dSPACE MAGAZINE

2/2019

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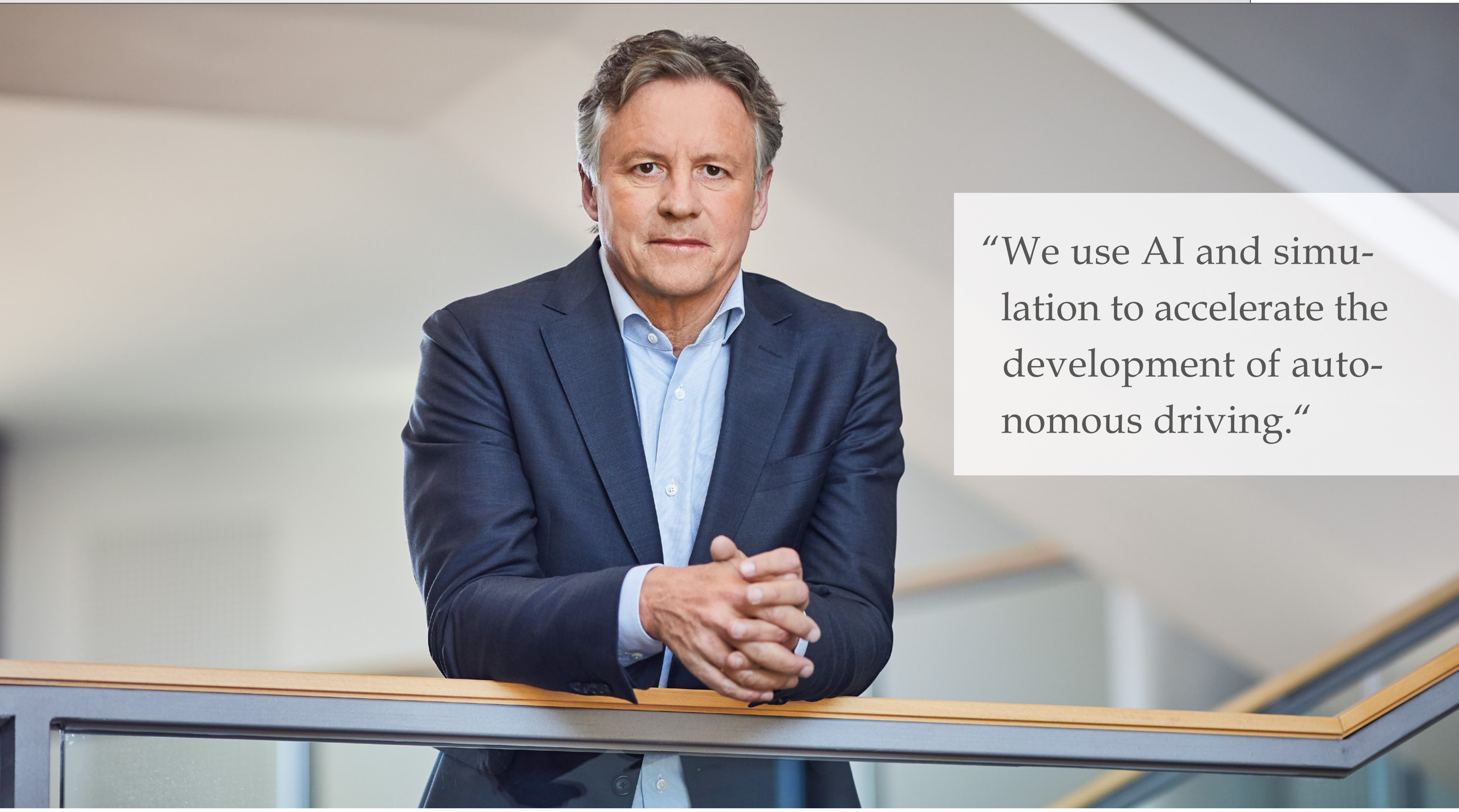
Electric City Bus

> "The electronic high-voltage test system from dSPACE enables us to precisely emulate an electric motor and a battery at power level. This lets us perform reliable tests of power control units under real electrical conditions."
>
> *Andreas Cleven, CTO, Avantest GmbH & Co. KG*

Electric bus, courtesy of Stadtwerke Münster.

Electromobility is picking up speed, particularly in urban and metropolitan areas. Electric city buses provide the low-emission mobility required in these areas. A high availability of buses is indispensable for public transport. Therefore, new drive systems have to be tested particularly thoroughly.

The company Avantest from Alsdorf in North Rhine-Westphalia provides services for the validation of power electronics and electric systems. For this purpose, their test lab is equipped with an electronic high-voltage test system from dSPACE. The system can emulate the motors and battery of a bus at power level, making it possible to test the electronic control units, including the power electronics, with precise real voltage and current.



> “We use AI and simulation to accelerate the development of autonomous driving.“

Dear Readers,

In our new issue of dSPACE Magazine, the great and sometimes disruptive changes in mobility take center stage.

In an interview, Dr. Dirk Walliser, head of research and development at ZF, describes the most important success factors that help ZF access new markets, e.g., autonomous driving, early on. In the article on page 6, ZF also gives us a glimpse of the development and validation of a technology platform for autonomous driving that is equipped with artificial intelligence. For this, the company uses solutions from dSPACE: With our systems, ZF simulates a one-of-a-kind realistic virtual 3-D environment for more than 20 radar, lidar, and camera sensors in real time. This shared success story proves that we are on the right track in expanding our range of development and testing solutions.

The specific projects for autonomous driving in the automotive industry make it quite clear that sizable investments must be made before vehicles can safely and autonomously master city traffic. Since everything is easier when working as a team and following a coordinated and focused approach, Germany’s leading innovators joined forces in the PEGASUS project and defined an internationally applicable process for the efficient and uniform evaluation and validation of driving functions. We also contributed our expertise and tools to the project. A few weeks ago, the partners jointly presented the results. The project also demonstrated that virtual validation is indispensable for meeting the complex requirements of autonomous driving. Our simulation models and our PC-based simulation platform VEOS make a valuable contribution to the field.

Simulation-based validation is also a topic for Sebastian Thrun, a former Stanford professor, founder of Waymo, and CEO of Kitty Hawk, a Silicon Valley startup that works on flying cars. In an exclusive interview with dSPACE Magazine, Thrun emphasizes the importance of virtual tests and AI expertise for the rapid development of autonomous driving functions – a topic on which dSPACE places a strategic focus. We are continuously strengthening our position as a benchmark for industry-proven validation systems. We are also steadily expanding our activities in AI and reinforcing the AI team.

Enjoy your read.

Martin Goetzeler

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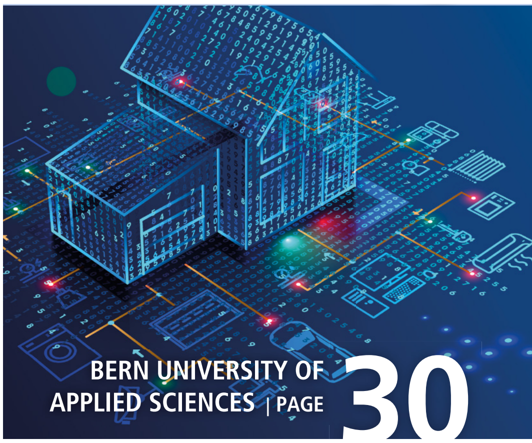

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AI-in-the-Loop

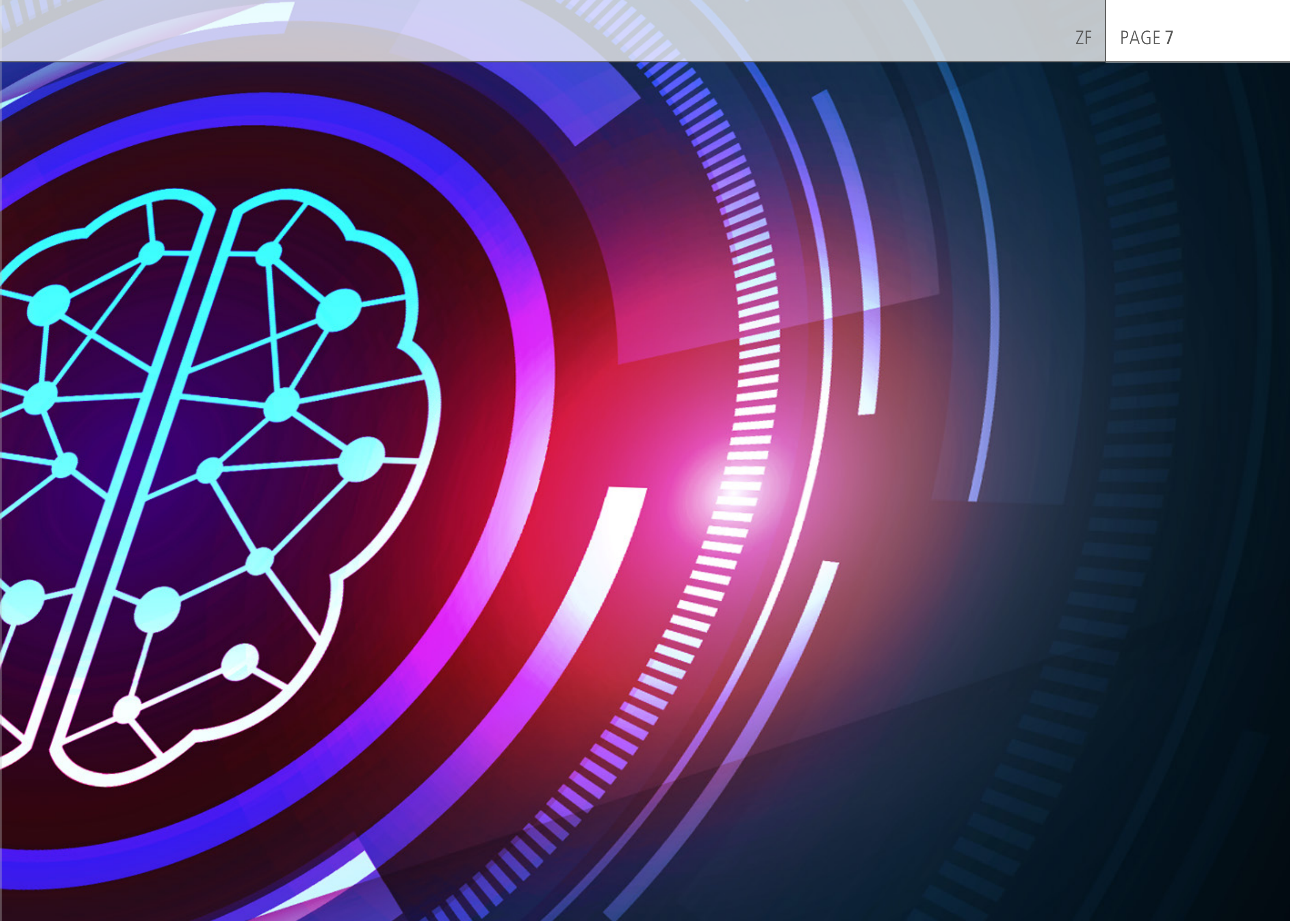
Presenting a new test system for validating an autonomous, AI-based vehicle using realistic sensor simulation

The exciting new challenge developers faced was how to validate a vehicle whose control system makes independent decisions. ZF has met this challenge by combining traditional HIL technology with a sensor-realistic environment simulation. The test system designed for this purpose is based on the dSPACE tool chain.

Getting a conventional driver-operated vehicle with a high level of quality and comfort ready for the road can only be done by expending considerable time and effort during the development and validation phases, especially because cost and time targets always have to be met. Introducing autonomous transport systems to the road brings quality, efficiency and safety requirements to completely new levels. The resulting complexity in the development phase can be overcome only by using particularly lean methods and tool chains. After all, it is not only about successfully introducing autonomous functions to the road, but also of being able to apply them safely under any weather, traffic or visibility conditions.

Autonomous Technology Platform

ZF is driving the development of a technology platform designed for an autonomous, battery-powered people mover. This feat highlights ZF's extensive expertise as a system architect for autonomous driving. To this end, the technology group uses its sophisticated network of experts – especially to determine and process environment and sensor data. The project also demonstrates the performance and practicality of the ZF ProAI supercomputer, which was introduced by ZF and NVIDIA only a year ago. The computer acts as the central control unit in the vehicle. The goal is a system architecture that is scalable and can be transferred to any vehicle, depending on the intended



use, available hardware equipment and desired level of automation.

Design of the Autonomous System

The vehicle is equipped with six lidar sensors, seven radar sensors, and twelve camera sensors for environment detection. A global navigation satellite system (GNSS) ensures that the exact location is determined. All sensor data is combined in the ZF ProAI central control unit. The control unit preprocesses and evaluates the data using the typical steps of perception, object identification and data fusion. The driving strategy is calculated as well. Derived from the above, control signals for the actuators (steering, driveline, and brake system) are generated. Algorithms that are partly based on artificial intelligence (AI) analyze the sensor data. Above all, the AI software accelerates data analysis and improves the precision of object recognition. The aim is to use the wealth of data to identify recurring patterns in traffic situations, such as a pedestrian crossing the road.

Validation Concept

An important validation step for electronic control units (ECUs) is the integration test, which involves testing an ECU combined with all sensors, actuators, and the electrics/electronics (E/E) architecture of the vehicle. This comprehensive view is important to fully validate all driving functions, including the involved components (sensors, actuators), and to evaluate the vehicle behavior. Hardware-in-the-loop (HIL) simulation is an established method for integration tests. Therefore, the development project contains a validation step that uses a HIL test solution.

HIL Simulator Concept

ZF worked with dSPACE to develop the concept for the HIL simulator. The

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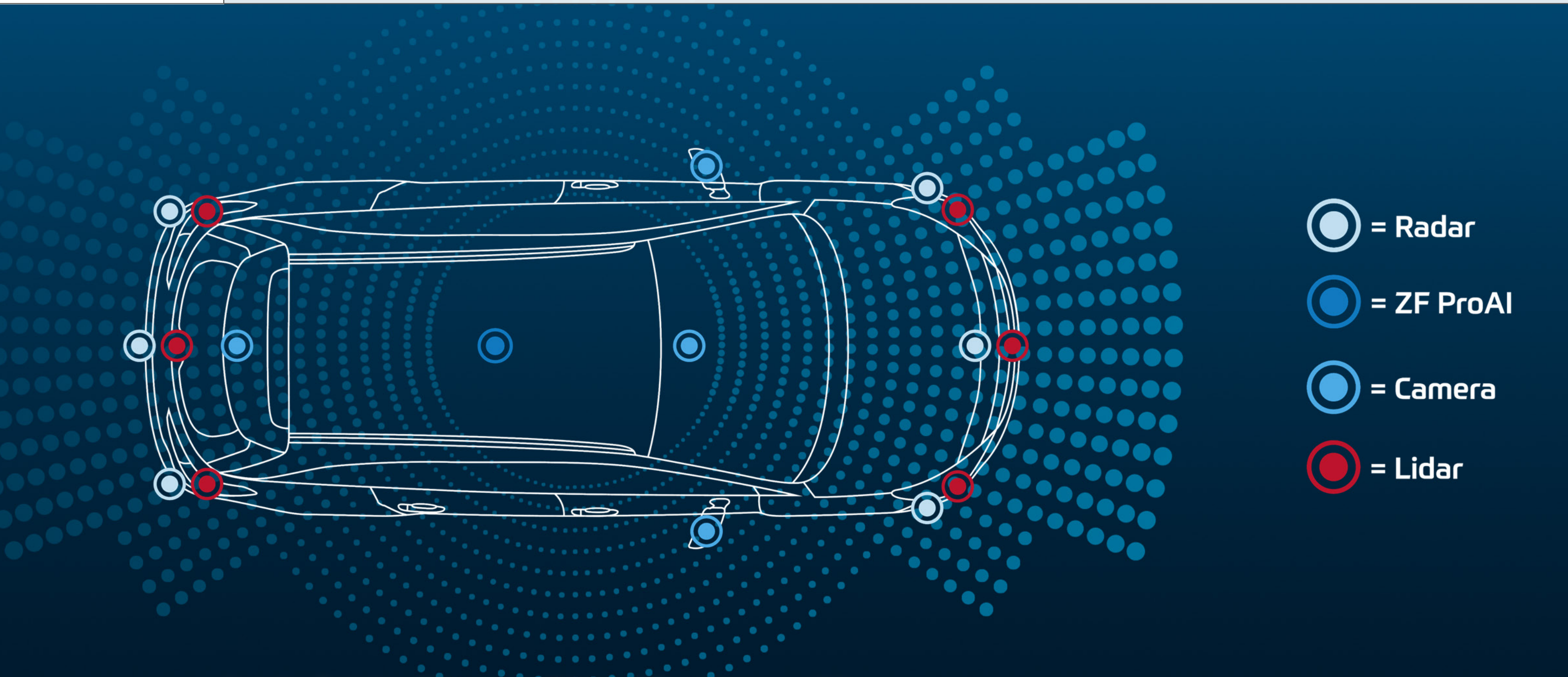
Artificial Intelligence

Artificial Intelligence (AI) is a branch of computer science that addresses the automation of intelligent behavior and machine learning. In general, artificial intelligence is the attempt to reproduce certain human decision-making structures by building and programming a computer in such a way that it can work on problems relatively independently.



Exemplary illustration of the sensor architecture of the autonomous vehicle.

Picture credits: © ZF

simulator is based on SCALEXIO technology and used to simulate the entire vehicle, including steering, brakes, electric drive, vehicle dynamics, and all sensors. As an ECU input, the simulator transmits all sensor signals. On the output side, it provides a restbus simulation as well as the I/O required for HIL operation of the vehicle actuators. To ensure a realistic simulation, the dSPACE Automotive Simulation Model (ASM) tool suite is used to calculate the vehicle and the vehicle dynamics – for the sensors and the vehicle in real time. This poses a particular challenge because AI systems themselves do not have any "hard" real-time properties and linear dependencies. The AI control unit is therefore "inserted" between the synchronized simulators for the sensors and actuators and thus operated exactly as under real conditions in the vehicle.

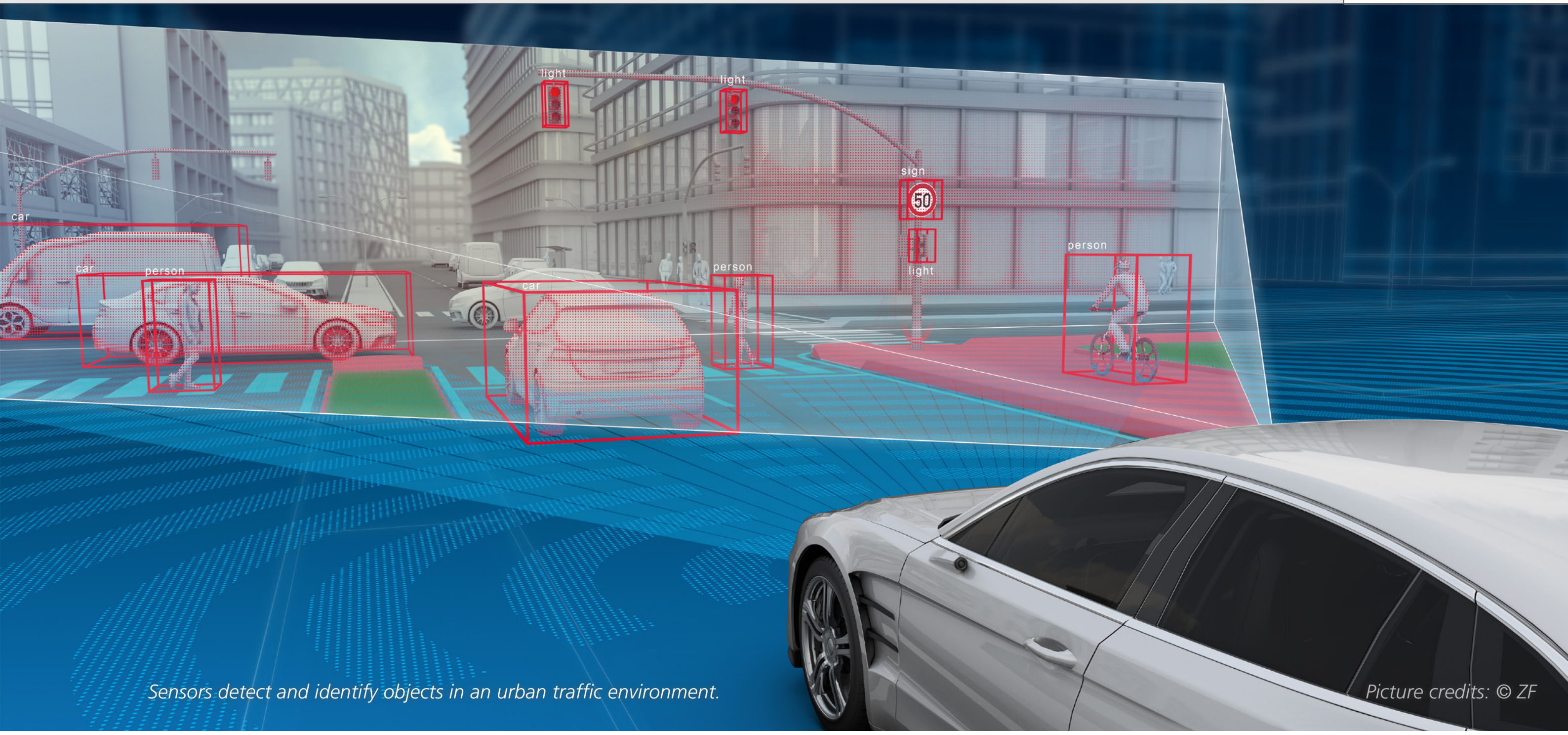
Sensor Emulation

The ZF ProAI control unit is designed to primarily process all raw sensor data directly. In addition, the sensor data is also read in as object lists. The object lists are provided by the ASM Traffic Model as part of a ground truth simulation of the surrounding traffic. For the raw data, all sensors must be emulated as realistically as possible.

