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Development and testing of distributed functions

Simulation and virtualization of vehicle systems

Thanks to intelligent systems that automate, connect and improve vehicles’ environmental compatibility, it is now possible to design a new class of vehicle. Because of the tough competition on the market for buyers of new cars, mobility options and added-value services, manufacturers must introduce vehicles with innovative systems to the market as soon as possible. And they must of course also make sure these function safely and reliably. ETAS COSYM allows manufacturers to efficiently test and validate connected, embedded systems in virtual environments. COSYM is also a platform for advanced continuous integration processes in system and software development.

How can automatic driving functions involving numerous electronically controlled vehicle systems be readied for production within a short amount of time and at a competitive price without compromising quality? How can complex drive systems with electric and combustion engines, traction batteries, catalytic converters, and automatic transmissions be designed in the most optimal way?

The typical components of electronic vehicle systems are sensors, actuators, vehicles buses, as well as open-loop or closed-loop control systems plus the vehicle drivetrain, steering system, brakes, and chassis. The development and testing of automatic driving functions requires the simulation of driving dynamics, distances travelled, road conditions, open terrain and developed areas, weather conditions, motorists and pedestrians, and of infrastructures such as vehicle-to-vehicle communication or traffic management systems. As a result, there has been a sharp increase in the amount of software deployed in the vehicle. At the same time, the logic of complex vehicle functions is in many cases spread across many interconnected electronic control systems that are integrated with sensor systems, for example, or that execute central calculations and coordination tasks (Fig. 1). These functions can no longer be efficiently safeguarded using conventional methods on hardware-in-the-loop (HiL) test benches and in the vehicle itself. In order to be able to test the complex behavior of distributed functions especially with regard to the safety and reliability of self-driving cars in sufficient scope, high-performance environments for the virtualization and simulation of connected systems are required.

Many of the new challenges can be overcome with an open and scalable simulation platform that can test and validate connected control units while simulating open-loop or closed-loop control systems and the environment. This article discusses the need for such a platform, its applications, the requirements it must satisfy, and the new solution COSYM from ETAS.

Key data

COSYM is an open platform based on new software technologies for testing and validating distributed functions and connected, embedded systems in a vehicle over the entire duration of the development cycle. COSYM enables you to continually integrate and test control unit software in the development process. The immediate availability of test results increases the efficiency of system and software validation.

Testing with MiL/SiL versus HiL

Executable specifications that model function behavior are used to evaluate new vehicle functions. They can be validated together with a suitable system simulation in a closed loop, what is known as a model-in-the-loop environment (MiL). After they have been specified, control unit functions are then mapped to software components which can be tested in software-in-the-loop environments (SiL). Together with the control units, the software is then released for test driving on the HiL test bench. Via physical input/output (I/O) and bus interfaces, the control units are connected with electrical loads and computer simulations of the rest of the system. By linking up several HiL test benches it is possible to carry out extensive tests of the overall system [1], see Fig. 2.

Fig. 1: Overall system model.

