Experiencing Safety Function Testing

BMW AG researched new development methods to satisfy the demands regarding reproducibility as well as significance in equal measure. The vehicle-in-the-loop method by IPG Automotive was implemented for the development of two functions, lane change warning and side collision warning, in the current BMW 7 Series and 5 Series.

LANE CHANGE WARNING AND SIDE COLLISION WARNING

The two systems, lane change warning and side collision warning, support the driver in the safe performance of overtaking manoeuvres. For this purpose, the lane change warning captures other road users that are present in or approaching the lateral or rear section of the vehicle. If another vehicle is detected, the driver is warned via a lit warning symbol that appears in the wing mirror. Should the driver indicate the intention to overtake by activating the directional indicator despite this warning, it is intensified: The warning symbol begins to flash and the steering wheel vibrates, bringing the imminent side collision distinctly to the driver's attention. If the driver continues to ignore the warnings and steers in the direction of the second vehicle, coming dangerously close, the side collision warning is activated. It correctively steers the vehicle obviously but always controllably in the opposite direction. The dangerous situation is thus defused, **FIGURE 1**.

MAXIMUM SAFETY

Since the functions of both systems act in concert in some situations, a development process is required that ensures the robust use of the overall function in all

traffic situations. A large number of the relevant situations can only be reproduced with great effort in traditional system testing. In addition to reproducibility, safety precautions are a challenge when conducting the tests. In pure simulation, in contrast, precise modelling of the plant, for example the test vehicle, and the available computing power are often limiting factors. The vehicle-in-the-loop method relies on a combination of both worlds. The real roadworthy test vehicle is embedded into a virtual traffic situation. The test engineer can thus adjust the systems in interaction without any risk of a collision with other traffic objects. At the push of a button, the traffic situations can be repeated precisely or modified if required. Relative speeds can thus be varied or distances be reduced, for instance, without any changes in danger when conducting the tests, **FIGURE 2**.

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VEHICLE-IN-THE-LOOP: EXPERIENCING VEHICLE DEVELOPMENT

The core of the method is a test vehicle on an open test area that is equipped with an Inertial Navigation System (INS). In the open integration and test platform CarMaker which is connected to the vehicle, a complete traffic scenario can be created and used as input for the vehicle. The test scenarios can be configured individually (for example with oncoming traffic, road markings or signs). Tests with vehicle-in-the-loop involve the modelling of information on the environment via virtual sensors that is transmitted to the real control unit. The virtual environment can be displayed to the driver by means of a range of techniques, for example via a monitor, see-through technology on AR glasses, etc. This method ensures a subjective assessment as well as high reproducibility which is particularly helpful considering the usual sensor dispersion, especially in the case of complex scenarios.

ADVANTAGES OF THE INTEGRATION INTO THE TESTING CHAIN

The combination of conventional test driving and simulated traffic situations offers advantages in many respects. In addition to safety and reproducibility, aspects such as the effort or costs involved as well as consistency play a role. A positive cost effect for testing is the fact that additional test vehicles and the corresponding test driver are not required. Depending on the scenario to be studied, it is neither required to close the test routes in order to secure exclusive use. Even car parks or connecting roads may be used for testing scenarios in which the test vehicle moves very slowly or not at all. Any necessary coordination with other users of a test area is thus considerably reduced.

The continuity in the test chain can be improved across the board. Vehicle-in-the-loop enables the direct transfer of test scenarios that were already used in the simulation into the test drive. Thus, manoeuvre catalogues can be created, for instance, which can be used at any point in the development. The individual variations of test scenarios can be prepared already in the office and evaluated in real-world testing with short vehicle access times.