Highly Accurate Sensor Environment Simulation

The generation of raw sensor data requires models that calculate the sensor environment based on defined test scenarios and simulate it with physical accuracy. The physical radar, lidar and camera models from the dSPACE tool chain are used for this purpose. These high-precision and high-resolution models calculate the transmission path between the environment and the sensor, including the sensor front end. The ray tracer of the radar and lidar models renders the entire transmission path from the transmitter to the receiver unit and supports multipath propagation. Several million beams are emitted in parallel. The exact number depends on the respective 3-D scene. In both models, the reflection and diffusion of complex objects are calculated based on physical behavior. It is also possible

The sensor simulation platform: The sensor data is simulated on the Sensor Simulation PC. The Environment Sensor Interface Unit (ESI Unit) is used to provide electrical signals in the same way as real sensors would.



Sensors detect and identify objects in an urban traffic environment.

Picture credits: © ZF

> "We rely on the powerful dSPACE tool chain to validate the AI-based control unit of our autonomous technology platform as early as possible and in combination with the sensors and actuators."
>
> *Oliver Maschmann, ZF*

to specify the number of 'hops' for multipath propagation. The lidar model is designed for both flash and scanning sensors. The camera model can accommodate different lens types and optical effects, such as chromatic aberration or dirt on the lens. Since all models are extremely complex, model components must be calculated on graphics processing units (GPUs) to meet the real-time demands. The NVIDIA P6000-equipped Sensor Simulation PC, which seamlessly integrates into the dSPACE real-time system, is used for this purpose.

Generating the Test Scenarios

The most important part of testing autonomous vehicles is generating suitable scenarios that can be used to reliably test and validate functions for autonomous driving. The Scenario Editor is used for this purpose. It can create complex surrounding traffic using convenient graphical methods. These scenarios consist of the maneuvers of an ego-vehicle (the vehicle to be tested including its sensors), the maneuvers of the surrounding traffic, and the infrastructure (roads, traffic signs, roadside structures, etc.). This creates a virtual, realistic 3-D world that is captured by the vehicle sensors. The flexible settings allow for a variety of tests, ranging from the exact implementation of standardized Euro NCAP specifications to individually structured, complex scenarios in urban areas. The 3-D environment, including

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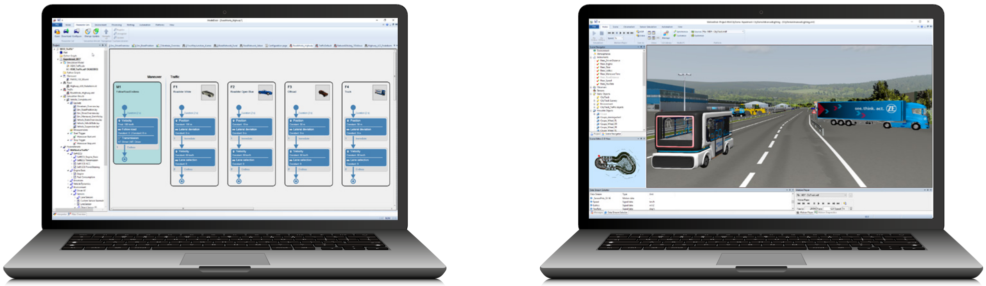
Powerful workstations equipped with ModelDesk, including the Scenario Editor (left), are used for parameterization and scenario generation, while MotionDesk (right) is used to visualize the simulated test drives.



The two HIL racks contain all components for sensor simulation: SCALEXIO real-time platform, Sensor Simulation PCs, and ESI Units. The ZF ProAI control unit to be tested is located in the left-hand rack. The simulator for the actuators is not shown.

Components of Sensor Simulation

The real-time sensor environment simulation is implemented using the following components:

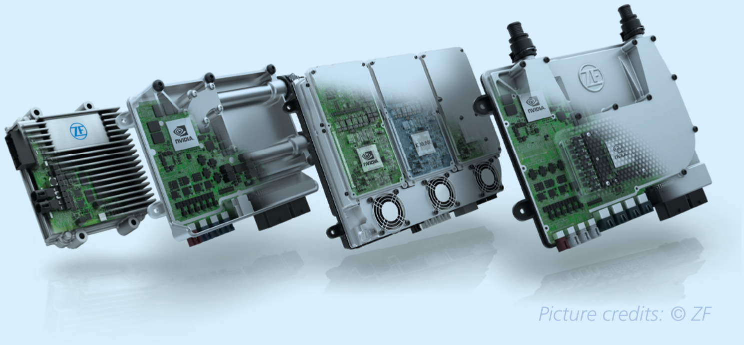
Typ	Number	ESI Unit	Sensor Simulation PC
Lidar	6	1	1
Radar	7	1	4
Camera	12	3	3

ZF ProAI

The ZF ProAI control unit provides high computing power and artificial intelligence (AI) for functions that enable automated driving. It uses an extremely powerful and scalable NVIDIA platform to process signals from camera, lidar, radar, and ultrasound sensors. It understands what is happening around the vehicle in real time and gathers experience through deep learning.

Benefits

- AI-capable
- Computing power of up to 150 TeraOPS (= 150 trillion computing operations per second), depending on the model
- Ready for functions that enable automated and autonomous driving
- Highly scalable interfaces and functions



Picture credits: © ZF

the 3-D objects of the vehicles as well as the sensor environment models, is simulated in real time using ASM. The trajectories of the road users are simulated using the ASM Traffic Model.

Validating the Autonomous Vehicle

The HIL simulator network presented here helps developers analyze the overall vehicle behavior of the virtualized technology platform under conditions that are fundamental for further development. This includes scenarios in test areas where the first vehicles delivered have to find their way completely autonomously. The simulator tests the vehicles' safe driving capabilities even when unforeseeable events occur in rain, snow, or on black ice, to name a few examples. Other typical HIL test methods are added, such as generating faults in the E/E system, i.e., broken wires, short circuits, or bus system errors. These comprehensive, continu-

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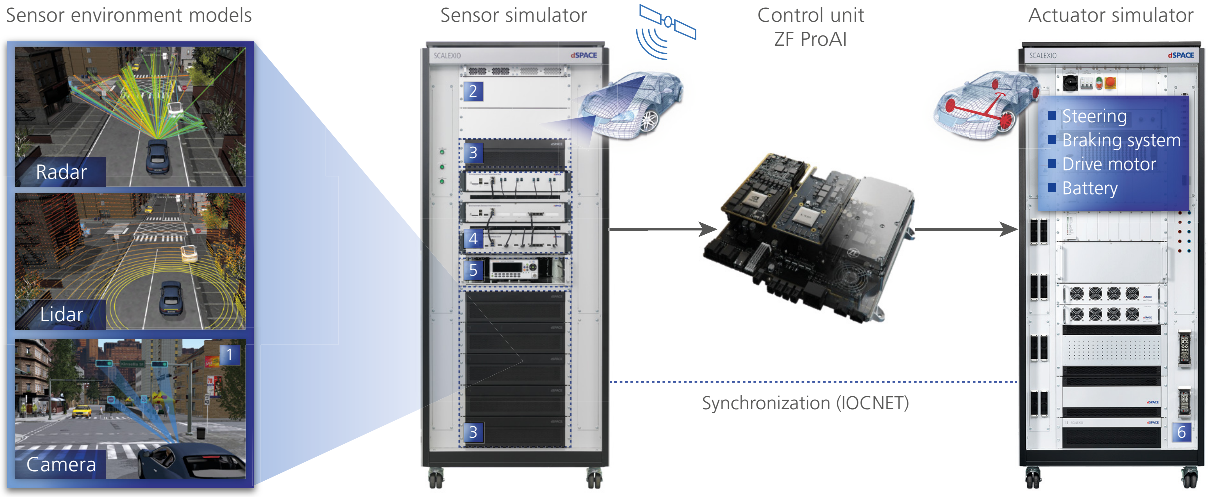
The HIL simulator synchronously generates the surrounding environment of the radar, lidar, and camera sensors, including their front end, in real time and subsequently provides it to the ZF ProAI control unit. ZF ProAI controls the simulated actuators according to the driving strategy.



1) Sensor environment models: Calculate the environment as seen by the sensor, including the sensor front end, with a high degree of realism and high resolution.
2) SCALEXIO + ASM Traffic: Simulate the surrounding traffic.
3) Sensor Simulation PCs: Enable deterministic real-time sensor simulation and issue raw sensor data via a standardized graphics interface.
4) ESI Units: Prepare the synchronized raw data for the individual requirements of the ECU interfaces.
5) GNSS: Provides the synchronized navigation coordinates.
6) SCALEXIO + ASM Vehicle Dynamics, multi-I/O boards, Ethernet interface, CAN FD interface: Simulate the actuators and vehicle dynamics.

Deep Learning

ZF engineers use the simulator to 'train' the vehicle in various driving functions. Training focuses particularly on urban traffic situations: for example, interaction with pedestrians and groups of pedestrians at crosswalks, collision assessment as well as behavior at traffic lights and in roundabouts. In contrast to highway or country road driving, establishing a thorough understanding of the current traffic situation that provides the basis for appropriate actions of a computer-controlled vehicle is much more difficult in urban areas.

> "The sensor-realistic simulation models from dSPACE make it possible to generate raw sensor data from complex 3-D scenarios that our ZF ProAI control unit can process directly. This enables us to conduct complex, realistic tests in early development phases comfortably and cost-efficiently."
>
> *Oliver Maschmann, ZF*

ously expanding test catalogs ensure that the safety-critical autonomous system is efficiently validated in terms of functionality.

Evaluation and Next Steps

The test system makes it possible to create scenarios that are crucial for validating the central control unit and the entire vehicle, especially including corner cases, such as emergency braking maneuvers, which are difficult to replicate in real test drives. The sensor-realistic environment simulation enables precise evaluations of how the sensors detect their environment and what effects this has on vehicle driving. Typical misinterpretations can also be evaluated, for example, when the radar sensor 'sees' only the wheels of a truck driving close ahead due to the sensor opening angle. The flexible configuration and parameterization options allow developers to analyze the effects that would result from changes to the sensor front end. Completely automating all tests will enable developers to conduct extensive test catalogs and, after evaluating the error reports, confirm the successful redesign in regression tests. In the future, the tests will be enhanced by additional environment data obtained during real drives. The entire infrastructure, roadside structures and surrounding traffic are recorded using sensors and then processed to form a virtual test environment in which the vehicle moves, thus further simplifying the generation of complex tests. ■

Oliver Maschmann, ZF

Oliver Maschmann
Oliver Maschmann is project manager at ZF in Friedrichshafen and responsible for the setup and operation of the HIL test benches for full vehicle integration testing.

At a Glance

The Task

- Validating an autonomous, battery electric technology platform
- Testing the AI-based vehicle guidance

The Challenge

- Emulating all sensors in real time
- Setting up a sensor-realistic real-time simulation of the sensor environment (3-D environment)
- Simulating the complete vehicle behavior in realistic traffic

The Solution

- Setting up a real-time platform for the high-precision simulation of radar, lidar, and camera sensors
- Simulating traffic, vehicle dynamics and electric drives in real time
- Conducting tests using easily adjustable scenarios in a virtual 3-D environment

Autonomous Driving is Manageable

In an interview with dSPACE Magazine, Dr. Dirk Walliser, Senior Vice President Corporate Research and Development Innovation and Technology of ZF Friedrichshafen AG, explains why autonomous driving is significant for the company and talks about the possible next steps towards market introduction.

Mr. Walliser, what is the role of autonomous driving for ZF?
Autonomous driving is an example of how developments advance much faster than anybody anticipated even a few years ago. We consider it an opportunity to expand our market position with innovative solutions at an early stage. Our strategic focus at ZF is therefore shifting even more to being a system provider for technologies that will impact the mobility of the future.

What is your development approach for these systems?
The first important step is to identify the market opportunities arising from the sometimes disruptive changes. The systems defined for these opportunities are created with a great deal of agility in development, supported by an experienced team with high development competence. For certain topics, we also draw on existing developments and competencies of partners. Thanks to this approach we were able to quickly set up our new, autonomous technology platform and quickly achieve a high degree of maturity, for example.

What are the application scenarios of the new ZF platform for autonomous technologies?
We are mainly focusing on mobility concepts such as ride hailing – autonomous shuttles that users can call via an app. Initially, these shuttles are planned to operate in non-public places like airports or large company premises. The technology of our platform can certainly be used for other applications such as ports, open pit mining, or agriculture.

What has to be done to get autonomous driving on public roads?
Industry has made a start. They have shown that the technology is manageable. This can also be achieved with validation systems as they are provided by dSPACE. Lawmakers now have to create the right framework for the approval of autonomous vehicles.

What is the special mark of ZF's new test system for the validation of autonomous vehicles?
With the new test system, we validate the central, AI-based control unit of our autonomous technology platform ZF ProAI. Using HIL technology, we can achieve this in early development phases and maintain cost-efficiency even when combined with sensors and actuators. You could say: AI-in-the-loop. This validation is performed during a sensor-realistic real-time simulation, i.e., in a virtual 3-D world taking into account the vehicle dynamics with traffic scenarios that can be flexibly defined. The virtual environment represents a digital twin of real routes and is generated from map data and high-precision vehicle measurements.

Dr. Walliser, thank you for this interview.

Augmented Reality

Vehicle-in-the-loop (VIL): Validating driver assistance systems with synchronous virtual and real test drives

One of the greatest challenges in validating vehicle electronics is finding ways to conduct virtual tests that will simulate real situations as accurately as possible. Using the dSPACE tool chain, Hyundai MOBIS has been able to implement an approach that combines real and virtual tests for optimizing validation processes.

The market for advanced driver-assistance systems (ADAS) and automated driving (AD) technology is experiencing a period of extremely dynamic growth. Functions that assist drivers or support autonomous driving are becoming increasingly complex, even as they are being implemented in today's motor vehicles. When designing and validating electronic control unit prototypes, developers have to have detailed, flexible, and versatile development methods at their disposal. A process based on model-in-the-loop (MIL), software-in-the-loop (SIL), and hardware-in-the-loop (HIL) has proven to be quite effective when it comes to simulation and validation. Due to the complexity of control systems and the precise interaction among various kinds of electronic control units and actuators, exact statements on quality and safety in certain areas can only be made with real test drives. However, real test drives are not fully suited for the validation of ADAS/AD functions because many test scenarios cannot be performed in reality due to the high risk of collisions. Therefore, new testing methods are required, that are sufficiently efficient, economical, and safety-oriented for such cases.

Tests Based on Augmented Reality

What is desirable is an approach that combines the realism and integration depth of real test drives with the flexible, almost unlimited possibilities of the HIL method, i.e., a combination of real and virtual worlds. This combination is often referred to as augmented reality or mixed reality, especially in terms of visual perception. Perception also plays a crucial role in the testing of ADAS/AD functions. Since the functions receive their input signals from radar, lidar, and camera sensors, it makes sense to use the sensors to implement the extended test options. This approach means that sensors capture information from a virtual world and use it to control and steer a real vehicle. Therefore, engineers can let a vehicle travel at high speeds in the real world and – at the same time – have a child dart into the street in the virtual world. The object, which is captured virtually, is then analyzed by the ADAS/AD function, which then triggers appropriate action in the real vehicle. Hyundai MOBIS has adopted this approach and implemented it in collaboration with experts from dSPACE and Hancom MDS Inc., the dSPACE distributor in Korea.

Setting Up the Test Environment

The test equipment includes a dSPACE AutoBox real-time system installed in the trunk of the vehicle under test. A complex simulation that includes vehicles, pedestrians, traffic signs, road surface markings, roadside perimeter and structures, etc. is executed on the real-time system. This virtual world serves as the input for the ADAS/AD control units instead of real sensor data. This is achieved by having an ego vehicle – which basically functions as a digital clone of the real test vehicle – travel through the virtual world. The ego vehicle and the test vehicle are equipped with the

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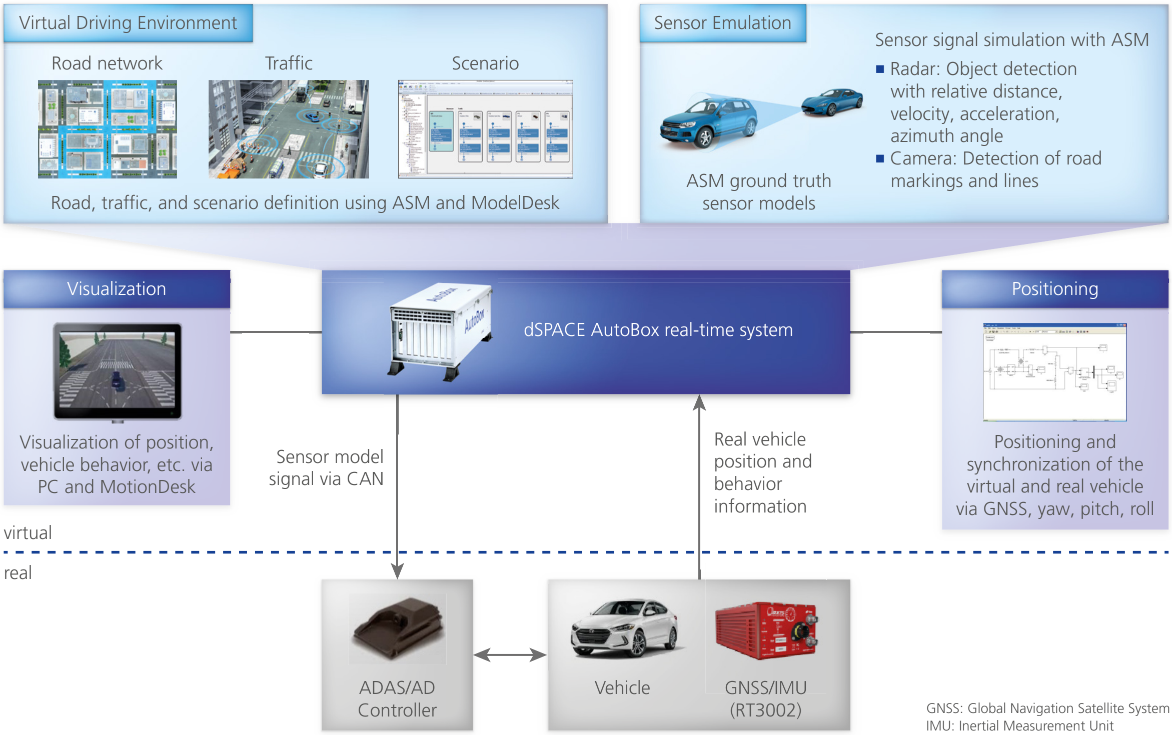
> "We take the vehicle-in-the-loop (VIL) approach when validating ADAS/AD functions because it gives us the combined advantages of real and virtual test drives. The robust real-time system from dSPACE enables us to implement this test method in the vehicle and achieve results that are extremely precise and realistic."

