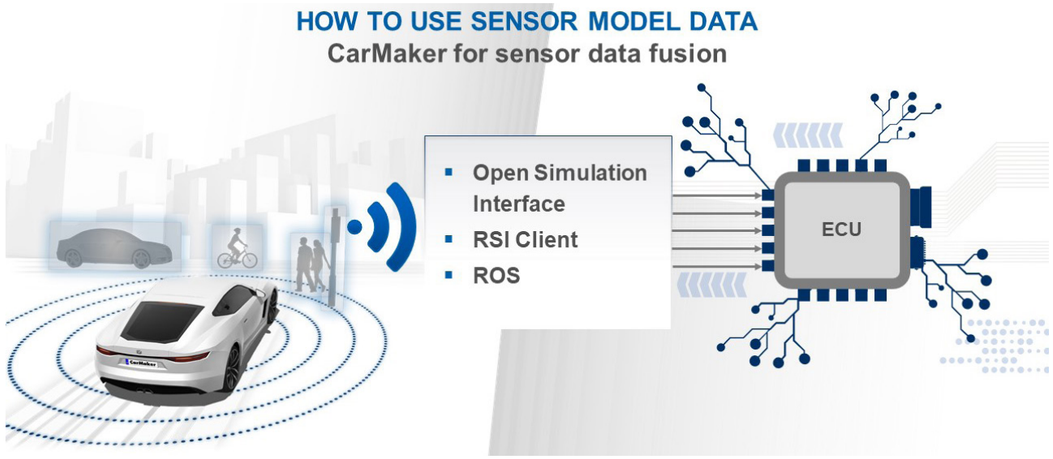
Frings: Accident data bases are a great source for scenarios because they classify real types of accidents and their severity. People interested in connecting CarMaker to accident data bases can be divided into different groups with different interests. First, the accident researchers looking at the consequences of an accident. For them it is crucial that the recorded event of the accident is faithfully rendered. On the one hand, the velocity plot has to be accurate. On the other hand, both the point of collision and the angle at which the vehicles meet have to match precisely. In this case, the simulation is no longer a closed-loop vehicle dynamics simulation. By indicating the position of the ego vehicle externally, we are relocating the vehicle.

Performing a re-simulation based on the database is also an option. This is an interesting approach for the second group: Engineers working on active safety and accident avoidance in the field of function research and development. They perform a simulation in-the-loop with the vehicle model.

Needless to say, sensors and the integration of driving functions play an important role here. In this use case, instead of driving the actual trajectory from the accident database, you might need to drive an intended trajectory. In other words, we are taking our scenario out of the database until we reach a determined position and observe how our system – namely vehicle, sensors and functions – reacts.

Speaking of safety – are there any news in the domain of NCAP?

Frings: We are continuously working on our Test Ware Package NCAP, based primarily on published tests. At first, we included the Euro NCAP test and in the meantime we have added China NCAP scenarios. We are following the road maps and are already delivering templates for test cases that are being discussed around the world. This year in



Possibilities to exchange sensor model data

July, we provided yet another an update of our package.

As to our roadmap for Euro NCAP 2022 and 2025, we are aware that various development departments are already working on the corresponding systems. CarMaker is already well equipped for future NCAP tests, in respect of the direction of travel or the type of object such as truck, motorcycle, cyclist or pedestrian. In addition, our new MovieNX allows for realistic simulations of tests with difficult light conditions.

How can NCAP test cases be translated into the development process while remaining methodologically correct?

Frings: At the beginning of the development process and to reach the required vehicle safety, studies using simulation are necessary to get a feel for the necessary components, the systems and their positioning. That is what ideal sensor models are needed for.

It is followed by a parameter study which examines to what degree parameters such as field of view, sensor range and signal noise affect the performance. Our HiFi sensor models are very useful to this end.

Shortly before the start of production, a virtual validation of the NCAP scenarios can be performed. This takes place after the selection of components, the exchange of corresponding models between OEM and supplier as well as after the virtual representation of the entire vehicle including precise actuator models and validated sensor models.

You mentioned sensor models: How can we recycle the data from sensor models generated in CarMaker in the development process and transfer the signals to the function or the ECU?

Herrmann: In my opinion there are three possible interfaces depending on the development progress and the preferences of the project partner.