REQUIREMENTS FOR TESTING

Testing the described functions entailed a number of specific requirements for the test environment which could be taken into account more readily in the virtual world. In function development, it is a general goal to validate the transition area, that is, in the case of the functions described, the warning behaviour for objects that drive in a staggered pattern in the lane – particularly in the case of short distances between the vehicles. This requires the reproducibility of the test situation to ensure that changes can also be validated reliably in the software. In order to manage the complexity of situations, the simulation environment needs to satisfy several conditions. For example, it needs to allow for the possibility of defining the positions and velocities of the objects in the different lanes and applying different driving manoeuvres to these such as changes in speed or swerving back and forth. The numerous events need to be triggered via different trigger mechanisms such as by reaching a specific relative distance between the ego vehicle and the traffic object or by the test driver reaching a specific target speed. Finally, for the test driver to experience the situation and for the purposes of comprehensibility, the entire scenario including the virtual objects needs to be visualised in the vehicle. The visualisation tool IPG-Movie that is integrated in CarMaker is employed for this.

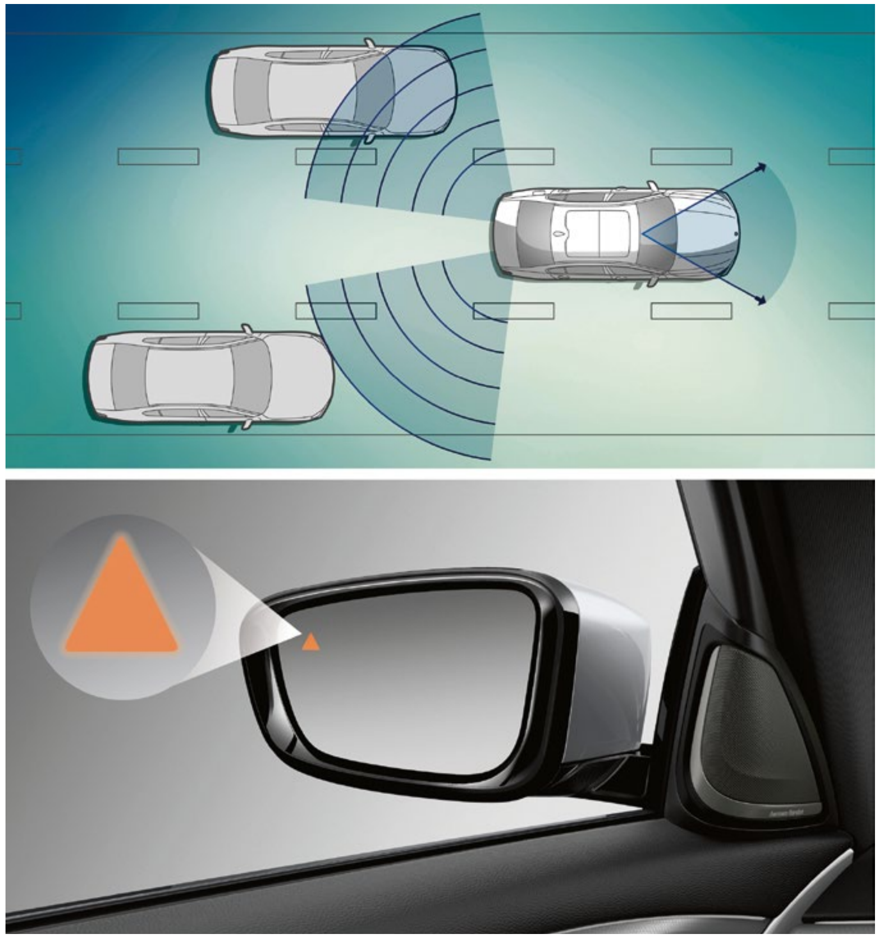

FIGURE 1 Lane change warning: drivers are alerted to vehicles in their blind spot (top) via a warning symbol in their wing mirror (bottom) (© BMW)

TECHNICAL IMPLEMENTATION

The functions side collision warning and lane change warning at BMW draw on the transmitted information of the radars and cameras installed in the vehicle. In the vehicle-in-the-loop setup, these sensors are either fully substituted on the bus level or raw data is entered into the real sensor via a debugging interface. The sensor device itself processes and analyses these data.

The raw data is calculated in real time directly in CarMaker based on virtual sensors. The calculated data is then entered into the real components via Ethernet using UDP. As an alternative, the data can also be entered into the vehicle's communication network on the bus level. This entails a deactivation of the electronic control units and their substitution with a restbus simulation. For this, all information that is required by the functions is dynamically calculated from the environment simulation. The data stems from the different virtual sensors available in CarMaker (for example line or free space sensor) and is processed for the restbus simulation. Signals that are not required by the function under test are populated with plausible substitute values.