Teaseung Kim, Hyundai MOBIS



Setup of the vehicle-in-the-loop (VIL) system for virtual-real validation.

> "The ASM tool suite supports virtual test drives in complex traffic environments with a high degree of realism so that sensor data can be generated for the validation of our ADAS/AD control units."
>
> *Teaseung Kim, Hyundai MOBIS*

same set of sensors. The simulation is generated with the Automotive Simulation Models (ASM) tool suite. ASM contains sensor models with which radar, lidar, and camera sensors can be simulated. ASM also enables test engineers to define an environment having any number of vehicles, intersecting traffic, pedestrians walking in any direction, etc. for simulation in real time. The simulation is synchronized with the real vehicle via IMU (Inertial Measurement Unit) and GNSS (Global Navigation Satellite System) so that multidirectional maneuvers can be transmitted from the real world into the virtual world. This results in a closed loop, and the test method can thus be classified as vehicle-in-the-loop (VIL).

Vehicle tests with VIL

VIL tests are conducted at the Hyundai MOBIS Seosan Proving Ground, an area providing ample unobstructed space for testing. A driver and a co-driver are seated in the real vehicle, with the AutoBox stowed away in the trunk. When the vehicle is moving, the co-driver launches test scenarios from which virtual sensor data is fed into the real sensors or the ADAS/AD control unit. For example, these scenarios can include obstacles, intersecting traffic or pedestrians walking onto the road. These are the types of scenarios that cannot be adequately

The test vehicle equipped with the VIL system.

Picture credits: © Hyundai MOBIS

Picture credits: © Hyundai MOBIS

The equipment for the real-time simulation of the virtual vehicle environment is installed in the trunk: The AutoBox (on the right) simulates traffic scenarios and then feeds the data into the real vehicle sensors.

tested in the real world because the risk of dangerous collisions is far too high, or where the metrics involved in a collision (crash point, crash speed) have to be analyzed. Test scenarios are drawn from standardized tests such as those in compliance with EuroNCAP, plus dedicated tests for validating special functions. Scenarios of relevance to AEB (Autonomous Emergency Braking) and LSS (Lane Support System) are used to test implemented ADAS solutions. Since Hyundai MOBIS already relies on several dSPACE HIL systems for validating ADAS in the lab, the tests developed for this purpose can easily be applied to VIL validation in the vehicle thanks to the consistency of the dSPACE tool chain.

Innovation and Evaluation of the VIL Approach

The VIL test method combines the advantages of real and virtual testing for the purpose of analyzing and validating ADAS/AD functions. VIL supports tests that deliver far more depth and coverage than is possible with conventional methods, while also reducing the complexity and costs involved in comparable real testing (with dummies, several real vehicles, etc.). Furthermore, VIL tests can also be conducted with a combination of series-produced control units and prototype units. There is also no requirement for modeling the restbus simulation – which might not render realistic behavior – because the real behavior of third-party control units is included in the tests. The high degree of maturity and realism of the tests constantly results in more precise data because it is real latencies that determine system behavior, for example. Moreover, the reusability of MIL, SIL, and HIL test scenarios results in an additional efficient validation methodology which is seamlessly and consistently integrated in the established development process. VIL offers all of the advantages expected from a simple, precise, and reproducible testing method. It can be said that the VIL approach enhances the well-known benefits of HIL by including vehicle-specific behavior, and it results in new validation options with very high levels of realism for ADAS/AD control units. ■

Teaseung Kim, Hyundai MOBIS

The video shows how a test drive with the VIL system is conducted from the driver's perspective. www.dspace.com/go/dMag_20192_VIL

Teaseung Kim
Teaseung Kim is responsible for Autonomous Vehicle Test Development at Hyundai MOBIS in Yongin-Shi, South Korea.

The driver monitors the virtual clone of the vehicle on a display during the test.

Picture credits: © Hyundai MOBIS

Generating stereo images for autonomous test drives with a stereo camera as the observer

3-D
Car Spotting

Hitachi Automotive Systems has set up a development environment to comprehensively test a wide range of functions for autonomous driving. They pay particular attention to the driving functions that require a stereo camera to provide depth information. Virtual test drives are performed on a dSPACE simulator.

Thanks to their two lenses, stereo cameras can capture scenes as 3-D images, exactly like the human eye.

The development activities of Hitachi Automotive Systems in autonomous driving began in 1996, with an initial focus on functionalities such as autonomous emergency braking (AEB) and lane keeping systems (LKS). These activities were followed by applications such as autonomous lane changing and slow vehicle passing. Recent activities include a system called One Fail-Operational System: If an ECU for autonomous driving fails, the One Fail-Operational System technology transfers some functions to the microcontroller of other components, for example, the stereo camera, enabling the vehicle to temporarily continue to drive autonomously and safely. Real test drives were carried out regularly, on public roads and on mock-up city streets on special testing grounds. The tests on the mock-up city streets also examined aspects such as sensor fusion, i.e., the vehicle's ability to generate an overall picture of the traffic situation in real time by combining the data of the various sensors.

Mastering the Challenges of Autonomous Driving

For the development of functions for autonomous driving, it is crucial to test driving functions in combination with the associated sensors (camera, radar, etc.), not only on the road but also under realistic conditions in simulated traffic scenarios in the laboratory. This is absolutely necessary because it is not possible to carry out all relevant test drives on the road, as this would involve driving millions of kilometers with real vehicles to cover all traffic scenarios. Some tests would even be dangerous if performed with a real vehicle. The use of stereo cameras increases the complexity even further, because stereo vision is more complex than single-lens vision. To test stereo cameras, two images with a slight offset in perspective have to be calculated – one for the left lens and one for the right lens of the stereo camera. And above all looms the general demand for ever shorter development times and increasing development quality.

Advantages of Stereo Cameras

Stereo cameras have one decisive advantage over single-lens cameras: They can capture scenes as 3-D images with depth information, exactly like the human eye. With the help of suitable software, it is then possible to analyze the direction of movement of objects and to predict their movement for a few seconds. This way, stereo cameras can detect collision hazards and thus enable the vehicle to avoid the obstacle or brake in time.

Setup for Testing the Stereo Camera

The setup for testing a stereo camera (figure 1) consists of a dSPACE hardware-in-the-loop (HIL) simulator running the Automotive Simulation Models (ASM). The models simulate the overall traffic situation and generate images that are then fed directly into the stereo camera via an interface board, i.e., the images are not filmed by the camera but fed electronically into the electronics behind the lens. The left and right images are synchronized within microseconds using the shutter signal of the stereo camera. This accuracy is required to ensure that the stereo camera interprets the data as realistic information about a running traffic scenario. >>

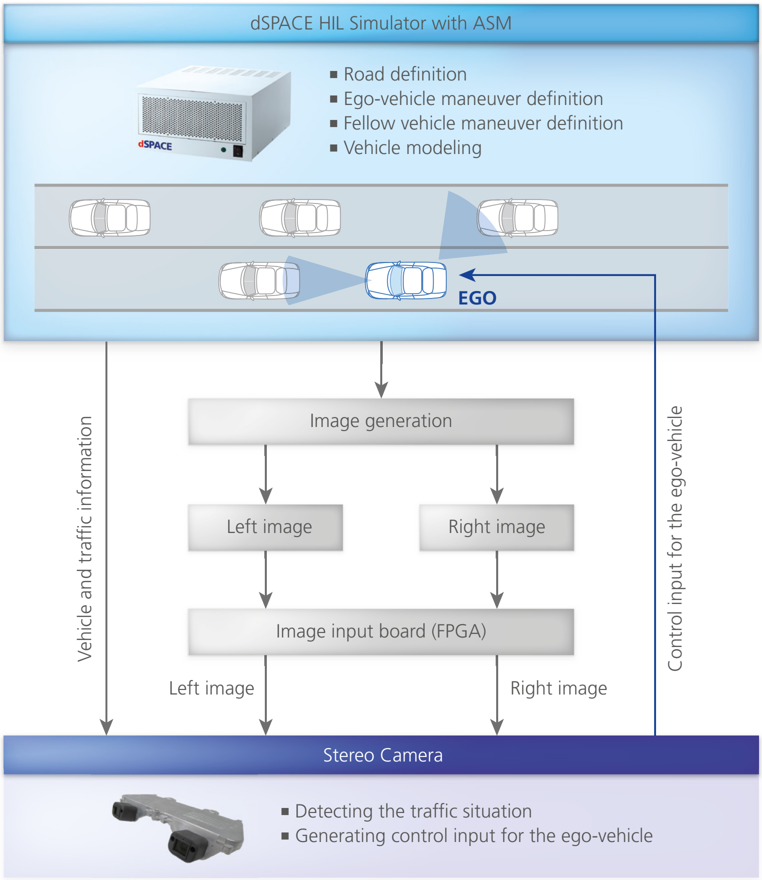


Figure 1: The setup for testing the stereo camera. It consists of a dSPACE simulator running a traffic scenario. The right and left images are created on the basis of this scenario and then fed into the stereo camera.

Setup of the Simulator for Autonomous Driving

To test the functionalities of the stereo camera in interaction with the other sensors in a realistic traffic situation, the test setup has been extended to a simulator for autonomous driving (figure 2). The central element of the setup is still the dSPACE simulator running the vehicle dynamics and traffic models of the ASM tool suite. This makes it possible to simulate a complete, realistic traffic situation with an ego-vehicle, including the sensors and the surrounding traffic. Hitachi Automotive Systems used ModelDesk to define and manage all parameters of the traffic scenario. Using the 3-D animation software MotionDesk, they visualized the traffic situations. This real-time 3-D animation gives users a clear understanding of the vehicle behavior during the driving maneuvers. With the experiment software ControlDesk, all data can be captured, recorded, and displayed in user-defined layouts, which can be set up using the comprehensive set of ControlDesk instruments. The sensor data generated in the simulator is transmitted to the real vehicle devices, i.e., the gateway and the ECU for autonomous

> "The seamless dSPACE tool chain offers the right tools for efficiently implementing our vision of an integrated simulation process for applications for autonomous driving."
>
> *Michio Morioka, Hitachi Automotive Systems*

Takayoshi Chiyoda
Takayoshi Chiyoda is an engineer in the Autonomous Driving Technology Development Department of the Advanced Mobility Development Center, Technology development Division at Hitachi Automotive Systems, Ltd. in Ibaraki, Japan.

Mitsugu Katayama
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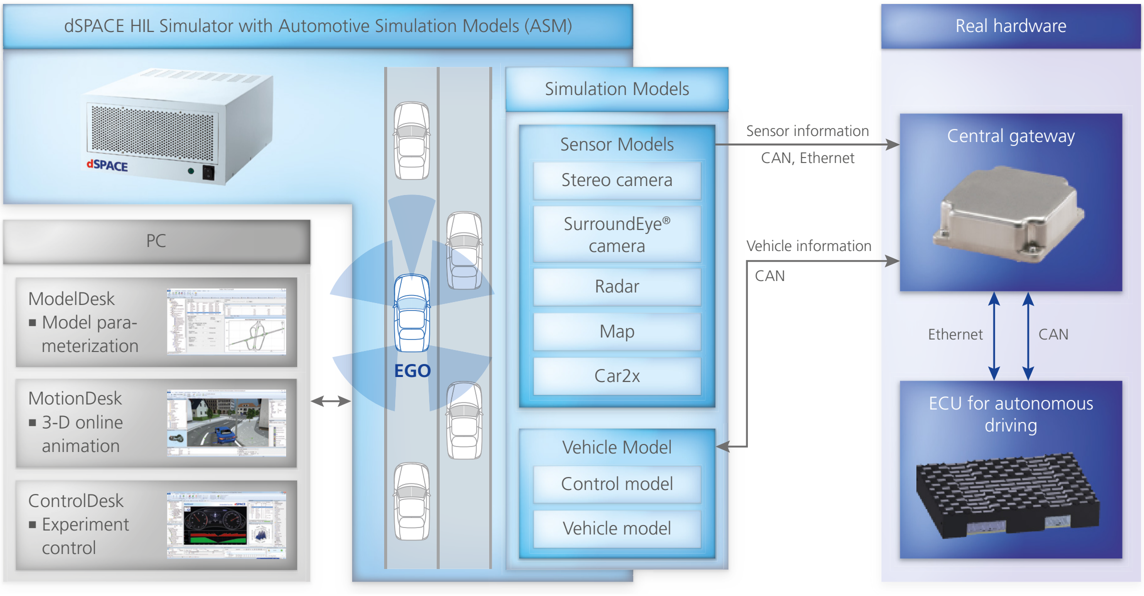

Figure 2: A traffic scenario created using the Automotive Simulation Models (ASM) is running on a dSPACE simulator. Based on this simulation, the real vehicle hardware makes its decisions, which are fed back into the dSPACE simulator.

> "The combination of a dSPACE HIL simulator and ASM makes it easy to create a detailed traffic scenario and test ECUs for autonomous driving."
>
> *Ryota Mita, Hitachi Automotive Systems*

driving (AD). Via the gateway, the sensor data is fed into the AD ECU, which makes its decisions on the basis of the simulated scenario and produces instructions. The instructions are then fed back into the vehicle model in the simulator. With this setup, complex driving function can be tested and validated in the lab.

Vision for the Future

Hitachi Automotive Systems is already working on their vision for the future, namely an integrated simulation process from scenario generation to test automation to result analysis. This process will make it possible to create and execute multiple complex scenarios in a cloud environment in parallel and automatically. Another important aspect will be an advanced function for the analysis of simulation results. ■

Takayoshi Chiyoda, Mitsugu Katayama,
Ryota Mita, Michio Morioka, Shoji Muramatsu,
Hitachi Automotive Systems

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Automatic test environment for body control modules leads to better quality and efficiency

Smart Automation

At Magneti Marelli, teams from the USA and Italy have developed a new test environment for the validation of their body control module (BCM). The BCM is an electronic control unit that controls the operation of a wide range of auxiliary functions, such as power windows and immobilizer systems. To support the extensive tests required early in the development process of the BCM, the teams recently introduced dSPACE AutomationDesk to their testing process.

Solving the technological challenges of future mobility is at the forefront of Magneti Marelli's efforts. Since 1919, this international manufacturer of high-tech systems and components has been committed to finding solutions that help advance the progress and evolution of the automotive world. The drive to find the best ways and methods to improve quality also extends to Magneti Marelli's testing processes. For their embedded electronics, this innovative company is turning to automated test sequences for better efficiency and easier configuration, debugging, and maintenance.

New Test Environment for BCM Validation

In the Lighting & Body Electronics group of Magneti Marelli Automotive Lighting, teams from the USA and Italy have developed an efficient testing process that enables engineers to automatically update parameter values in test cases. The teams are currently using this new test environment, which they have named Diagnosis Automatic Test Environment (DANTE), to validate their body control module (BCM). The BCM is an electronic control unit (ECU) that controls the operation of a wide range of auxiliary functions related to the body of the vehicle. This vehicle body equipment includes power windows, internal lights, immobilizer systems, central locking, etc. The BCM com-

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> "An important benefit of AutomationDesk is its ability to reuse test scripts with new parameters."
>
> *Basel Samman, Lighting & Body Electronics System Validation Manager at Magneti Marelli Automotive Lighting LLC*

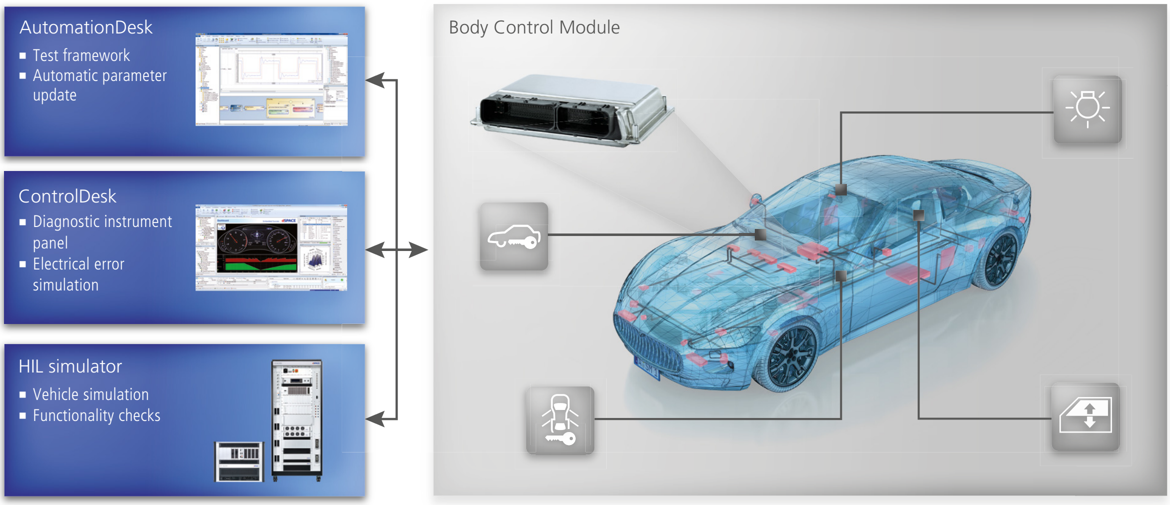

Figure 1: At Magneti Marelli, dSPACE tools are used for testing body control modules (BCMs). The BCM controls the operation of auxiliary functions related to the body of the vehicle, such as power windows, internal lights, immobilizer systems, and central locking.

municates with other ECUs via a vehicle bus (e.g., CAN/LIN) to control the behavior of the electronic systems. It can also detect malfunctions in wiring and in components.

Functional and Diagnostic Testing

Because the BCM controls many capabilities in the vehicle, it has to be extensively tested early in the development process to verify that the functions of the vehicle body equipment are performed properly and that requirements and technical specifications are consistently met. Two types of tests are performed on the BCM: functional testing and diagnostic testing. Functional testing entails translating requirements into a test that is then validated. This can be done by assigning certain values to the variables involved and checking if the BCM reacts correctly. Diagnostic testing includes various tasks, such as checking network traffic between internal functions and connected ECUs, as well as checking the validity of diagnostic trouble codes (DTCs). This is where the teams are focused on improving their testing process.

Solution to Diagnostic Testing Challenges

Prior to developing DANTE, the teams were experiencing limitations in their diagnostic testing process. Every time software was modified, a new library block had to be created as well as new parameterization. This process was time-consuming. To solve the problem, the teams introduced AutomationDesk, the test automation software from dSPACE, to implement two strategic changes:

1. They established a customized test framework that enables test engineers to automatically update various test parameters.
2. They automated a process for importing different diagnostic input files with a Microsoft® Excel® sheet, which greatly simplifies test configurations.

The result was a fully automated process for diagnostic testing. “Now everything is handled automatically, as the Excel sheet seamlessly parameterizes library blocks. No script rewrite is required,” said Basel Samman, Lighting & Body Electronics System Validation Manager at Magneti Marelli Automotive Lighting LLC. “Equipped with this, our test engineer is able to easily write validation routines, as the test configuration is less complex with

> “With AutomationDesk, debugging and maintenance become easier, regardless of the number of diagnostic trouble codes that have to be addressed.”
>
> *Basel Samman, Lighting & Body Electronics System Validation Manager at Magneti Marelli Automotive Lighting LLC*

AutomationDesk. Now we have one single test sequence for all diagnostic trouble codes.” Samman explained that with AutomationDesk, diagnostic input files such as DTC configurations or the Vector description files CDD and DBC can be automatically imported and configured. The test engineers can now automatically update various parameters for diagnostic trouble code test sequences. By attaching CAN trace as log data to test result data, debugging is made much easier. “An important benefit of AutomationDesk is its ability to reuse test scripts with new parameters,” Samman said. “With AutomationDesk, debugging and maintenance also become easier, regardless of the number of diagnostic trouble codes that have to be addressed.”

Several dSPACE Tools Used

In addition to AutomationDesk, the diagnostic testing process with DANTE also includes dSPACE hardware-in-the-loop (HIL) simulators and ControlDesk, the dSPACE experiment and visualization software. The HIL systems are used to simulate the vehicle connected to the BCM and to test different functionalities. Standardized ASAM ODX (Open Diagnostic Data Exchange) files are generated from proprietary files, such as CDD. Using the diagnostic instrument panel from ControlDesk, these ODX files are then used as input to send diagnostic commands. This is done both manually and by means of AutomationDesk scripting, using the logical link name of the diagnostic instrument. The teams also use ControlDesk for the definition and execution of electrical error simulation, which is then automated with AutomationDesk. As part of its automated testing environment, the Lighting & Body Electronics group currently has eight PHS-based and two SCALEXIO-based HIL systems in the USA, Italy, and India. Additional systems are used by other groups at Magneti Marelli. The company plans to extend its automated testing environment to lighting ECU applications in the future.