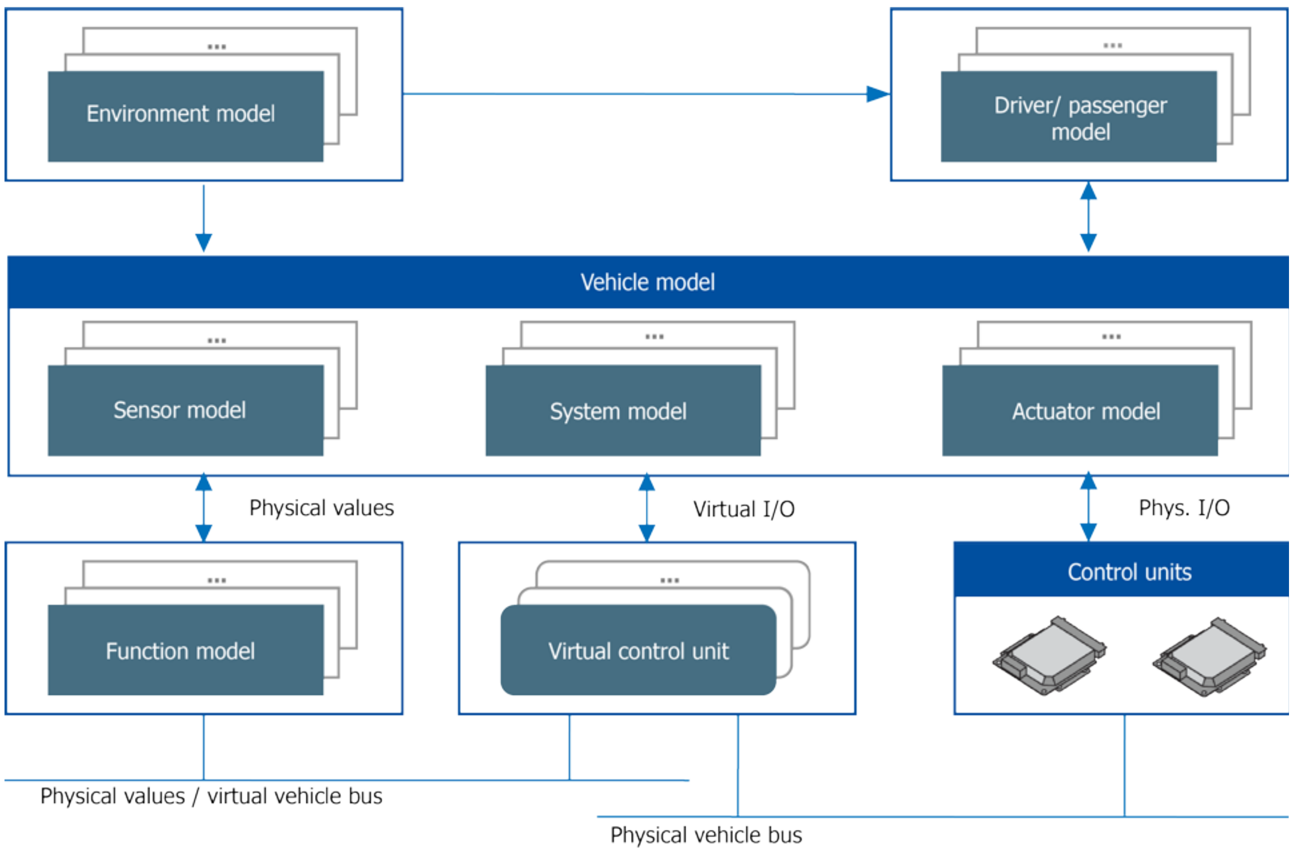

Fig. 2: HiL test bench for ETAS NETWORK-LABCAR.

For SiL tests, the use of virtual control units is advantageous as they have the same software architecture as the target control units. Because they can be made available and be reproduced without additional cost regardless of the hardware prototypes of the target control units, virtual control units can also be used to good effect in HiL tests. Virtual control units can be connected with the simulation via either virtualized or physical I/O and bus interfaces. With the aid of virtual control unit networks, it is possible to accurately model the bus communication, for example, and replace the conventional residual bus simulation in this way.

The conventional procedure was to carry out MiL, SiL and HiL tests sequentially in different departments of various sections of Development and Quality Assurance. The system simulations fit the task at hand, which ranges from testing functions, software components, software integration, control units and systems testing, and checking onboard and fault diagnostics right up to the validation of the E/E architecture of the entire vehicle. Test engineers will typically use different simulations on the HiL test benches to function and software developers in their MiL/SiL environments.

Paradigm shift

To achieve rapid market maturity of new, complex systems, development procedures must interact more closely and become more agile. If, for example, test cases that do not necessarily have to be validated on costly HiL test benches can instead be run on computers as MiL/SiL tests, this enables the test to be carried out faster and at lower cost. This calls for scalable system simulations that can be jointly used for MiL/SiL and HiL tests.

Moreover, a paradigm change in procedures and organization is necessary to achieve agile processes and put an end to the complete separation of tasks in the Development and Testing departments. This is the only way to continually integrate and validate new versions of software components for distributed functions, for example, where several teams from different companies are involved in their development.

To ensure the smooth introduction of new processes and methods into Development and Testing departments, new solutions must interact flexibly with existing tools, models, configurations and processes. The same applies for reusing results and configurations from previous development steps and other projects.

Continuous system simulations are needed

The seamless development and flexible testing of new functions with the aid of MiL/SiL and HiL environments requires high-performance environments for generating virtual control units, advanced tools for integrating and configurating modular system models, and scalable platforms for performing simulations. The individual components of the system models represent individual system components which can be flexibly combined to simulate an individual or connected system. In the case of individual system tests, simulation can take place on a single computer node and in the case of a networked system test in parallel on several computer nodes. Depending on the type of simulation required, the computing platform could be a standard Windows laptop or it could be the multi-realtime computer structure belonging to a large network HiL system for testing the entire vehicle's E/E.

