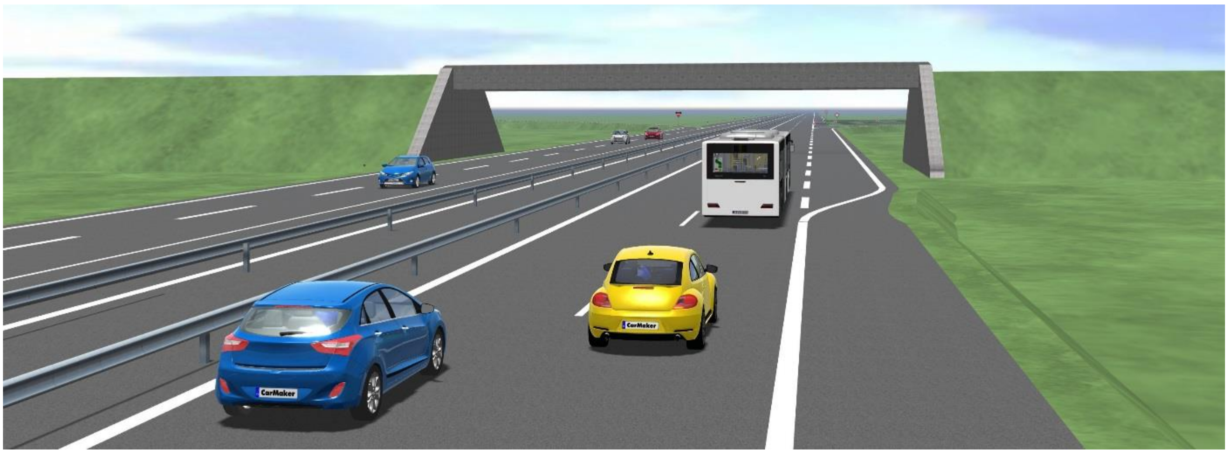

From the Video to the Simulation – Automatic Generation of Realistic Traffic Scenarios for CarMaker *by Dipl.-Ing. Jochen Kramer (FZI)*

The FZI Research Center for Information Technology in Karlsruhe has developed a novel method for taking real driving situations into the simulation. Driving and traffic scenarios are recorded in road traffic with a camera and analyzed using algorithms for object detection. Subsequently, the movements of the detected traffic objects are seamlessly transferred to the simulation environment of CarMaker. Thus, realistic simulation scenarios are generated for the analysis of assistance systems that may help achieve an energy-efficient traffic flow.

You brake, you lose – energy, that is. In order to save fuel, drivers should therefore go with the traffic flow as much as possible and smartly compensate for variations in speed. Especially on freeways and highways, there is a considerable potential to decrease the energy consumption with this strategy. However, traffic flow is a complex system that can be disturbed even by minor changes, as the following situation illustrates: When a truck swerves left in order to overtake on the freeway, the following vehicles often brake abruptly before regenerating the lost kinetic energy as fast as possible once the truck, shortly after, returns to the right lane. This situation occurs fairly frequently in dense traffic. Especially in this case, constant accelerating and braking can cause traffic jams which do not only put a strain on the drivers but also on the environment.

But how can the driving habits of the road users be adapted in order to achieve a smooth traffic flow? For one, each driver contributes to unnecessary changes in speed with a forward-looking driving style. However, each driver is an individual that fails in the face of such a global task – as evidenced by the recurring traffic jams that appear virtually out of nowhere.

Overview	
Client	FZI Research Center for Information Technology at the Karlsruhe Institute of Technology
Challenge	Reproducible testing of driver assistance and Car2X systems in traffic scenarios in which several road users are involved.
Solution	Traffic situations are video-recorded during rides on freeways and rural roads and subsequently transferred to the simulation environment of CarMaker.
Products	CarMaker

Intelligent traffic flow with driver assistance and Car2X communication

Advanced driver assistance systems can offer support by enhancing each driver's perception. In the project EnopTraFlow, scientists at the FZI Research Center for Information Technology at the Karlsruhe Institute of Technology investigate ways to homogenize the traffic flow with the capabilities of driver assistance. They research systems that capture the driving status and the direct surroundings of the vehicle (via radar, lidar, ultrasonic or GPS technologies) and also communicate with other vehicles (Car2Car) or the infrastructure (Car2Infrastructure).