Conclusion

To test their BCMs, the teams from Magneti Marelli developed customized solutions in AutomationDesk. It is the tool’s wide range of features as well as its flexibility to extend functionalities as required that considerably helped the teams when optimizing their testing process. The number of errors was reduced significantly, and test configuration as well as maintenance and debugging tasks have become much easier and less time-consuming, providing Magneti Marelli with an efficient process for BCM testing. ■

With the kind support of Magneti Marelli

Magneti Marelli supplies a wide range of automotive systems and components to automobile manufacturers around the world. These products include:

- Electronic systems, such as instrument clusters, infotainment and telematics as well as lighting and body electronics
- Automotive lighting, i.e., front and rear lighting systems
- Powertrain components, such as engine control systems for gasoline, diesel, and multi-fuel engines as well as automated manual transmission gearboxes
- Suspension systems, such as shock absorbers and dynamic systems
- Exhaust systems, such as catalytic converters and silencing systems
- Electronic and electromechanical systems for motorsport applications

Geely and Volvo are jointly developing the vehicles of tomorrow on their Compact Modular Architecture platform.

Modular Fascination

Modern vehicles have to be safer and make driving more fun, while also being more economical in consumption. Efficiently developing these new vehicles requires the latest simulation methods. For the development of an innovative hybrid drive for a new SUV, Geely and Volvo relied on the SCALEXIO real-time system.

To develop new vehicles more efficiently and launch them on the market faster, Geely and Volvo have jointly designed a new vehicle platform for compact vehicles in the last years: the Compact Modular Architecture (CMA). The two companies also share this platform with the Geely subsidiary Lynk & Co. The company's first vehicle, the Lynk & Co 01, was developed using the platform and has already hit the road. With the CMA, Geely has created a highly versatile vehicle platform that, as a compact basis, allows for a modular design. Only the distance between the center of the front wheels and the pedal box is fixed. Everything else can be configured according to the intended vehicle design, including the drive types. In the coming years, the CMA will serve as a platform for vehicles with classic gasoline and diesel engines as well as for hybrid and all-electric vehicles.

Picture credits: © Lynk&Co

The Ambition: Building the Best Vehicle

For the development of the Lynk & Co 01 SUV, Geely gave the development team only three requirements, but they were nothing short of ambitious:

- They were to design the best vehicle in the entire industry.
- They had to develop a global vehicle.
- They had to take a different approach than the rest of the automotive industry.

As a result, the hybrid version of the Lynk & Co 01 features an innovative drivetrain based on a three-cylinder miller engine and a hybrid seven-speed dual clutch transmission (7DCTH) including an electric motor. A look at the engine management system for the current hybrid engine illustrates the complexity of the task (figure 1). For example, a number of functions had to be integrated into the system, including transmission control and the hybrid power management system. This was the only way to ensure that they would reliably guarantee the required safety and desired comfort at all times, under all operating conditions.

Test System for Powertrain Management

Geely and dSPACE have developed a closed-loop test system to comprehensively test the functions of the engine management system and transmission

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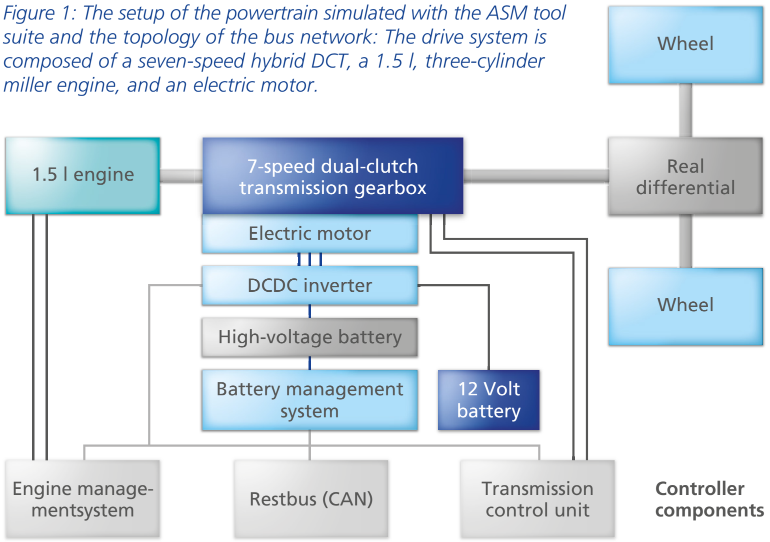
> "With the SCALEXIO real-time platform and the ASM simulation tool suite, we were able to master the challenges of economic efficiency and functionality involved in developing and testing the ECUs for a new hybrid drive."
>
> *Hui Yu, Geely*

Figure 1: The setup of the powertrain simulated with the ASM tool suite and the topology of the bus network: The drive system is composed of a seven-speed hybrid DCT, a 1.5 l, three-cylinder miller engine, and an electric motor.

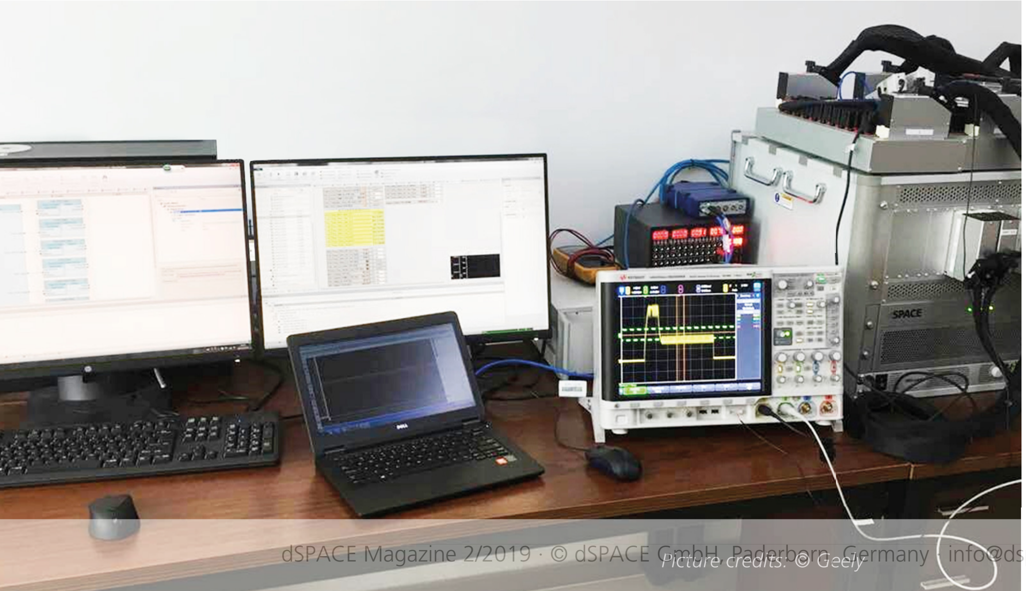


control. The aim was to test the fast, highly integrated controls of engine and transmission controls reproducibly under dedicated test conditions. For this it was necessary to simulate the engine and motor, the turbocharger, and the seven-speed dual clutch transmission with high precision. Such complex control systems cannot be implemented at a reasonable cost and within a suitable timeframe without specially tuned high-precision simulators. Even the design and parameterization of vehicle models with particularly high accuracy requirements in a hardware-in-the-loop application pose major challenges. In search of a reliable and powerful simulation solution, Geely finally chose the SCALEXIO real-time platform and the Automotive Simulation Models (ASM) tool suite, both from dSPACE. The compact SCALEXIO system has extensive input/output functions and high computing power (figure 2). Specific actuators are integrated in the simulation as real loads.

Open Simulation Models for Added Value

During systemic model design, the team used the advantages of the open Automotive Simulation Models (ASM), such as ASM Gasoline Engine InCylinder, for the engine simulation with operating cycle resolution. The components of an ASM model can easily be supplemented or replaced by customer-specific models. This makes it possible to adapt the model properties to individual projects, while the standardized interfaces of the ASMs simplify model extensions. It was important for all participants to parameterize the model as accurately as possible by using engine test bench measurements to realistically simulate the changes in engine temperature and pressure in the cylinder. A semi-physical simulation of turbocharging was another vital aspect in this project to plausibly simulate the required sensor data and validate the control strategies (figure 3). In addition to simulating the engine, the developers focused on parameterizing the transmission model. The ASM model simulated a complete seven-speed dual clutch transmission, including the hydraulics circuit and mechanical structure. Because the real transmission control unit was not yet available, Geely used the transmission

Figure 2: The dSPACE test bench consists of a SCALEXIO simulator and a drive load box. The compact system has a small footprint. It is easy to operate from the host PC. The signals are measured with an oscilloscope.



Picture credits: © Geely

control unit from ASM to simulate the control logic of the actuator. This enabled them to implement and suitably validate the gear switch requirements of the engine management system.

Central Simulation Control and Data Acquisition

A core component of the simulator system is the experiment software dSPACE ControlDesk. It lets the developers capture, modify and calibrate data online, and replay it offline. The software provides a comprehensive set of tools for setting up a user interface for the experiment that is close to the actual instruments in the real vehicle. In addition, the animation lets users better observe and comprehend the simulated physical processes (figure 4).

Joint Success

To validate the complex management systems of the powertrain in hybrid vehicle variants of the new CMA platform, Geely relies on a simulation solution built with the SCALEXIO simulation platform and the ASM tool suite from dSPACE. The powerful simulator supports engineers both in developing new functions and in their validation. Together, Geely and dSPACE were able to develop precise plant models for the demanding simulation tasks, thereby creating a realistic test environment.

Thanks to the dSPACE technologies and services, the Geely development team was able to implement the hybrid drive. A successful project whose result is already safely roaming the streets in form of the Lynk & Co 01. ■

Xueying Xu, Hui Yu, Geely

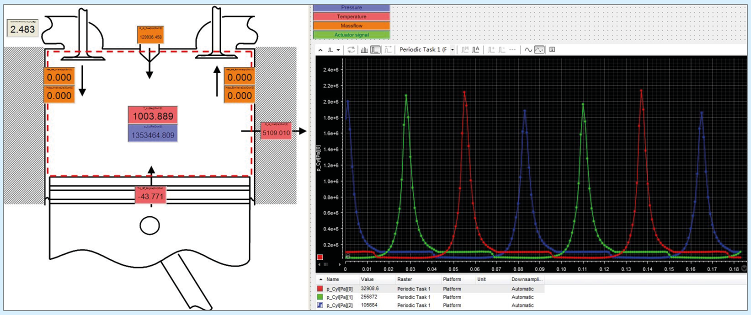


Figure 3: Real-time simulation of the pressure change in the 1.5 l three-cylinder engine with the ASM Gasoline Engine InCylinder Model.

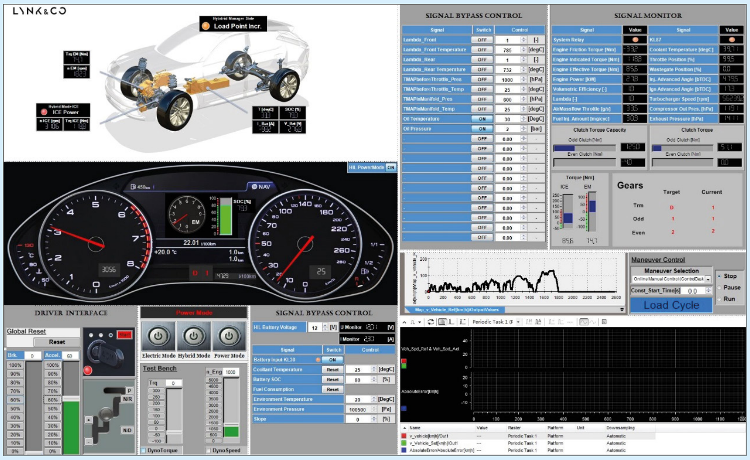


Figure 4: A user-friendly interface was designed using the many instruments of the ControlDesk experiment software, making realistic simulation of all processes very convenient.

Xueying Xu
Xueying Xu is a lead EMS System Development Engineer in the Validation Team at Geely in NingBo, China.

Hui Yu
Hui Yu is senior HIL test engineer in the Validation Team at Geely in NingBo, China.

The Bern University of Applied Sciences relies on a HIL lab environment for the realistic and reproducible testing of system components found in modern private households. The dSPACE MicroLabBox is used to control individual systems and the emulation environment.

Give and Take

Lab Testing of Load Flow Management for Prosumer Households

Modern households are becoming more and more complex due to advancements in connectivity. Photovoltaic systems, storage batteries, heat pumps and, energy management systems (EMS) all interact with each other and consequently increase the self-consumption of the generated energy. These types of households are called prosumers because they consume electrical energy while also producing their own energy at the same time. Energy management systems used to intelligently control the flow of energy will enable prosumers to play a more active role in the future electrical energy market. For example, these management systems can control the energy input or output of batteries, or even switch heat pumps on or off. To do this, however, they require access to various interfaces and communication protocols. In addition to optimizing energy consumption in the home, an EMS can also stabilize the voltage quality in low-voltage grids. The research, development, and certification processes of relevance to both proven and innovative components for modern households have to be completed in controlled environments on test benches that support the integration and grid connectivity of various electrical devices. These laboratory environments are ideal for examining and optimizing the interaction of components and their impact on low-voltage grids in realistic scenarios.

Modern Households as HIL Test Benches

The Prosumer-Lab at the Bern University of Applied Sciences replicates a modern household in a laboratory environment. The hardware-in-the-loop (HIL) test bench supports the analysis, comparison, and development of system components under controlled and reproducible conditions. This is possible thanks to a combination of software simulation and hardware emulation using system components such as batteries and inverters that are readily available in the market. Researchers are able to replicate the flow of electrical and thermal energy in a household equipped with a photovoltaic system, heat pump, storage battery, and energy management system right up to the grid access point with real voltage and current. The following questions are of interest to university researchers: How can the flow of energy inside a building be guided and controlled intelligently with an energy management system? How do decentralized energy sources and storage batteries impact the stability of power grids? How can decentralized prosumers be integrated in the low-voltage grid in ways that are feasible in the market?

Modular Test Bench with High Flexibility

The computers in the Prosumer-Lab emulate household appliances (heat pump, hot water heater, cooking stove, etc.) and their consumption within the laboratory grid up to a maximum power level of 50 kVA – this emulation is reproducible. Another emulation device is used to create an electrical power grid in which voltage quality parameters such as harmonic oscillation or voltage dips can be set to take effect at any particular time. Eight photovoltaic (PV) emulators with up to 5 kW each are used to emulate PV systems in various roof positions. Additional components such as the storage battery, the PV inverter, and the EMS are real and installed on-site so that they can be tested under real-life conditions. The simulations in the test bench are specifically intended for use in the computation of thermal profiles and the simulation of thermal components, which cannot easily be integrated in the test bench in ways which are real and reproducible. A thermal building simulation, for example, determines

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Picture credits: © BFH

Batteries, emulators, and circuit and control technology for load flow management.

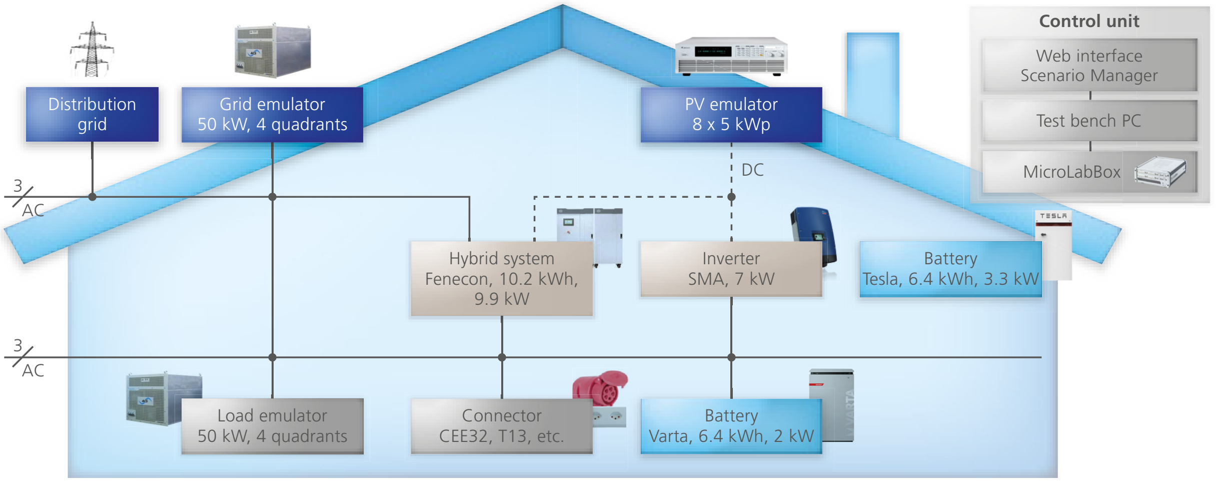
> “Thanks to its many analog and digital interfaces, various communications protocols, and bus systems such as Ethernet, the MicroLabBox offers enormous flexibility for the huge number of fast-changing requirements in today’s research environment.”
>
> *Steffen Wienands, Bern University of Applied Sciences*

the profile for room temperatures, hot water requirements, heat pumps, or energy losses in thermal storage units. Figure 1 shows the intentionally modular and flexible design of the test environment that supports an easy activation and deactivation of components. This concept enables the emulation of households with various system components in the Prosumer-Lab. The emulation devices and the real system components are equipped with a wide and diverse range of interfaces and communication protocols. Connecting all of the test devices to build a network is a major challenge. Furthermore, an overarching control program has to be written for managing all of the individual emulation devices. This program must function in real time and run with a resolution of 10 kHz.

Central Control of the Test Bench Hardware

The MicroLabBox provides a high level of flexibility for the test bench thanks to its many interfaces for Ethernet and RS485, as well as analog and digital I/O. Figure 2 shows the large number of diverse interfaces that enable the MicroLabBox to manage the devices of the test bench. The values defined for the devices are computed by the Scenario Manager or the simulation software before they are applied to the test bench via the MicroLabBox. Once a comprehensive system has been completed, the control algorithm for the load emulator is quite easy to implement in MATLAB®/Simulink®. The control algorithm increases the precision of the defined target value on the emulators and enhances their functions to enable the application of electrical current and voltage characteristics. The 10 kHz resolution required to do this is achieved without the need for any FPGA programming. The MicroLabBox serves as the central control unit for all of the test bench devices – it communicates the target values to the devices and reads the actual output values from the devices.

Figure 1: Electric current flows and modular concept of the Prosumer-Lab test bench.



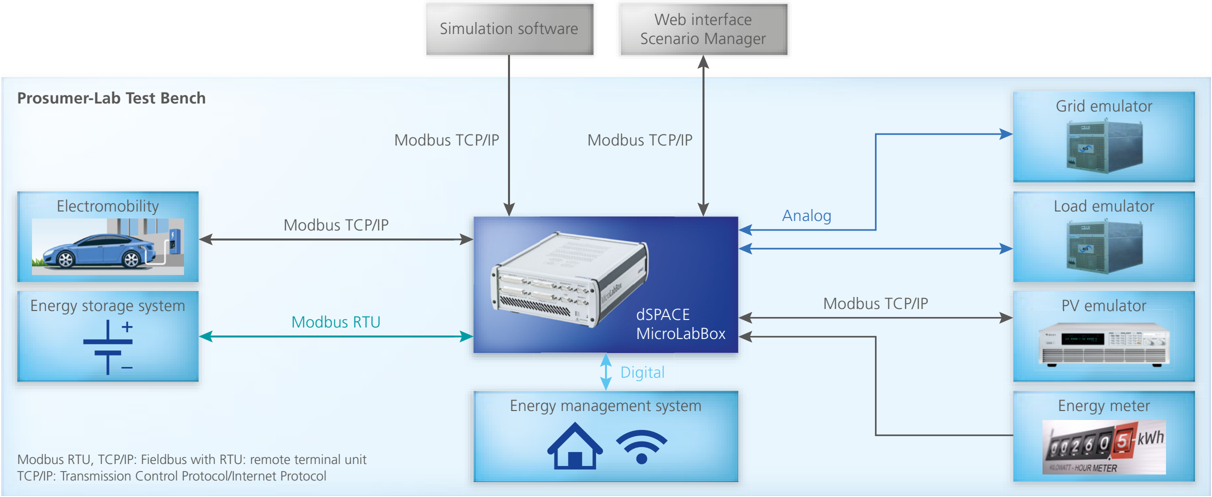


Figure 2: External access to the real-time system.