One of them is the open simulation interface (OSI) that was developed by BMW and the Technical University of Munich and is now being standardized by ASAM e.V.. The goal is to couple sensor models and parts of autonomous driving functions from suppliers with parts and functions of virtual prototypes from OEMs as well as with simulation tools by using standard interfaces. This leads to a simplified exchange of models and an improved cooperation in early development stages while protecting intellectual property and knowledge on sensor and software elements.

Another option is to recreate the interface and the communication protocol of the real sensor: In the real vehicle for example, lidar sensors often communicate with a central ECU via a UDP Ethernet connection. We created a solution to replace these real sensors with CarMaker. We use the same UDP protocols as the standard lidar sensors and fill them with sensor model data from our simulation environment. The ECU does not notice whether a real sensor or CarMaker is connected to it.

Scenarios in CarMaker

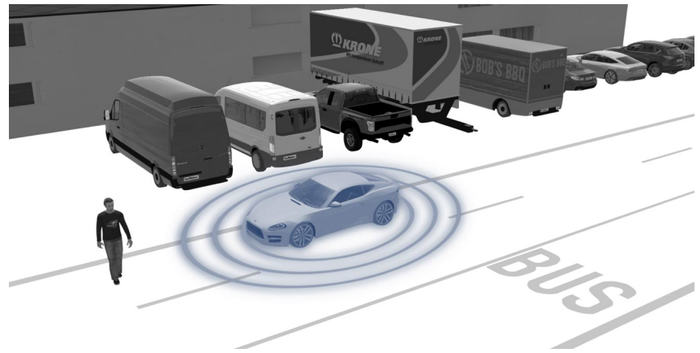
Finally, the third option is to employ ROS as an interface between sensor data and driving functions. Many customers use ROS as a development platform. For some time now, we have uploaded an example of how to create a ROS node in CarMaker. This example can be adapted to any sensor or sensor class in CarMaker as well as to the Video Data Stream for camera applications.

Thanks to the generated environment model, decisions can be made in the planning functions and motion control can be implemented. What influence do vehicle dynamics have on motion control?

Herrmann: In general, the planning module provides a target trajectory for motion control. But how can we find out if this target trajectory makes sense and can be reached safely?

In motion control it is crucial to implement the calculated target trajectory as precisely as possible. The perceived comfort, manifested by jerk-free motion control, is another relevant factor for the passengers. In the real world it is impossible to test all factors of influence on motion control such as load, weather conditions or road coefficient of friction. Not to mention road geometry including inclines or slopes. It is self-evident that these factors cannot be varied freely on the proving ground.

With autonomous driving, new vehicle concepts and sometimes new vehicle dynamics options are also added to the picture, especially because the driver is no longer needed and also due to usage restrictions. These aspects have to be considered when planning and regulating trajectories to implement



Emergency Braking Simulation in CarMaker

the vehicle behavior correctly and to enable fast and appropriate reactions in emergency situations.

A simulation platform such as CarMaker, with highly precise vehicle dynamics simulation and the necessary actuator interfaces, allows for higher efficiency and test coverage with relatively low effort.

It is vital to know the vehicle dynamics potential at all times, isn't it?

Herrmann: Yes indeed. It is crucial to know what is physically possible right now to be able to calculate the planning algorithm of valid target trajectories in the first place. In the real world, characterizing potential motion behavior has become virtually impossible nowadays because tests would have to be performed under all imaginable boundary conditions. In simulation, however, a precise analysis of the vehicle behavior in simple maneuvers is relatively easy to achieve by varying the boundary conditions and learning the behavior.

The characterization has to be completed in order to indicate physically realistic boundaries and achievable planned trajectories to the planning module. Only then can the optimal trajectory be chosen from the available options considering efficiency, comfort and especially safety. The perceived safety is extremely important for the passengers as well.

So CarMaker offers all necessary bases for a highly precise vehicle dynamics simulation.

Herrmann: Exactly. The models for tires, steering, chassis, brakes and powertrain with an appropriate modeling depth are the base, but they need to be parameterized of course. Engineers from IPG Automotive who successfully completed numerous projects dealing with the parameterization of virtual prototypes based on measurement data or design parameters can offer support. They can also help with model validation based on measurement drives with physical prototypes for example to validate active components, including motion control and actuators, directly. The vehicle-in-the-loop method can also be applied for validation purposes.

Thank you for sharing your very valuable insights with us!