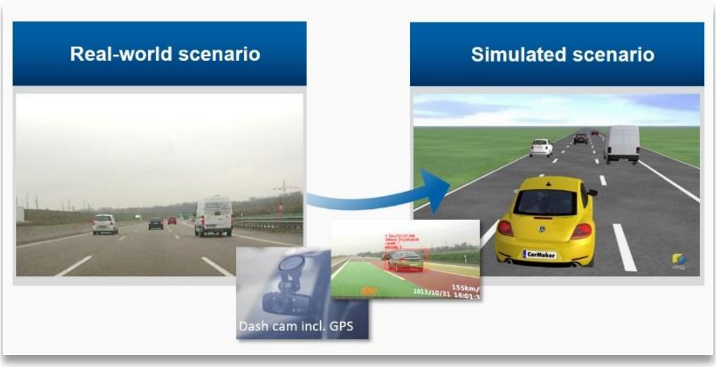

Figure 1: Automatic generation of simulation scenarios from video recordings

Here, simulation with CarMaker serves as an important analytics tool. In the simulation, advanced driver assistance systems can be tested under reproducible conditions in virtual traffic scenarios. To this end, CarMaker offers a comfortable test methodology in addition to the simulation of the driver, vehicle, road, traffic and infrastructure. The generation even of complex test scenarios thus becomes fast and simple. Once they have been configured, they can be reused at any time and automated.

Generation of test scenarios

But which are the important traffic scenarios in which the highly networked Car2X-based assistance systems should be tested? Which process is suited for the derivation of relevant test scenarios? Traditionally, developers work with comprehensive scenario catalogs when validating rule-based driver assistance systems. These are usually derived from the systems' function specifications and knowledge gained in road traffic. In the case of systems that involve cross-vehicle communication, however, this method soon reaches its limits. There are countless external factors that have an influence on the systems and therefore on their modes of operation. The scope of parameters to be considered comprises a multitude of dimensions and is subject to stochastic influences. Moreover, the scenarios derived from theoretical assumptions may differ from real traffic situations.

The researchers at the FZI have therefore focused on an alternative method of taking realistic test scenarios into the simulation. They have developed a method that involves the automatic generation of simulation scenarios based on video recordings and their transfer into the virtual vehicle environment in CarMaker (see Figure 1).

The process comprises the following steps:

- Recording of real-world traffic scenarios
- Pre-processing of the video data
- Object detection via algorithms for pattern recognition
- Determination of the objects and their properties
- Transfer of the scenarios into the simulation

The feasibility of this method was assessed in a study. For this purpose, real-world scenarios on freeways and rural roads were recorded by means of commercial dash cams. In addition, integrated accelerometers and GPS receivers captured the movements of the ego vehicle. The real-world scenarios were subsequently transferred to the virtual world of CarMaker as described below.

Transfer of real scenarios into the simulation

In a first step, the researchers assessed whether the video material was suited for further processing and prepared the video data for image processing. As snow, rain or intense sunlight have a negative effect on the quality of the data, affected recordings were rejected. Furthermore, the images were cropped for image recognition and the distortion of the relevant sections corrected via camera calibration. The pre-processing was finalized with the manual selection of the layer on which the road was located in order to facilitate the use of the corresponding pixels for distance calculation following the object detection.

The object detection that was subsequently performed was based on algorithms from the open program library OpenCV. With these algorithms, the video sequences were analyzed image by image. For each image, objects lists were created listing the detected objects. The object

lists were then logically connected to the captured vehicles, lanes and signs. In the processed image, a bounding box encloses the recognized object.
In order to determine the distances and speeds of the detected vehicles in relation to the ego vehicle, the selected images were transformed into bird's-eye view via the selected layer pixels, i.e. all recognized image pixels

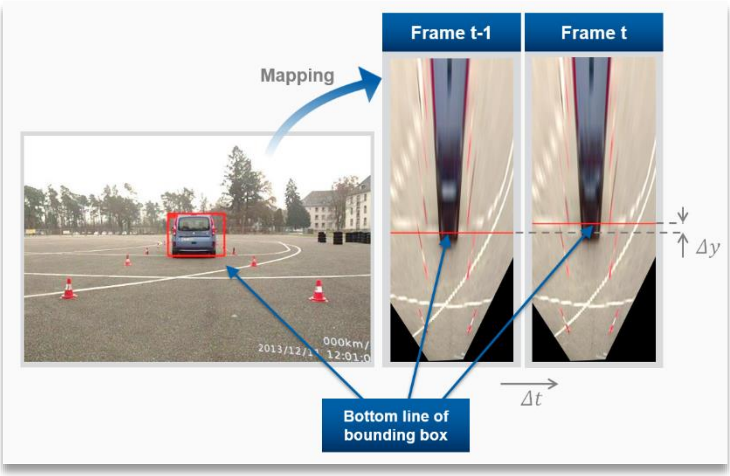

Figure 2: Calculation of the distances and speeds between the ego vehicle and the detected vehicle

and the bounding boxes were mapped onto the road surface. This allowed for a calculation of the distance of the detected object via the margin of the bottom edge of the image and the bottom line of the bounding box. The relative speed was calculated by means of the difference of the intervals between two sequential images and the frame rate (Figure 2).