External Access to the Real-Time System

To make data easily available, a web application was created, which sets up a server-client structure. The MicroLabBox is integrated into this structure via ASAM XIL API. By using the ASAM XIL MAPort (Model Access Port), the program can access application values during ongoing operations and process the data, which can then be displayed directly or exported to other analytic processes.

Start-Up Phase Completed

The start-up phase of the test bench was completed with a performance analysis. Special attention was placed on controlling the load emulator with 10 kHz via the MicroLabBox along with external measuring and analytic devices. Results indicate that controlling the load emulator through the MicroLabBox leads to a significant boost in performance. The load emulator control features outstanding flexibility and high precision across the entire performance range.

Summary and Outlook

Thanks to the real-time system, it was possible to connect various kinds of test bench devices within the environment and to create a central control unit. Access to the MicroLabBox is possible at any time via the ASAM-XIL standard. The HIL test bench can be used to test system components at the early stages of development and even those that are scheduled for market launch – the testing includes the interfaces, communication protocols, and control algorithms, not to mention the realistic interaction of components in the prosumer household. Once the test bench was set up and put into operation, the first tests of energy management systems were conducted immediately in the Prosumer-Lab. The future lab agenda includes further and more detailed tests as well as the development of a new EMS algorithm. Projects with interested partners from industry and research are planned for energy management systems, charging stations for electromobility and storage batteries. ■

Steffen Wienands, Andrea Vezzini,
Bern University of Applied Sciences (BFH)

Picture credits: © BFH

Steffen Wienands
Steffen Wienands is the Deputy Project Manager of the Prosumer-Lab at the BFH Energy Storage Research Centre.

Andrea Vezzini
Andrea Vezzini is Professor of Industrial Electronics at the Bern University of Applied Sciences and Head of the BFH Energy Storage Research Centre.

Speed is Key to Safety

Developing algorithms for autonomous driving that respond promptly and precisely to the perceived environment

Indiana University – Purdue University Indianapolis (IUPUI) is researching ways to improve road transport safety for autonomous applications by analyzing the benefits of high-speed sensor data processing. RTMaps Embedded and NXP BlueBox are serving as the core real-time execution platform for embedded computing capabilities.

The number of sensors and electronic control units (ECUs) used in autonomous vehicles is growing exponentially, making it critical for automakers to use advanced and efficient solutions to handle numerous tasks with real-time execution performance. Data logging, time stamp synchronization, and processing from various sensors, such as cameras, laser scanners, radars, and global navigation satellite system (GNSS) receivers, have to be completed within milliseconds to ensure the precise position of a vehicle and its safe operation. Students at the Purdue School of Engineering and Technology at Indiana University – Purdue University Indianapolis (IUPUI) recently completed several studies to test the use of a high-speed computational platform for processing sensor data for four different autonomous applications.

Building the Test Platform

To begin their research, the students set up a test platform that included RTMaps Embedded (version 4.5.0) by Intempora. RTMaps Embedded, distributed by dSPACE, is a software solution for real-time multisensor applications that handles time coherency among numerous software tasks and provides a high bandwidth of raw data streams with powerful real-time execution performance. The RTMaps solution encompasses several independent modules: RTMaps Runtime Engine, RTMaps Studio, RTMaps Component Library and RTMaps SDK (Software Development Kit). "RTMaps Embedded is designed to face and win multisensory challenges," said Professor Mohamed El-Sharkawy, Purdue School of Engineering and Technology. "It provides an efficient and easy-to-use framework for fast and robust developments in areas such as advanced driver assistance systems, automotive vehicles, and robotics. It was easy for us to develop, test, validate, benchmark, and execute applications." The test platform also featured NXP BlueBox, an embedded computing system that allows the vehicle to create a real-time, high-definition 3-D image of its surroundings. Specifically, the students used BlueBox Version 2.0, which incorporates the S32V234 automotive vision and sensor fusion processor, the LS2084A integrated communication processor, and the S32VR27 radar micro controller. "NXP BlueBox provides the performance required to analyze driving environments and assess risk factors as well as automotive reliability to develop self-driving cars, "Professor El-Sharkawy added "BlueBox provides the required performance, func-

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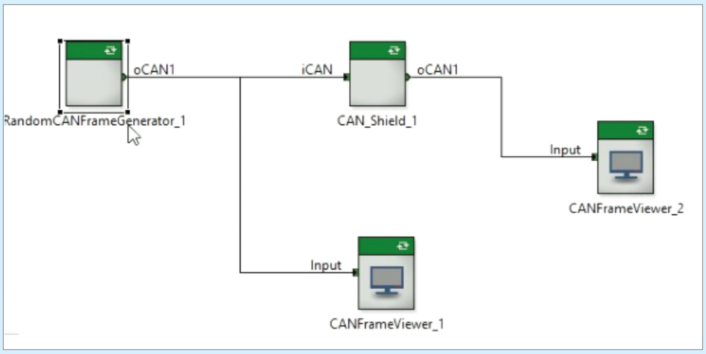
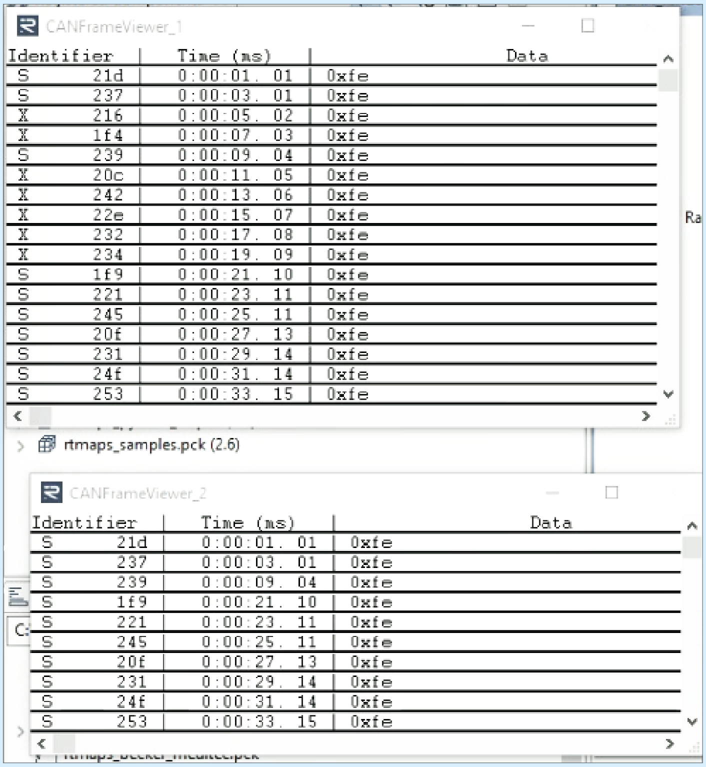


Figure 1: RTMaps workspace for a user-defined component package.



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 S     237 | 0:00:03. 01 | 0xfe
 X     216 | 0:00:05. 02 | 0xfe
 X     1f4 | 0:00:07. 03 | 0xfe
 S     239 | 0:00:09. 04 | 0xfe
 X     20c | 0:00:11. 05 | 0xfe
 X     242 | 0:00:13. 06 | 0xfe
 X     22e | 0:00:15. 07 | 0xfe
 X     232 | 0:00:17. 08 | 0xfe
 X     234 | 0:00:19. 09 | 0xfe
 S     1f9 | 0:00:21. 10 | 0xfe
 S     221 | 0:00:23. 11 | 0xfe
 S     245 | 0:00:25. 11 | 0xfe
 S     20f | 0:00:27. 13 | 0xfe
 S     231 | 0:00:29. 14 | 0xfe
 S     24f | 0:00:31. 14 | 0xfe
 S     253 | 0:00:33. 15 | 0xfe
```

```
Identifier |   Time (ms)   |            Data
 S     21d | 0:00:01. 01 | 0xfe
 S     237 | 0:00:03. 01 | 0xfe
 S     239 | 0:00:09. 04 | 0xfe
 S     1f9 | 0:00:21. 10 | 0xfe
 S     221 | 0:00:23. 11 | 0xfe
 S     245 | 0:00:25. 11 | 0xfe
 S     20f | 0:00:27. 13 | 0xfe
 S     231 | 0:00:29. 14 | 0xfe
 S     24f | 0:00:31. 14 | 0xfe
 S     253 | 0:00:33. 15 | 0xfe
```

Figure 2: Display of output using CAN Frame viewer in RTMaps.

tional safety, and automotive reliability, and it can be integrated with RTMaps."

Note: RTMaps Embedded is also compatible with the dSPACE MicroAutoBox Embedded SPU – a prototyping platform for functions for automated driving.

Testing Five Applications

With their test platform set up, the students set out to study and prototype five applications for autonomous driving:

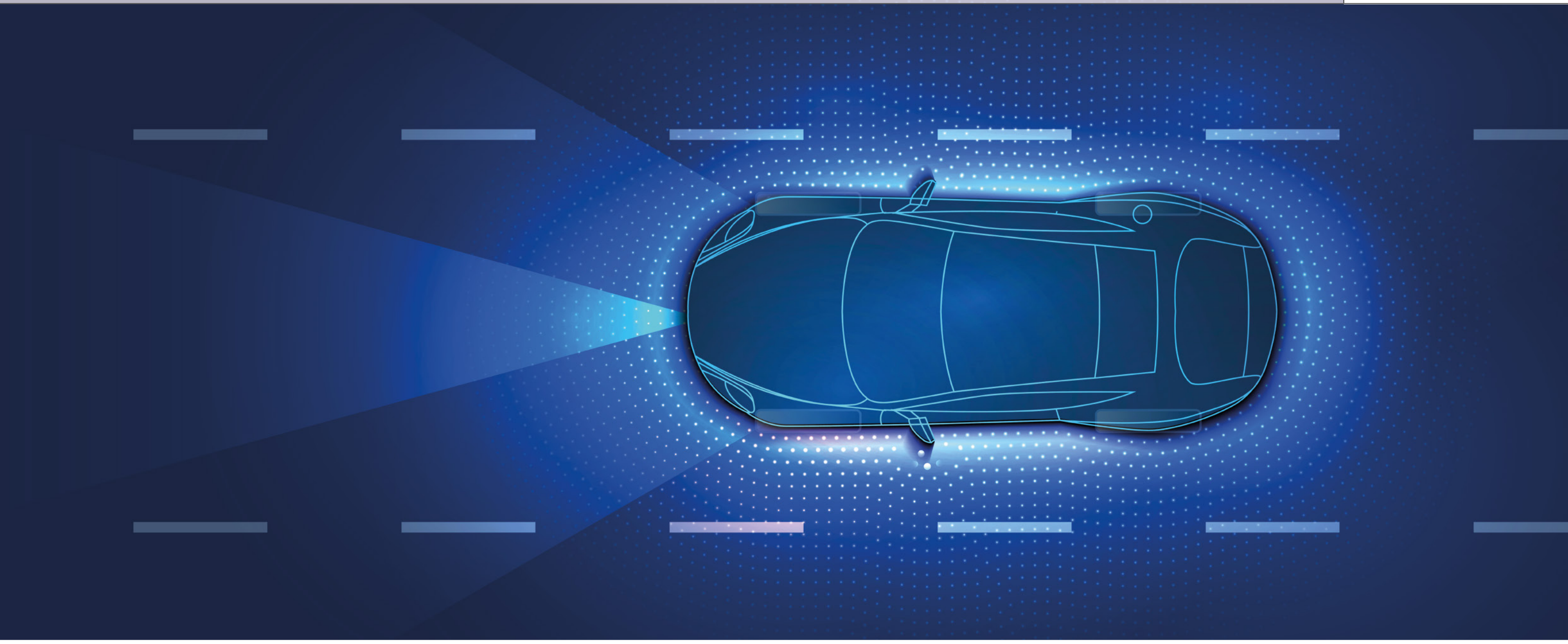
1. Creating a user-defined component package
2. Developing a neural network Python component
3. Pedestrian detection
4. Recording and replaying of real-time scenarios
5. Forward collision warning using SVM classifier

Application 1: Creating a User-Defined Component Package

The students used the RTMaps Studio graphical development environment and the RTMaps Component Library, and integrated C/C++ and Python code to create a component package. They used RTMaps SDK to import the component package to the RTMaps project workspace. In RTMaps Studio, applications are represented by connected components provided by the RTMaps Component Library. "The Studio tool provides an easy way to set up complex modular applications," said IUPUI engineering student Sreeram Venkitachalam. "Components can simply be dragged to the Studio workspace from the library. The components are used for communication, interface sensors, building an algorithm, and connecting the actuators." Figure 1 illustrates a user-defined component package that was imported into RTMaps Studio. The RandomCANFrameGenerator package was used to generate CAN frames, both standard and extended. The incoming CAN data was filtered so that only the standard frames were displayed in a data viewer, which is a built-in component of RTMaps. Two actions are incorporated for the generator component to control the generation speed of CAN frames. The 'speed up' action doubles the current speed of CAN generation, and the 'speed down' action reduces the speed of the CAN generation by 50%.

Application 2: Developing a Neural Network Python Component

In their next application project, the students developed a neural network Python component and classified the input image. For this, they used the Python component of the RTMaps Embedded package, which features an editor with syntax coloration to help users develop Python scripts. The



editor can be opened by right-clicking the component module. The Python block of RTMaps generates a class called 'RTMaps_Python', which can be used to reactively or periodically call an input. The core function in the RTMaps_Python class acts as an infinite loop running the main program. Using the Python component of RTMaps Embedded, the students were able to complete two example projects: vehicle detection and traffic sign classification.

Vehicle Detection

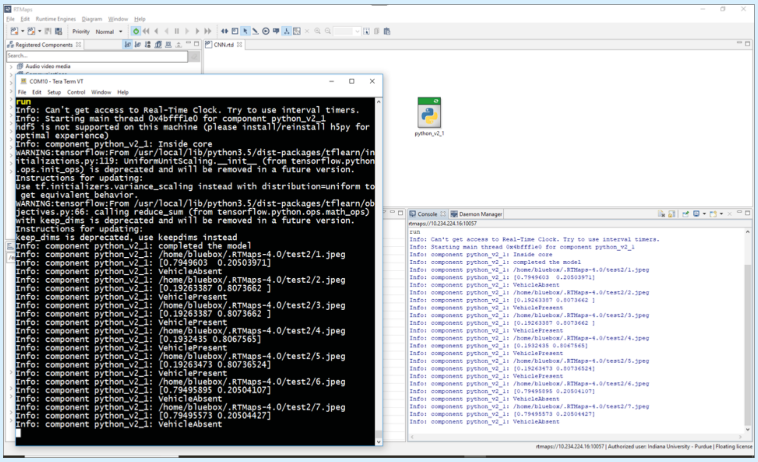
To detect vehicles, an image was implemented using a five-layer convolutional neural network (CNN) with pooling in each layer. The network used two fully connected layers as well as a drop-out layer to prevent overfitting of the network. The model was trained using a regression model and optimized with an Adam optimizer. The skeleton structure of the neural network was added to the RTMaps Python block, and the trained weights for the block were fed to the network as saved data. The network in the Python block checks whether an image contains a vehicle. The RTMaps application is sent to the BlueBox to run on the embedded platform. The RTMaps Python libraries in the BlueBox are modified to include a TensorFlow deep learning library (tflearn) for building the CNN structure.

> "The Studio tool of RTMaps provides us with an easy way to set up complex modular applications."
>
> *Sreeram Venkitachalam, IUPUI engineering student*

Traffic Sign Classification

In their second example project, the students were able to classify German traffic signs using a TensorFlow model. They used the model to identify the traffic signs, assign each of them to one of 43 classes, and display the meaning of the detected traffic sign in the image. The classification model used approx. 39,000 images to train the model. The TensorFlow model was recreated for testing, and the model weights, saved using the training model, were added to predict the class of the input image. The entire test structure was created in the RTMaps Python component. The trained model and the captured images were sent to the BlueBox, and according to the sign in the image, the output was predicted as a label, indicating the meaning of the traffic sign.

>>