The actual device under test is the central driver assistance control unit which is connected with the sensor control units via Ethernet (Some/IP) and CAN. The CarMaker simulation with all sensor calculations runs on a real-time computer (RoadBox) installed in the test vehicle, which can be controlled via a separate host PC, for example a laptop. In addition, the INS as well as the required vehicle busses are connected to the real-time computer in order to determine the vehicle's position, movement and orientation as well as other vehicle quantities and to transmit these to the simulation. The ego vehicle in the simulation fully mirrors the behaviour of the test vehicle in reality, **FIGURE 3**.

This approach allows for the development and validation of both functions, which are available as standard in the current BMW 7 Series and 5 Series, with the vehicle-in-the-loop method.

THE SAFE TESTING OF THE FUTURE

The vehicle-in-the-loop method presented here entails several major advantages for development and testing: The reproducibility of the scenarios facilitates the testing of complex traffic scenarios and allows for the examination of the targeted influence of individual changes to parameters. The safe execution of tests enables the easy testing of safety-critical driving manoeuvres. The simple transferability of scenarios and test cases of other test instances to the vehicle allows for the easy verification of test results in the vehicle. In the development and testing of automated driving functions, the advantages of this method are significant as well. BMW will therefore further enhance and apply this method for the company's proprietary applications.

REFERENCE

[1] Bock, T.: Vehicle in the Loop – Test- und Simulationsumgebung für Fahrerassistenzsysteme. Göttingen: Cuvillier-Verlag, 2008

THANKS

The authors would like to thank Patrick Deisenhofer and Paul Tschritter of IPG Automotive for the technical support and the implementation in the project.

FIGURE 2 The test vehicle in a safe environment without other objects (top) and a exemplary scene (bottom) used as input for the test vehicle (© IPG, BMW)

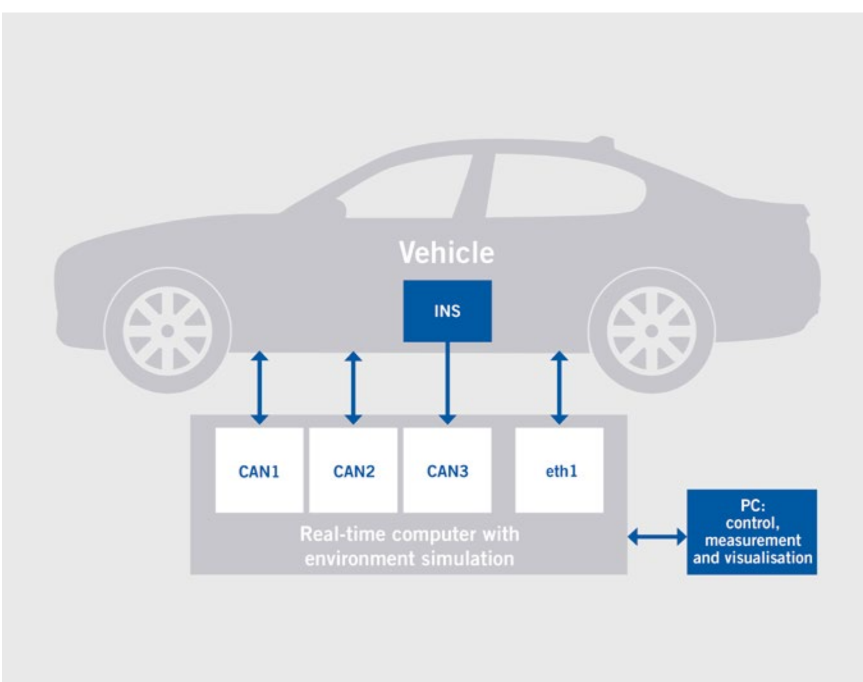

FIGURE 3 Schematic outline of the vehicle-in-the-loop setup (© IPG, BMW)