Using the information on the captured traffic objects as well as the available motion data of the ego vehicle, the recorded traffic scenarios were transferred to the simulation with CarMaker. In order to perform the maneuvers in the simulation, an update of the motion data of the virtual ego vehicle and the virtual traffic object was completed every second with the previously created data structures. Image 3 illustrates the animation of a traffic scenario generated with this method.

Validation of the method

But how valid is the method presented? The researchers of the FZI prepared the following test set-up to assess this: With pylons, they marked off a straight test track 3 meters in width. The pylons were positioned in 5 meter intervals. On this track, an ego vehicle followed a vehicle driving at constant differential speed (reference speed). The driving scenario was recorded with a camera placed inside the ego vehicle. Based on the video data, the distance and differential speeds were calculated during the experiment as described above. After filtering the calculated signals, the mean speed over time and the reference speed were compared. Figure 4 shows the results of this comparison obtained in 30 test drives.

The validation showed that the scenarios can be transferred to the simulation with sufficient accuracy using the developed method. It is a clear advantage that this can be realized with comparatively inexpensive means such as commercial dash cams and accessible tools such as OpenCV and CarMaker. This approach is especially suited for the simulation of longer, complex test scenarios as the driving maneuvers of the ego vehicle and the road users do not need to be configured manually but can be generated automatically from the video recordings. In addition, the use of realistic scenarios is thus ensured for researchers working on new concepts for the regulation of an intelligent traffic flow. CarMaker enables the simulation and systematic analysis of the effects of different driver assistance and Car2X systems.

Outlook

The positive results have encouraged the researchers to refine their approach. They are currently focusing on extending the detection periphery of the video recordings. In addition to the dash cam behind the windshield, a camera positioned behind the rear window is supposed to capture the vehicle's surroundings from the rear perspective. Here, the challenge is the required synchronization of the video streams of both cameras in terms of time and distance. The results of the study presented will also contribute to another research project focusing on the seamless use of real-world driving and traffic scenarios in the simulation. In the project LogDaSim, the FZI, in cooperation with IPG Automotive and X2E, is working on capturing the sensor data (e.g. from the accelerometer or angular rate sensor) in addition to the video recordings as well as in-vehicle information (e.g. from the CAN bus) and their time-synchronous recording. The goal of this project is to gather a maximum of information from the test drives with prototype vehicles or test vehicles equipped with special instruments. A scenario catalog is to be compiled on this basis which

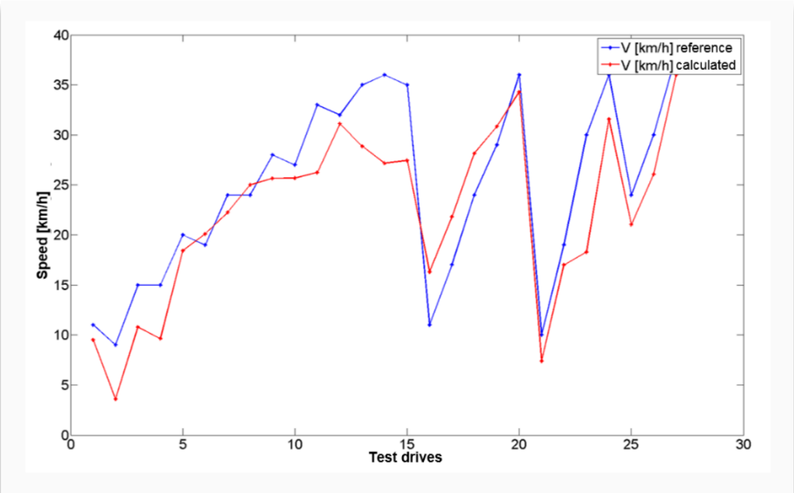

Figure 4: Validation results

can be directly transferred to virtual test scenarios. At the same time, this catalog can be used as a scenario filter in order to analyze the data gathered in real-world test drives with more precision than before. The driving situation and vehicle handling can thus be taken into account in data analysis with high accuracy. The test results obtained in the test drive can be precisely reproduced and analyzed in detail in the simulation with CarMaker.