```
run
Info: Can't get access to Real-Time Clock. Try to use interval timers.
Info: Starting main thread 0x4bfff1e0 for component python_v2_1
hdf5 is not supported on this machine (please install/reinstall h5py for
optimal experience)
Info: component python_v2_1: Inside core
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tflearn/in
itializations.py:119: UniformUnitScaling.__init__ (from tensorflow.python
.ops.init_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.initializers.variance_scaling instead with distribution=uniform to
 get equivalent behavior.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tflearn/ob
jectives.py:66: calling reduce_sum (from tensorflow.python.ops.math_ops)
with keep_dims is deprecated and will be removed in a future version.
Instructions for updating:
keep_dims is deprecated, use keepdims instead
Info: component python_v2_1: completed the model
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/1.jpeg
Info: component python_v2_1: [0.7949603  0.20503971]
Info: component python_v2_1: VehicleAbsent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/2.jpeg
Info: component python_v2_1: [0.19263387 0.8073662 ]
Info: component python_v2_1: VehiclePresent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/3.jpeg
Info: component python_v2_1: [0.19263387 0.8073662 ]
Info: component python_v2_1: VehiclePresent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/4.jpeg
Info: component python_v2_1: [0.1932435 0.8067565]
Info: component python_v2_1: VehiclePresent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/5.jpeg
Info: component python_v2_1: [0.19263473 0.80736524]
Info: component python_v2_1: VehiclePresent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/6.jpeg
Info: component python_v2_1: [0.79495895 0.20504107]
Info: component python_v2_1: VehicleAbsent
Info: component python_v2_1: /home/bluebox/.RTMaps-4.0/test2/7.jpeg
Info: component python_v2_1: [0.79495573 0.20504427]
Info: component python_v2_1: VehicleAbsent
```

Figure 3: Output display for vehicle detection based on a convolutional neural network (CNN) using BlueBox.

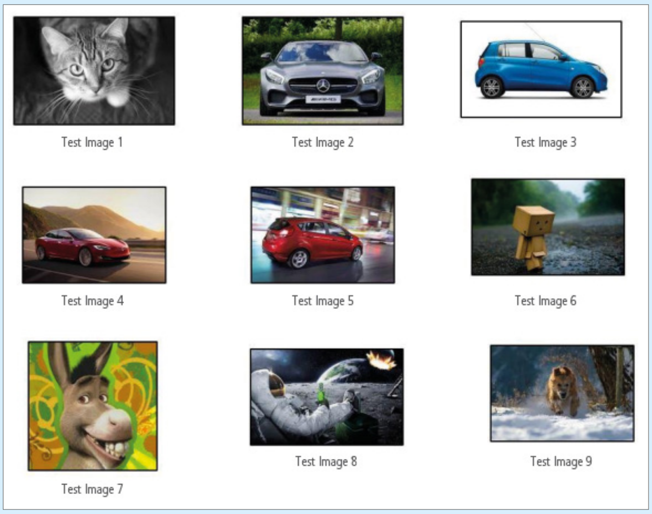


Figure 4: Input images for testing vehicle detection.

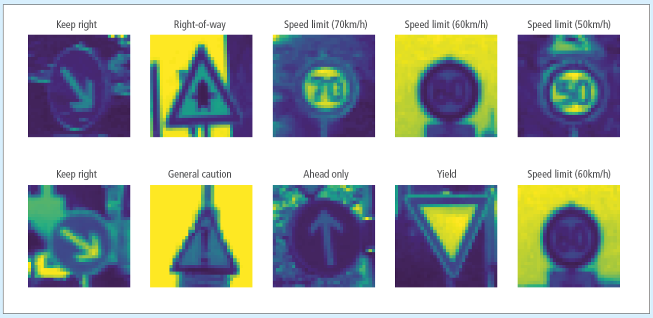


Figure 5: German traffic signs classified using a TensorFlow model.

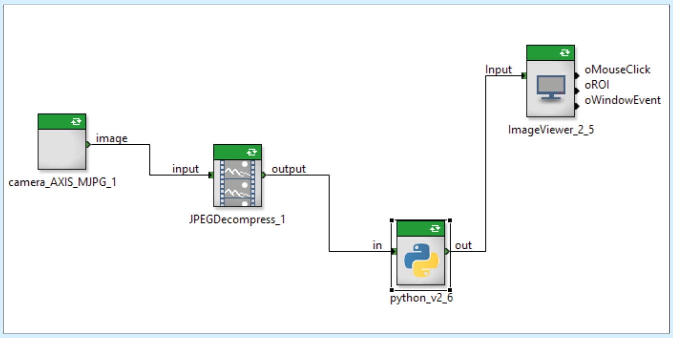


Figure 6: Diagram of IPCAM-based pedestrian detection.

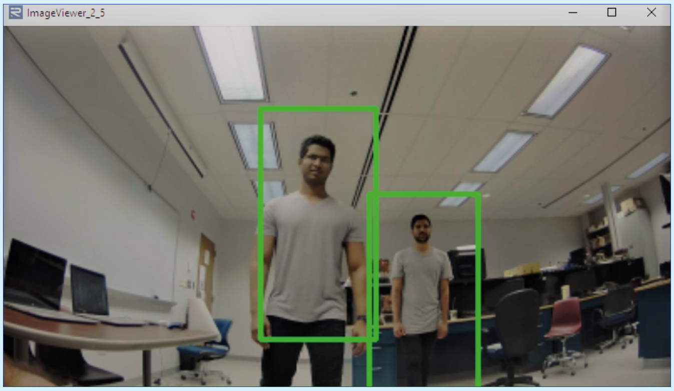


Figure 7: Bounding boxes are drawn around detected pedestrians.

> "RTMaps Embedded is designed to face and win multisensor challenges. It provides us with an efficient and easy-to-use framework for fast and robust developments in areas such as advanced driver assistance systems, automotive vehicles, and robotics."
>
> *Professor Mohamed El-Sharkawy, Purdue School of Engineering and Technology*

Application 3: Detecting Pedestrians

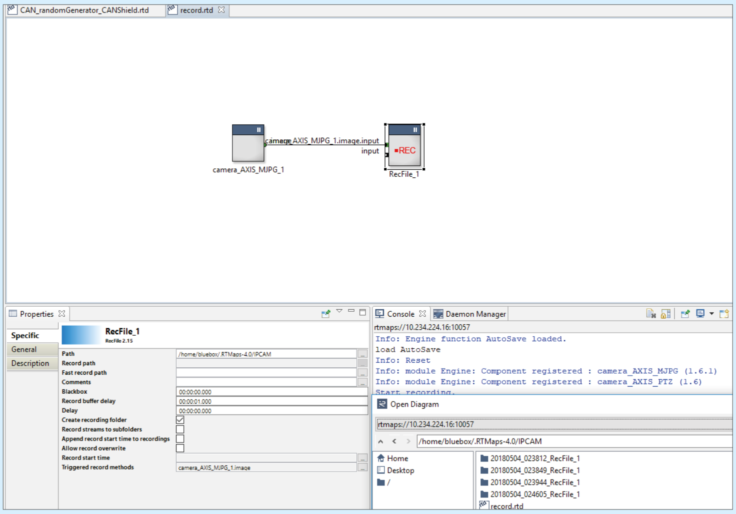
In their next application experiment, the students were able to achieve pedestrian detection by capturing real-time frames with an Axis IP camera (IPCAM). The pedestrian detection model in the Python application of RTMaps detects persons in the input image and draws a bounding box for each one (figure 7). A histogram of oriented gradients (HOG) and a linear supported vector machine (SVM) were used as a pretrained detector. To avoid an overlapping of bounding boxes, non-maxima suppression (NMS) was used. The pedestrian detection model was integrated with the IPCAM and the input images from the IPCAM were fed into the Python application. The detected pedestrians and the related bounding boxes were then displayed in the image viewer of RTMaps.

Application 4: Recording and Replaying Real-Time Scenarios

In their fourth application project, the students were able to demonstrate the ability of RTMaps to record and play back real-time data. The captured data was saved as a REC file that the students were able to play back. In this example, the IPCAM was integrated into the LS2084A of BlueBox to capture the images and save them to the IPCAM folder as REC files.

Application 5: Forward Collision Warning Using SVM Classifier

With their final application project, the students set out to implement a forward collision warning system that included a forward-looking automotive radar model and a classifier algorithm. The outputs from the radar model were the velocity/acceleration



Path: /home/bluebox/.RTMaps-4.0/IPCAM
Record path:
Fast record path:
Comments:
Blackbox: 00:00:00.000
Record buffer delay: 00:00:01.000
Delay: 00:00:00.000
Create recording folder ☑
Record streams to subfolders ☐
Append record start time to recordings ☐
Allow record overwrite ☐
Record start time:
Triggered record methods: camera_AXIS_MJPG_1.image

```
rtmaps://10.234.224.16:10057
Info: Engine function AutoSave loaded.
load AutoSave
Info: Reset
Info: module Engine: Component registered : camera_AXIS_MJPG (1.6.1)
Info: module Engine: Component registered : camera_AXIS_PTZ (1.6)
Start recording.
```

rtmaps://10.234.224.16:10057
/home/bluebox/.RTMaps-4.0/IPCAM

20180504_023812_RecFile_1
20180504_023849_RecFile_1
20180504_023944_RecFile_1
20180504_024605_RecFile_1
record.rtd

Figure 8: BlueBox recording example.

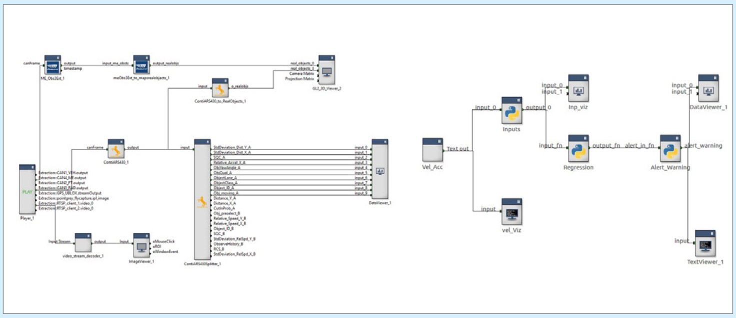


Figure 9: Diagram of forward collision warning using SVM classifier.

and separation distance. These outputs were used as inputs to the linear regression and the support vector machine (SVM) classifier to predict the warning range, i.e., the range in which a collision could occur between the ego-vehicle and the leading vehicle.

Conclusion

The IUPUI engineering students were able to complete various application projects for autonomous driving with the RTMaps Embedded platform and NXP BlueBox. They completed the development and testing of five different application examples to reaffirm the integration feasibility of Intempora RTMaps 4.5.0 with the computational platform BlueBox 2.0. While the data volume and complexity of ADAS algorithms increases, the students benefit from the computing power of RTMaps and BlueBox to ensure that the autonomous vehicle quickly detects and responds to its surrounding traffic environment and driving conditions. ■

Courtesy of the Indiana University – Purdue University Indianapolis

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SCALEXIO Power for the Trunk

Experiencing and Testing New Functions in Early Development Phases

SCALEXIO, the universal real-time platform from dSPACE, is adding a new member to the family: The SCALEXIO AutoBox, a very powerful in-vehicle system from dSPACE that offers tremendous processing power, excellent real-time properties, and comprehensive support for automotive bus systems. Developers can now experience and test new functions at an early stage in real driving tests. In this interview, Christian Wördehoff, Product Manager for Rapid Prototyping Systems at dSPACE, discusses the key aspects of using real-time systems in real vehicles.

What are the use cases for the SCALEXIO AutoBox?

Our customers in the automotive industry are increasingly demanding powerful prototyping systems that enable them to test complex functions directly on the road. In particular, the development of functions for highly automated driving leads to an increased demand for computing power and the data bandwidths required for the integration of high-quality assistance and automation functions in the vehicle network, for example. However, in the area of e-mobility, fast closed-loop behavior as well as high accuracy of signal processing and generation play an important role. The SCALEXIO platform, which has been on the market for several years, offers all of these options. The SCALEXIO AutoBox now takes this added value from the laboratory to the road.

What are the core characteristics of a mobile system for in-vehicle operation?

First of all, stable operation must be guaranteed in all general automotive conditions. A critical point is the power supply. This is why we have equipped the AutoBox with a wide-range power supply unit that supports operation in the typical on-board network architectures from 12 to 48 V. It is important to be able to compensate for short-term voltage drops or peaks, such as those that occur when high power loads are switched on or off. This can happen quite frequently, especially when vehicle components are still in the development phase. Furthermore, operation of the real-time system in real driving tests requires an extended temperature range compared to laboratory use, not to mention an increased resistance to shock and vibration. Therefore, a powerful active cooling concept optimized in-vehicle applications is a key AutoBox feature. In addition, the AutoBox has a special shock and vibration damping system. The robustness of the system has been tested by an external institute according to the ISO 16750-3 standard.

How does AutoBox fit into the large SCALEXIO family in terms of technology?

We gave the SCALEXIO AutoBox exactly the same DNA as all other systems in the family: the latest Intel processors and customer-programmable FPGA components for the fast calculation of complex applications, a high-performance real-time operating system, and our intelligent I/O network, IOCNET, which provides not only low transmission latencies but also plenty of database bandwidth. The modular concept of SCALEXIO also offers a high degree of flexibility and scalability.

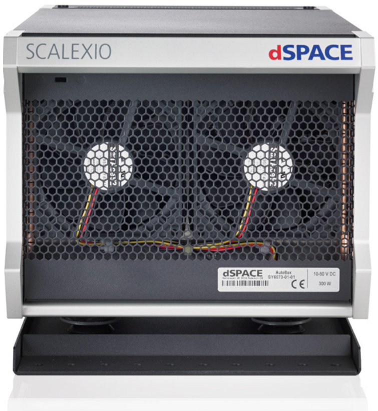
Typical project durations in automotive development are three to four years. How about the longevity of the systems?

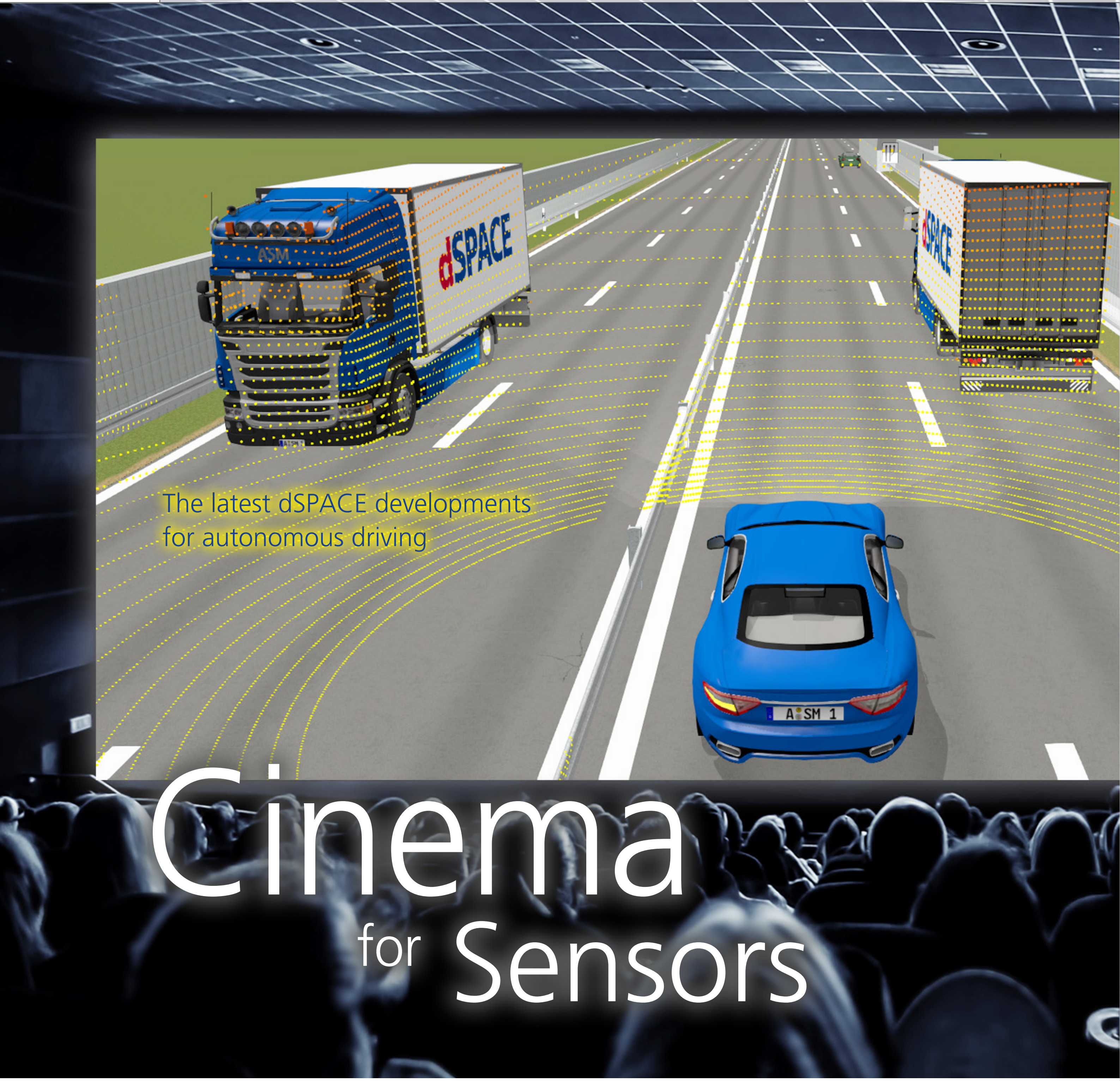
Experience has shown that some of our customers continue to use their systems far beyond the specified standard lifecycle. For example, I know of users whose real-time systems have been in reliable operation for over ten years. To achieve the highest possible availability of the system, we test our SCALEXIO AutoBox systems in extreme conditions that correspond to a mileage of far more than 100,000 kilometers in standard road operation. When our customers use our products over many years and for various projects, it is also important that they are always able to adapt AutoBox to more demanding and changing requirements. Especially when developing functions in the areas of driver assistance or autonomous driving, the market is still quite dynamic for example with regard to new Ethernet interfaces or the increasing demand for more computing power to cope with the constantly growing complexity of algorithms. We can keep the modular systems up to date in the field over the long term, for example, by offering new, more powerful processors and plug-in cards with new interfaces. This enables us to provide our customers with a protection on their investment.

Final question: What makes the SCALEXIO AutoBox so unique compared to other products on the market?

The strength of dSPACE prototyping systems is the combination of powerful hardware, high reliability, and convenient customer access with an impressive level of functional depth. This combination makes the SCALEXIO AutoBox unique. Ultimately, our goal is to provide our customers with a worry-free solution so they can fully concentrate on their own development tasks - today and in the future.

Mr. Wördehoff, thank you very much for this interview.

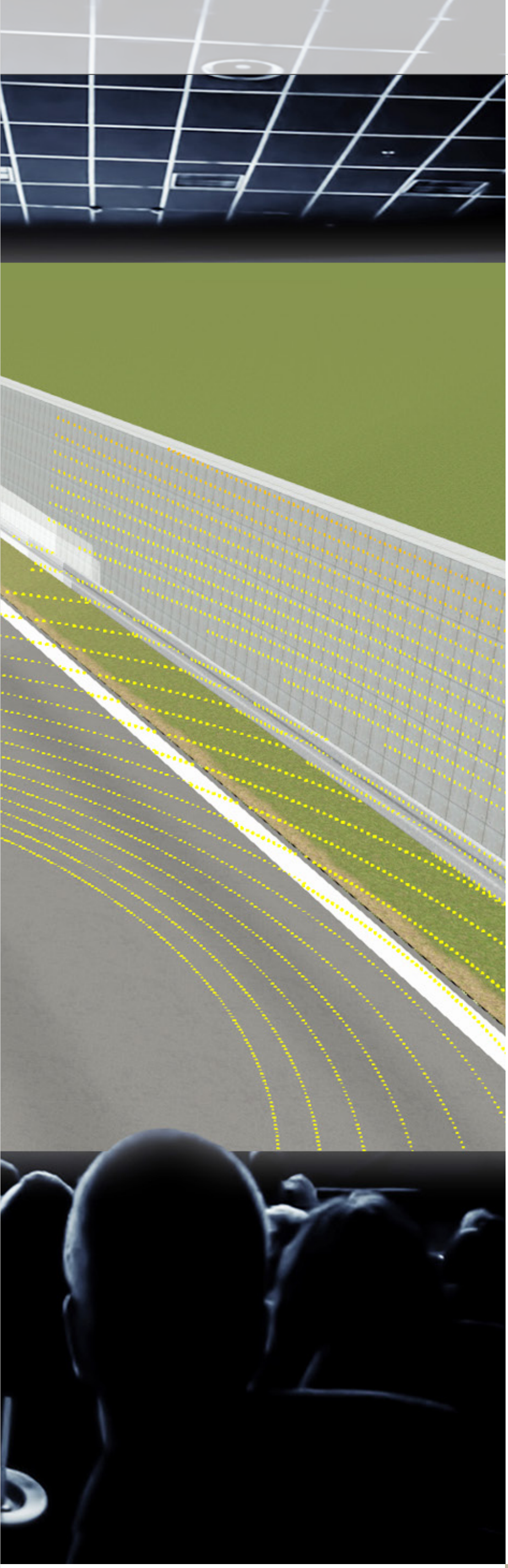




Cinema for Sensors

The latest dSPACE developments for autonomous driving

Autonomous vehicles will be equipped with a wide variety of environment sensors. Testing their functions and complex interaction is an enormous challenge. Holger Krumm and Sebastian Graf, co-responsible for the latest developments for this area at dSPACE, will give an insight into the latest dSPACE activities and the challenges ahead.



Mr. Krumm, the term sensor-realistic simulation is often used in connection with the development of autonomous vehicles. What exactly does this mean?
Krumm: This means virtually reproducing road traffic in the laboratory as it is perceived and recorded by the sensor, i.e., camera, radar, lidar. It is imperative that the sensor functions be validated in the laboratory, because we are looking at many millions of test kilometers due to the wide range of traffic situations. This cannot be done on the road. The dSPACE tools therefore ensure realistic simulation and stimulation of sensors in the laboratory.

Where are sensor-realistic simulations used?
Krumm: This happens wherever the functional chain from the perception algorithm to the object identification must be validated at an early stage. In virtual 3-D worlds used to test ADAS/AD applications, the models return the same signals as real sensors. For this, customers want to perform testing and validation at an early stage of the development cycle for sensors and processing units, such as a central ADAS control unit. This gives greater weight to model- (MIL) and software-in-the-loop (SIL) topics.

Which sensor-realistic models does dSPACE offer today?
Krumm: Sensor Simulation is the generic term used for the software modules for camera, radar and lidar sensor simulation. As of dSPACE Release 2018-B, we have offered an independent module for camera-based raw data generation that simulates the environment, traffic objects, and effects for weather- and daytime-based lighting conditions. As of dSPACE Release 2019-A, we released two additional modules: the radar module and the lidar module. Both are based on the ray tracing technology. This involves sending beams into a 3-D scene and capturing their reflections, which allows for the integration of physical effects such as multipath propagation into the modeling. The result is a physically correct simulation of the propagation of radar waves or a near infrared laser beam, which is essential for the stimulation and emulation of sensors.

Mr. Graf, what level of detail and scope of services do the models have?
Graf: Generally, the models calculate the transmission path between the environment and the sensor front end as well as parts of the front end itself, for example, the radar antenna.

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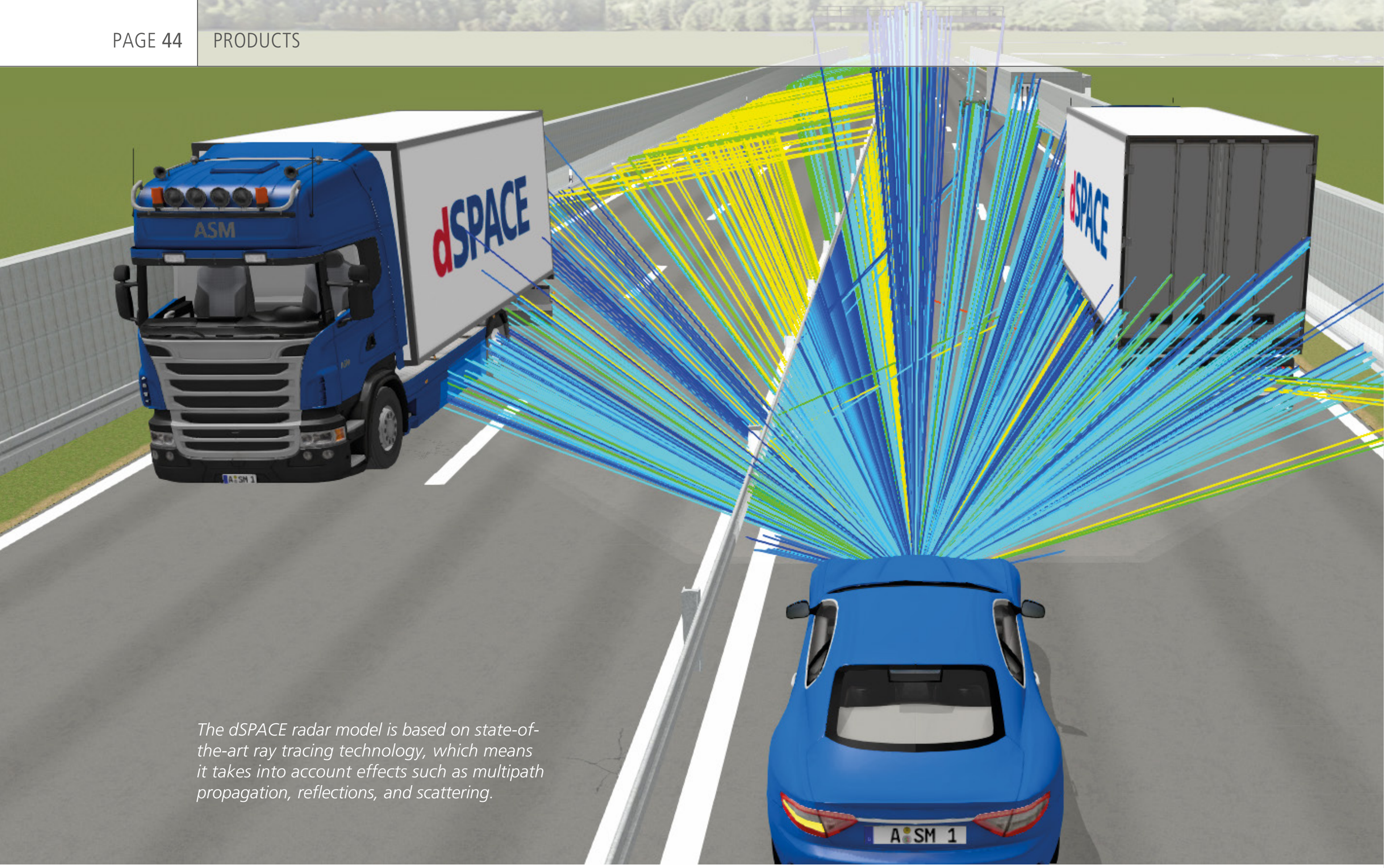
Holger Krumm (left) is Product Manager for Prototyping and Validation Software Tools at dSPACE, Dr. Sebastian Graf (right) is Senior Application Engineer at dSPACE.



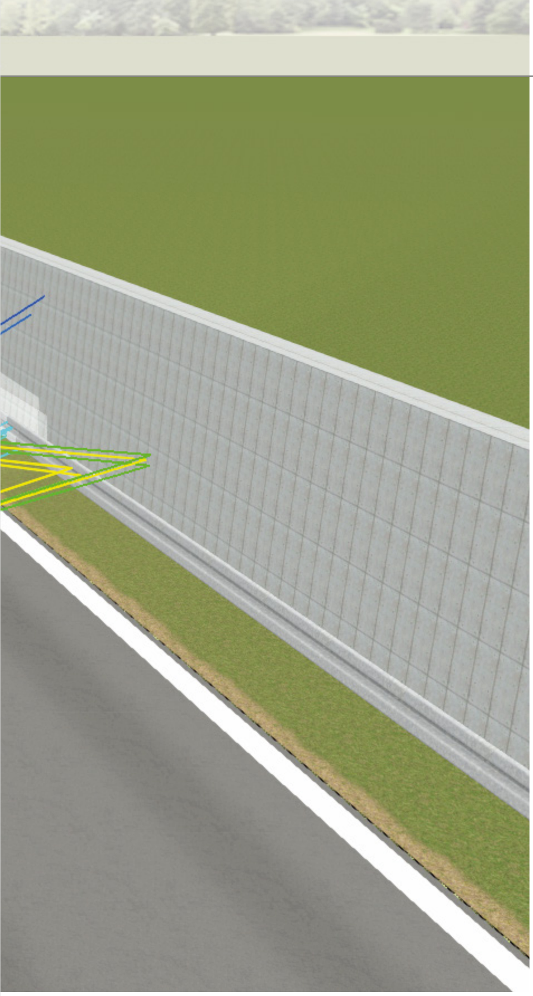
The dSPACE radar model is based on state-of-the-art ray tracing technology, which means it takes into account effects such as multipath propagation, reflections, and scattering.

> With the ray tracing engine in Sensor Simulation, the propagation of mm waves and infrared radiation can be simulated with physical accuracy – an essential capability for stimulating and emulating radar and lidar sensors.

In addition to the wave propagation calculation, the radar and lidar modules have a powerful postprocessing interface that allows for processing the acquired data. This enables creating a detection list or a point cloud for radar and lidar, for example. For the camera, the properties of the front end, meaning the lens system and the image sensor, are simulated. This includes effects such as chromatic aberration, vignetting, complex lens profiles, fish-eye distortion if required, and the output of the image sensor such as the Bayer filter and high dynamic range. Due to open interfaces, the customer can integrate their own postprocessing for special features of their own ECU. This applies to all sensor models.

What are the requirements for using Sensor Simulation?
Graf: The SIL setup requires a standard PC and an NVIDIA graphics card. Using a Sensor Simulation PC from dSPACE is also an option. It offers the benefit of being designed for operation in the dSPACE tool chain. In a HIL setup, on the other hand, the sensor simulation is always performed with a Sensor Simulation PC. The scalability of these PCs makes it possible to simulate any number of sensors. For this purpose, the PCs require a description of the vehicle environment and a simulation of the vehicle dynamics. Both are provided by a SCALEXIO simulator on which the ASM tool suite is executed. Because the sensor simulation products will be platform-independent in the future, they will also run under Linux, for example, so they can also be used on clusters or in any cloud services.

Are there any unique selling points of Sensor Simulation compared to other suppliers?
Krumm: Sensor Simulation is based on a complete vehicle dynamics simulation of the ego-vehicle. This means that all movements of the sensor are taken into account, e.g., when the vehicle leans into a road curve or pitches on cobblestones. Sensor Simulation rises to the special challenge of testing sensors not only by SIL, but also by HIL simulation. This requires real-time capability. The simulation of the radar wave propagation happens



> Sensor simulation is based on a complete vehicle dynamics simulation of the ego-vehicle, i.e., all movements of the sensor are taken into account.

so fast that a stimulation of real sensors – by injecting the raw data – takes place at run time. These computing speeds, which two to three years ago were undreamed-of, are now possible thanks to the parallel use of modern high-end graphics cards. Sensor Simulation is the only tool chain that simulates all three important sensor types, i.e., camera, radar and lidar, at this level. Another remarkable feature of the dSPACE tool chain is the simple transition from SIL to HIL simulation.

Do your customers already use Sensor Simulation? For what purposes do they use it?
Graf: Yes – we have a few key customers in the German automotive industry who are already using the tool in various areas. For this, we picked customers at various levels of the supply chain. Key customers include a large German OEM, ZF as a Tier 0.5, and HELLA as a radar supplier. We also engage in several other medium-sized and smaller cooperations and joint projects. All users give us feedback to make the simulation even more realistic and to adapt the tool chain to the specific challenges of a Tier 2, Tier 1, or OEM.

Can you tell us about the innovations that dSPACE is working on?
Graf: Among other things, we will increase visualization quality to enable camera function testing even in special light and weather conditions. Another topic is neural networks for environment detection. For this type of highly realistic visualization, we use modern, specialized graphics engines to achieve an entirely new level of camera sensor simulation. We are working at full speed to offer our customers full coverage of their applications. For the end of 2019, we are also planning to offer an option to assign material properties to objects. For radar and lidar, prototypes for SIL and HIL implementation at the raw data level of the sensor are already available. This enables testing of the digital sensor back end. For the last few years, this has been the latest standard for cameras. However, this is new territory for radar and lidar. Especially suppliers are extremely accepting of this technology, which proves to us that we are on the right track. The potential lies in testing during development. Moreover, the OEM also benefits from the fact that the supplier can provide sensor-specific models thanks to the straight-forward interface.

Mr. Graf , Mr. Krumm, thank you for this interview.

In the modern vehicle cockpit, Michael Beine and Olaf Grajetzky discuss what it means for TargetLink if functional requirements increase and development cycles become shorter and shorter.

20 Years of TargetLink

TargetLink has been generating highly efficient code for series production quickly and reliably for 20 years. Today, TargetLink-generated code is used everywhere in the vehicle, and TargetLink is an integral part of automotive software development worldwide. Impressive use cases can also be found in other industries. We discussed the role of TargetLink with Michael Beine, Lead Product Manager, and Olaf Grajetzky, Group Manager Engineering at dSPACE. Both have contributed to the success story of TargetLink.

From highly efficient production code generator to agile model-based software development

Validation on Real-Time Hardware

TargetLink now makes testing production code on SCALEXIO hardware even easier by using Simulink implementation containers (SIC). Learn more about the benefits of this option on page 49.

Mr. Beine, what was the greatest benefit for our customers when they introduced TargetLink?

Michael Beine: From the very beginning, TargetLink was more than a new software product. TargetLink closed the gap between the function model and the ECU. Because our customers were able to switch from manual programming to automatic code generation, they were able to significantly accelerate their development process. Before TargetLink was introduced, the turnaround time from design to implementation was weeks or even months. After the initial configuration, TargetLink generated code at the click of a button. And in addition to the considerable increase in efficiency, our customers were able to further improve software quality assurance. This was possible because code and models are consistent and the process for comparing them using MIL, SIL and PIL simulation is simple. The first projects for which Nissan and MAN used TargetLink were something of a revolution.

When you look back at the beginnings of TargetLink: What has changed since then?

Michael Beine: Initially, the focus was clearly on code generation and primarily on code efficiency. Today, it is very important to enable teams and entire departments to develop and validate model-based software efficiently and safely. With this in mind, we continuously developed TargetLink and built a comprehensive software ecosystem that addresses model-based software development, including validation.

What were the important development steps?

Michael Beine: From the very beginning, weworked closely with many customers in their projects. This, for example, lead to creating the TargetLink Data Dictionary. For the first time, it was possible to disconnect the implementation details from the model and exchange them within the team and across teams. Moreover, we were and are active pioneers in the field of AUTOSAR. In 2006, TargetLink was the first code generator to support AUTOSAR. Since then the tool has offered unparalleled AUTOSAR support at product level. We are currently working on Adaptive AUTOSAR. Not to forget: Since 2009, TargetLink has been officially certified by TÜV Süd for use in safety-critical projects.

Speaking of safety. How much safety does TargetLink offer?

Michael Beine: Developers and engineers are on the safe side when developing software with TargetLink. An important point of orientation for our customers is a reference workflow that is part of the TÜV approval. This workflow provides guidance for model-based development of safety-related software using TargetLink. In this context, our two strategic partners, Model Engineering Solutions and BTC Embedded Systems, play an important role. Their tools in conjunction with TargetLink ensure the required quality

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at the model and code levels. Modeling guidelines, MISRA compliance, dedicated support by dSPACE experts, regular Automotive SPICE development audits, and patches for earlier TargetLink versions are further aspects that show how important quality and reliability are to us.

Mr. Grajetzky, in which areas is TargetLink used, and which use cases do you particularly remember?
Olaf Grajetzky: Production code that was generated with TargetLink can be found in any ECU in a car, for example, in the powertrain, chassis, body, or ADAS areas. Morevoer, TargetLink has also proven itself in many other industries. For example, in motor controls for angle grinders, where you would hardly suspect automatically generated production code. Developments for self-propelled harvesters are quite impressive, and it is remarkable that even satellites in orbit are equipped with control systems that contain TargetLink code.

dSPACE is on site to implement many projects. How does the user support look like?
Olaf Grajetzky: One example is a major automotive customer, for whom we have been supporting a highly automated tool chain for more than ten years. This tool chain now supports all relevant specifications of AUTOSAR 4. In my opinion, this is one of the most consistent and sophisticated applications of AUTOSAR. In many other projects, we provide our know-how only for short-term support at the start of the project. Our customers then take over the operation. For almost 20 years, we have been on site with our customers and can quickly find solutions most suitable for their requirements. Even if problems arise, we can help at short notice. This is important because requirements can be very different around the globe, therefore we often have to be rather flexible.

Especially in the automotive sector, functional requirements are increasing and development cycles are becoming shorter. What does this mean for the continued development of TargetLink?
Michael Beine: We are currently working on implementing Adaptive AUTOSAR, another standard that, among other things, allows for updating ECUs and thus advances function development for autonomous driving. TargetLink will support requirements that involve new technologies, such as continuous integration and agile methods, and help our customers further increase their development speed. Generally, it is important to continue on the path towards agile, model-based software development and to ensure smooth interaction throughout the entire tool chain.

What role will TargetLink play once the vision of autonomous driving becomes a reality?
Olaf Grajetzky: One important role will remain unchanged: Production code generated with TargetLink will always be required for vehicles to drive safely on the road. Because code that is used to steer, accelerate, or brake vehicles not only in critical situations has to be absolutely secure, deterministic, and reliable.

Mr. Beine, Mr. Grajetzky, thank you for talking to us.

Michael Beine is Lead Product Manager at dSPACE.

Olaf Grajetzky is Group Manager Engineering at dSPACE.

Validation on Real-Time Hardware

Let's take a closer look at one of the latest developments in TargetLink: As of Version 4.4 (dSPACE Release 2018-B), TargetLink offers the option of exporting production code directly from TargetLink as Simulink implementation containers (SIC), executing it on the dSPACE SCALEXIO real-time hardware via ConfigurationDesk, and thus validating the code quickly and particularly conveniently. Product Manager Felix Engel explains the benefits of this additional validation step.

Mr. Engel, which users and applications does the new feature address?
First of all, the feature is aimed at software developers. They can actively work with the real production code generated by TargetLink, which has already been tested using model-in-the-loop, software-in-the-loop, and processor-in-the-loop simulation, early in the development process with real-time hardware on a real controlled system. This allows developers to directly see the effect that the specific implementation of an algorithm as production code has on the function – taking into account resource restrictions and quantization effects of all kinds. We also address test engineers who want to systematically test functionality that is available as a TargetLink model with real-time hardware on the real controlled system. Thanks to the clear interface of the SIC container, our implementation software ConfigurationDesk now makes this workflow easy to use and also ensures the highest degree of process reliability because function and I/O are separated. As a result, relevant file versions, for example, can be clearly assigned.

What is the benefit of this validation method compared to the well-known MIL/SIL/PIL simulations?
The methods complement each other. The MIL/PIL/SIL simulations allow for testing a wide variety of variants. If required, they let you easily compute high data volumes in parallel in large clusters. As a result, they can cover a great variety of tests in all dimensions. The validation of the production code on the real controlled system adds the element of early random checks for simulation plausibility to the tests. The objective is to notice effects that are not visible during the simulation. These effects can be detected very early on and thus remedied easily.

Which effects can go unnoticed in simulations?
In addition to the quantization effects mentioned above, an environment model might not represent the environment accurately enough, for example. In reality, however, the function modified for production code use must prove that it can cope with the complex details of the environment. Executing production code on SCALEXIO hardware leads to quick answers.

Which hardware is used?
You can use all ConfigurationDesk-supported systems. The SCALEXIO LabBox and, above all, the new SCALEXIO AutoBox (see interview on page 40), which were both designed as prototyping systems, are particularly suitable for validating production code.

What does the additional validation step mean for the overall ECU validation process?
It further increases confidence in the validation of production code and the later control unit. In addition, the overall costs are reduced, because more and more risks are identified and eliminated in advance.

Mr. Engel, thank you for talking to us.

Felix Engel is Product Manager at dSPACE.

Sebastian Thrun is a scientist, educator, inventor, and entrepreneur. Sebastian is the CEO of Kitty Hawk, whose vision is to free people from traffic. He is also the founder, chairman, and president of Udacity, whose mission is to democratize education. Sebastian was the founder of X (previously Google X), where he led the development of the self-driving car, Google Glass, and other projects. He spent several years as a professor at Stanford University where he led the Stanford Racing Team, whose 'Stanley' won the DARPA Grand Challenge.

In a few years time, AI will be on everyone's career horizon according to Sebastian Thrun

Flying Cars

Will Become Reality

For scientist, educator, inventor, and entrepreneur Sebastian Thrun, the future of mobility is autonomous and will happen in a three-dimensional space. In an exclusive interview with dSPACE Magazine, Sebastian Thrun talks about why artificial intelligence (AI) will be important for all of us in the future and why flying cars are so exciting.

Mr. Thrun, you developed autonomous vehicles at Stanford, and now you're working on the flying car. What will mobility look like in 20 years time?
I envision a future where you hop into a vehicle, fly up into the air, and zip to your destination in a straight line. I want to avoid a future in which we are all stuck in traffic on the highway. My dream is for Amazon to deliver my food by air transport within five minutes of my order. The air is so free of congestion and so vast compared to the ground, it has to happen.

Everybody is talking about how the future belongs to the autonomous car. When will it start?
It's already started! Waymo, which I founded, is testing self-driving cars in many different parts of the United States, and they've just partnered with Lyft to offer self-driving cars to the public for the first time. Voyage, which was started by engineers I first hired at Udacity, is already transporting senior citizens via autonomous vehicles around retirement communities throughout the United States. There are many more examples of self-driving cars in action around the world.

What are the big hurdles?
The biggest hurdles are still technical and they relate to all of the unusual scenarios self-driving cars encounter in the real-world. Engineers call these 'edge' or 'corner' cases, because they're so unusual, but the vehicle has to handle them properly in order to work 100% of the time. Every self-driving car engineer has to take into account bizarre events that could occur on the road – people driving on the wrong side of the highway, objects falling from the sky, animals coming out of nowhere. Handling these situations requires a lot of effort.

> "Within the next 5 years everyone – including me – will use some form of AI in their job."
>
> *Sebastian Thrun*

Millions and millions of test drive kilometers will have to be reeled off in test operation before autonomous vehicles can be put on the road. How many kilometers have to be driven in the real world, how many in the virtual world?
Simulation has become critical to the development of autonomous vehicles. In particular, simulation helps verify and validate software systems. The system can be checked by running previously recorded data in a simulator to confirm that the software handles the scenario properly. Simulation is also getting better at creating brand new scenarios from scratch, but I don't think we'll ever get away from having to gather data and using test systems in the real world.

What does this mean for car manufacturers and their suppliers?
Car manufacturers and suppliers have traditionally focused on mechanical engineering or fairly low-level systems software. These skills are still necessary, but higher-level software engineering, such as simulation and AI, are becoming critical. In some cases, it makes sense for companies to train their own engineers, in other cases it makes sense for them to partner with suppliers who have these skills.

Picture credits: © Udacity

> "Simulation has become critical to the development of autonomous vehicles."

Driverless cars are supposed to be safer. What role do software developers play in making them safer and how can these developers be optimally prepared for their tasks?
A self-driving car is basically a robot. As such, it has three main functions: perceive, plan, and act. Perception systems use sensors to understand the environment. This requires a lot of software engineering, particularly in fields like computer vision and machine learning. We learn what a person or a car looks like by seeing lots of people and cars, and that's roughly how a computer learns. The planning system also primarily relies on software, especially AI and probabilistic systems. The car has to predict how likely it is that another vehicle will turn or stay straight, and then has to make decisions accordingly. The final step are actuation systems. They used to be largely mechanical but are now increasingly powered by software. Most modern steering and braking systems are powered 'by wire' through a computer instead of relying on mechanical components. Electric powertrains, which make a lot of sense for self-driving cars, are also largely run by software.

At Udacity you have a strong focus on Deep Learning and AI. Can you explain why?
Within the next 5 years everyone – including me – will use some form of AI in their job. No matter your profession – business leader, accountant, farmer, programmer, or virtually any other role – AI is on your career horizon. Healthcare is abuzz with new reports suggesting staggering increases in the number of lives that can be saved by using AI. Legal and security experts are predicting dramatic decreases in online exploitation and fraud thanks to AI. Education innovators are creating virtual instructors to bring the classroom to underserved areas across the planet. Everyone, from marketers to manufacturers, is looking to the future and seeing the potential of AI. When Udacity began teaching AI online more than five years ago, much of this was still speculative. Now it's real, and we are constantly updating and expanding our AI offerings to ensure that everyone can learn these skills. Any student anywhere in the world can learn the skills required for these rapidly growing career opportunities.

What role do the established vehicle manufacturers play in development? How does the approach of the new players in the Silicon Valley differ from that of established manufacturers?
Traditional automotive companies are much better at designing and building cars than Silicon Valley startups. But the automotive industry can be very slow. The big advantage of new companies is speed. By developing new technology quickly and safely, new entrants to the automotive market are pushing the entire industry to become more agile and improve the world.

Back to your vision of the flying car. What are the advantages of going up in the air? And is this a dream that will be affordable for many some day?
I am so excited for flying cars. They open up so many possibilities that are not possible on two dimensional roads. When I first started working on self-driving cars, people thought I was crazy. But now self-driving cars are a reality. Today, when I tell people I'm building flying cars, they also think I'm crazy. Faster than you can imagine, flying cars will become a reality. ■

Mr. Thrun, thank you for talking to us.

About Udacity

Udacity is a global, online, lifelong learning platform connecting education to jobs and providing students with skills to advance careers. Udacity Nanodegree programs provide credentials earned through a series of online courses and projects in an array of subjects from self-driving cars and AI to data science and digital marketing. Udacity collaborates with more than 200 global industry partners, including AT&T, Google, Facebook, Lyft, and IBM, to close talent gaps. Headquartered in Mountain View, Calif., the privately-funded company has operations in China, Egypt, Germany, India and the United Arab Emirates. Its investors include Bertelsmann, Andreessen Horowitz, Charles River Ventures and Drive Capital. For more information, please visit **www.udacity.com.**

> "Faster than you can imagine, flying cars will become a reality."

PEGASUS-Project

Faster Validation of Functions for Autonomous Driving with Simulation-Based Tests

Get in the car, choose your destination, sit back, and relax. This is what many drivers want. Yet, how can we be sure that the driving function also makes the right decisions? How do you prove that an autonomous vehicle is safe? The collaborative PEGASUS project, funded by the Federal Ministry of Economics and Energy (BMWi), took on this task.

In mid-May 2019, 17 project partners from industry and science presented the results of three and a half years of practical research and development that focused on validating functions for autonomous driving at the Volkswagen test site in Ehra-Lessien, Lower Saxony. dSPACE was an associated partner and provided expertise for the testing subproject. During the PEGASUS project, the researchers developed a procedure that ensures a uniform evaluation and validation of the driving functions in the most efficient manner possible. "We discussed the findings with experts nationally and internationally through the course of the project to ensure that the results are also viable in practice," said Prof. Karsten Lemmer, DLR Executive Director for Transport and Energy and one of the two PEGASUS coordinators. Professor Thomas Form, responsible for vehicle technology and mobility experience at Volkswagen AG and also a project coordinator, added: "PEGASUS makes an important contribution to the future approval of autonomous vehicles by developing requirements, processes,

*André Manicke (TraceTronic), Dr. Mark Schiementz (BMW),
Dr. Karsten Krügel (dSPACE), and Jens O. Schindler (TraceTronic).*

metrics, and tools that in combination lead to a consistent overall method for the approval of the driving function."

Presentation of Results on VW Test Site

At the final presentation, the project partners demonstrated the tool chain developed during the project at the Volkswagen test site in Ehra-Lessien. They clearly demonstrated the individual steps involved in validating and approving functions for autonomous driving using digital posters, exhibits, and (driving) simulators as well as outdoor driving tests.

In 2016, the project partners decided on a tangible application case, the Highway-Chauffeur to test the universal PEGASUS approach for validating a driving function. The Highway-Chauffeur controls the vehicle on highways and expressways at a speed range from 0 to 130 kilometers per hour. It can also independently change lanes.

The PEGASUS overall method enables a continuous test sequence through a collection of all requirements for the driving function and a collection of relevant traffic situations. The data collection is based on field test, simulator and accident data. The data is processed uniformly and made available via a central database for applications in simulation, on the test site and in real traffic. This results in a release recommendation for the driving function, which is supported by process recommendations and the final safety evaluation.

dSPACE Support by Means of a Scenario-Based Tool Chain

The large number of simulation-based tests makes the tests in PEGASUS particularly efficient. Uniform interfaces are used, which also enables integration into existing environments. The simulation results are validated by means of tests on the test site. The simulation approaches in particular are also suitable for the early phases of the development processes of autonomous vehicles. PEGASUS therefore transfers the previously manufacturer-specific procedure for testing and validating assistance functions to a new, universal procedure for which all developers can apply the same criteria and dimensions.

dSPACE supported the project in setting up an exemplary scenario-based tool chain in which standard formats such as FMI (models), OSI (sensors), OpenSCENARIO, and OpenDRIVE (scenarios) were implemented and used by BMW as prototypes. With dSPACE VEOS, all these interfaces were integrated into a single simulation platform and combined with the ASM environment models. The result was a powerful software environment for validating and verifying ADAS and AD functions.

Test tools from the other project partners were easily connected via standard interfaces as shown by the prototype from TraceTronic. Therefore, it was possible to implement the PEGASUS idea of intelligent, scenario-based SIL tests with comprehensive as well as various practical scenarios. "In combination with the VEOS ability to simulate virtual ECUs based on the Classic or Adaptive AUTOSAR standard, the project partners have come much closer to their goal of performing tests in a realistic, reproducible, and highly scalable manner," says Dr. Karsten Krügel, Senior Product Manager Virtual Validation at dSPACE. As a result, the requirement of expensive real test drives will be greatly reduced. ■

> "PEGASUS makes an important contribution to the later approval of autonomous vehicles."

*For more information, go to:
www.dspace.com/go/pegasos*

PEGASUS

FMI: The Functional Mock-up Interface defines a standardized interface that supports the connection of simulation software.

OSI: The Open Simulation Interface is the standard for connecting the development of functions for automated driving with a variety of frameworks for driving simulation.

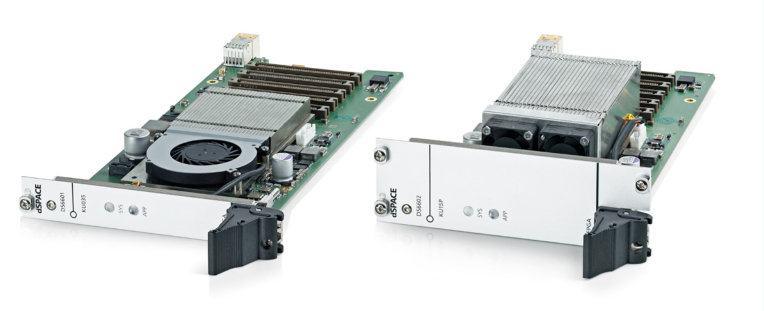
OpenSCENARIO defines a file format for the description of dynamic traffic maneuvers (scenarios) for use in driving simulators.

OpenDRIVE defines a data model for the highly accurate, logical description of road networks.

ASM is a dSPACE tool suite for simulating combustion engines, vehicle dynamics, electric components, and the traffic environment.

SCALEXIO: Latest FPGA Technology for Advanced Electromobility Applications

dSPACE is strengthening its SCALEXIO product portfolio for ECU development and testing with two new FPGA base boards based on the latest Xilinx® FPGA technology. The DS6602 FPGA Base Board with its powerful Xilinx® Kintex® UltraScale+™ FPGA meets the highest requirements in the field of HIL testing, for example, in handling very large, nonlinear motor models or topology-based circuit simulations. Its smaller sibling, the DS6601 FPGA Base Board, is a cost-effective all-rounder with the Xilinx® Kintex® UltraScale™ FPGA and is particularly suitable for RCP applications. Thanks to the versatile expansion options offered by plug-on I/O modules, the two high-performance FPGA boards can be used in a wide range of applications, for example, in electric drive technology, hybrid vehicles, power electronics, and electric power engineering. ■



SIL-in-the-Cloud

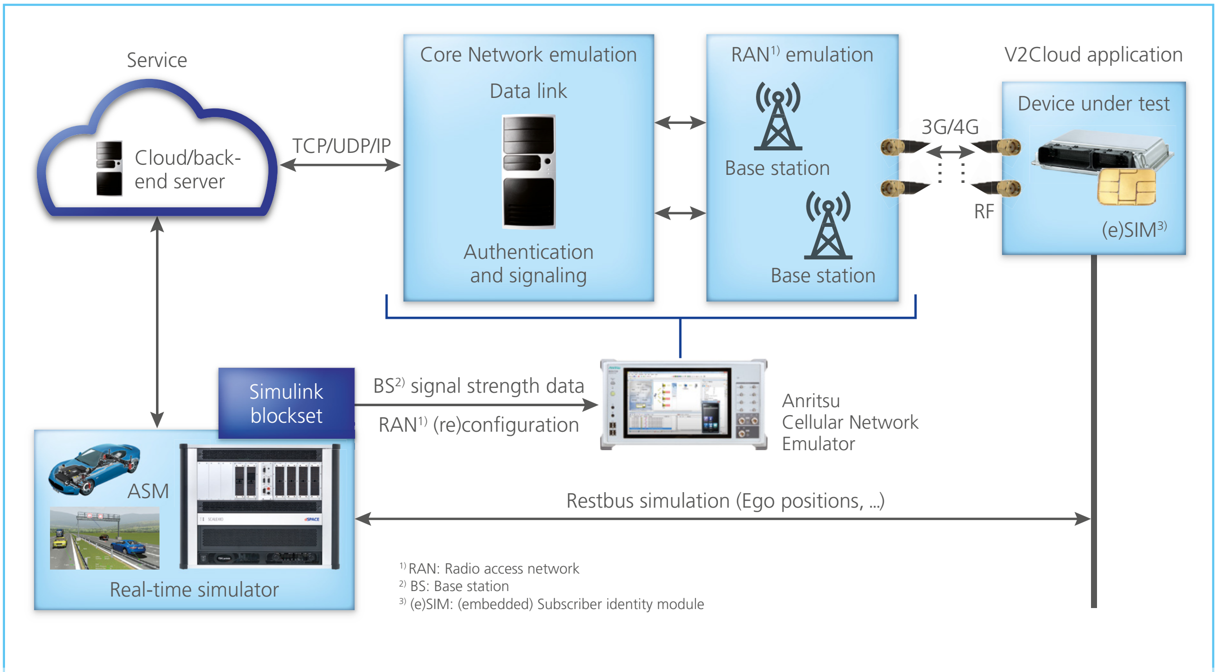
To test autonomous vehicles adequately, millions of test kilometers have to be driven in various scenarios under different environmental conditions and testing must also include marginal and critical situations. Ideally, this is done in virtual test environments. However, even software-in-the-loop (SIL) simulations of this magnitude can no longer be performed efficiently with locally installed test systems.

dSPACE is therefore working on a solution to shift the computing power required for SIL tests to the cloud. This allows for significantly expanding the scope of testing, because tests are longer performed on computers with limited resources, but rather on scalable cloud infrastructures. This enables you to take full advantage of automatically generated scenario-based tests and validate the entire range of test kilometers.

Find out more in the next issue of dSPACE Magazine. ■

Realistically Testing V2Cloud Applications

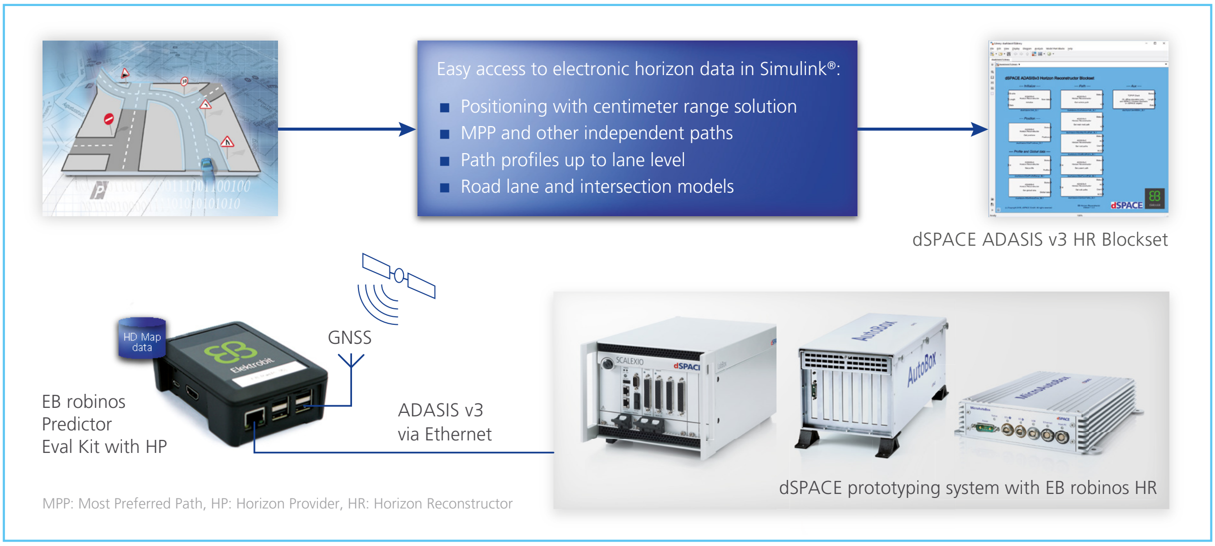
Drivers can already use their smartphone to locate their vehicles or comfortably navigate to the nearest free parking space. For this purpose, they often employ V2Cloud applications, which use mobile communication to exchange the required data such as vehicle position, free parking spaces, etc. with Internet services in almost real time and make them available to the user in a user friendly form. The new generation of these applications, such as software over-the-air updates or remote diagnostics, will be integrated in the vehicle more extensively and will place high demands on data throughput, latency, and reliability, not least of all on the mobile communication interface. This makes using HIL simulation for securing the entire chain of action a sensible choice – from the function in the vehicle to communication with the cloud service. The dSPACE approach is to integrate a mobile communications network emulator, which provides a realistic test network of base stations (Radio Access Network) and a mobile communications core network in the laboratory. This mobile communications network emulator is controlled by the HIL Simulator using a Simulink® blockset. This enables, for example, the reconfiguration of the mobile communications network to manipulate data throughput and latency times, and also supports mobility scenarios such as a handover. During a virtual test drive, the mobile communications link is transferred from one base station to the next without losing the data link. The blockset supports the MD8475B Signalling Tester from Anritsu and is ready for 5G. ■



[1] RAN: Radio access network
[2] BS: Base station
[3] (e)SIM: (embedded) Subscriber identity module

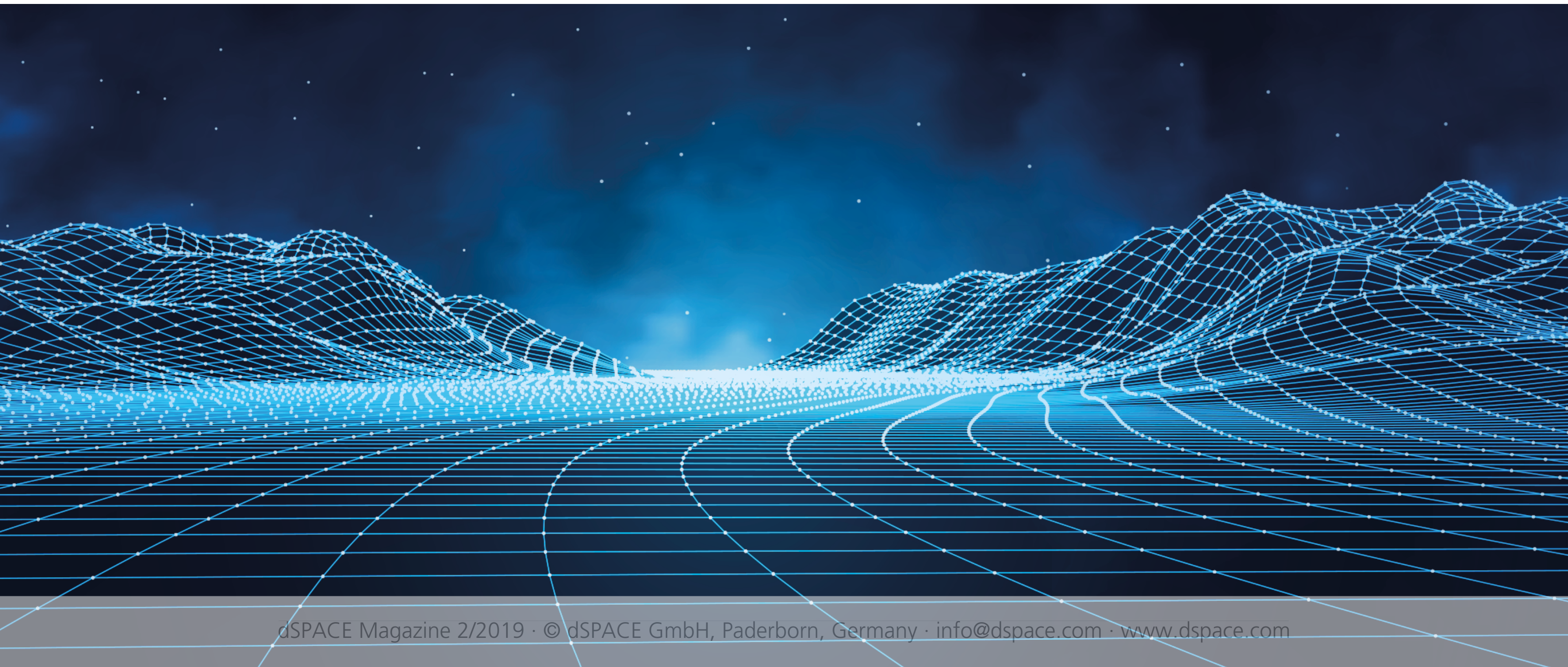
Autonomous Driving with Electronic Horizon in HD

The new dSPACE ADASIS v3 Horizon Reconstructor Blockset uses the standardized ADASIS v3 protocol to access electronic horizon data from Simulink®. It supports users in developing map-based applications and functions for autonomous driving on dSPACE prototyping systems and the PC-based VEOS simulation platform. The blockset is based on the EB robinos reconstructor by Elektrobit that is suitable for series production, which eliminates the need to implement a proprietary horizon reconstructor or know the details of the ADASIS protocol. The clear block structure allows easy access to detailed environment data, e.g.,for precise maneuver calculations. Developers also benefit from the new map management, which lets them manage large volumes of data. The horizon reconstructor makes only required data available and automatically deletes superfluous data.


Easy access to electronic horizon data in Simulink®:

- Positioning with centimeter range solution
- MPP and other independent paths
- Path profiles up to lane level
- Road lane and intersection models

MPP: Most Preferred Path, HP: Horizon Provider, HR: Horizon Reconstructor



dSPACE WORLD CONFERENCE

2019 MUNICH

First dSPACE World Conference!

November 19-20, 2019, Munich

dSPACE is pleased to announce that it will be holding its first World Conference on Nov. 19-20, 2019, at the Hilton Munich Airport Hotel. This event will serve as an international networking platform for **Autonomous Driving** and **E-Mobility** projects:

- Inspiring lectures from global players
- Stimulating workshops presented by experts
- Discover innovations, the latest technologies and view live product demonstrations
- Enjoy an exciting evening in a relaxing atmosphere

Come together, connect, and join in discussions with dSPACE experts, technology partners, and colleagues from around the globe. The dSPACE World Conference 2019 paves the way for getting your innovations on the road faster!

https://www.dspace.com/go/World-Conference

With us, autonomous driving gets more drive.

dSPACE is already working with automobile manufacturers from all over the world today to actually put the idea of autonomous driving on the road. We offer an innovative, scalable tool chain for development and testing – from a single source. This is how ideas become reality faster. **www.dspace.com**

Embedded Success dSPACE