A variety of modelling environments from different manufacturers for specific tasks are offered on the market, many of which have a high level of maturity. Also elaborated models which represent the behavior of individual systems, the vehicle, and the environment often already exist. If possible, existing, proven models should be reused as part of an overall simulation.

Openness is a requirement

The integration of function models, virtual and physical control units with system simulations in MiL/SiL and HiL environments varies with respect to time behavior and interfaces. At the HiL, control units are connected with the simulation via physical I/O and bus interfaces. Function models, however, can be directly embedded into a simulation via the exchange of physical and logical values. HiL tests take place in real time whereas the time scales of MiL/SiL simulations can be adapted to the specific issues pertaining to individual test assignments. For these reasons, the hardware configuration of a HiL test bench, for example, and the configuration of the system simulation on the computer platform should be viewed separately.

When embedding a new tool into the existing development and test environments, an open architecture supported by standards such as FMU/FMI, ACOSAR and AUTOSAR, and the relevant communications protocols on the LIN, CAN, FlexRay or Automotive Ethernet networks are essential, as are buses that link system and function models as well as control unit networks. To integrate domain-specific system models and control unit functions, the relevant interfaces and protocols should be available or can simply be expanded. To automate test procedures, a test automation interface is necessary. The ASAM-standardized XIL API allows users to employ their tools of choice to perform and automate tests.

To protect manufacturers' and suppliers' intellectual property when collaborating on joint projects, suitable mechanisms are necessary to restrict access to source information of artefacts.

COSYM

ETAS COSYM offers an open simulation platform based on new software technologies, see Fig. 3. In short, COSYM enables continuous MiL/SiL/HiL (XiL) testing of systems, paying special attention to control unit networks. COSYM comprises tools for the following steps:

— **Creating a system model**, for example by importing system, function and residual bus models and their signal combination. It will be possible to create virtual networks and link them to virtual and physical control units. The system model created does not merely link model signals but can also take network communication into consideration. If the virtual control unit is integrated at the microcontroller abstraction layer with ETAS ISOLAR-EVE for example, this results in a much more accurate simulation than if it were integrated at the application software layer, see Fig. 4.

— **Configuring the simulation** for MiL, SiL and HiL environments, depending on the execution platform and time behavior (real time or in synchronism with the simulation timescale).

— **Executing experiments** with the aid of the proven ETAS experiment environment.

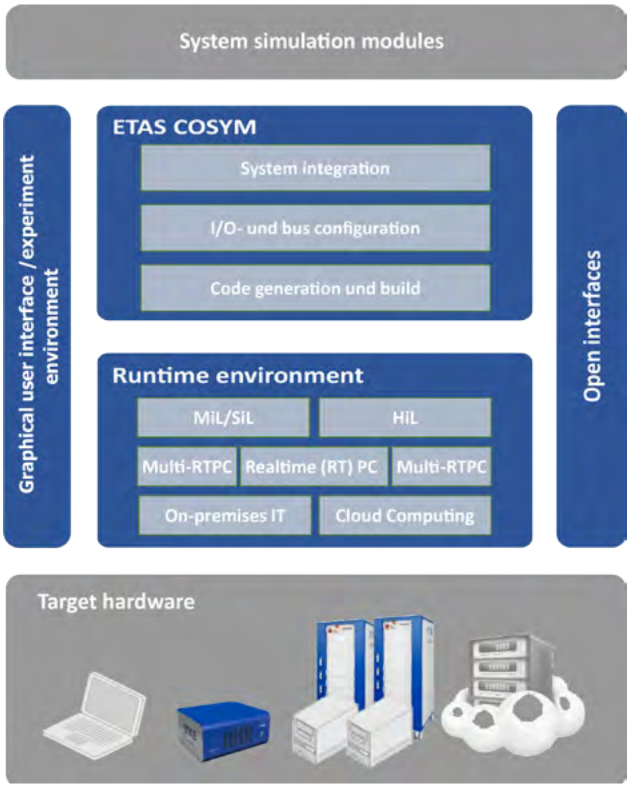

Fig. 3: ETAS COSYM – System overview.

— **Automation** via the XiL API or the native REST interface which allows continuous integration environments to be added by means of advanced software. In this way, COSYM enables projects to be created and, in the future, experiments to be carried out on a server.

COSYM is based on modern software technology with deliberate separation of services and user guidance. The well-documented REST interface for services enables simple integration into proprietary user guidance or automation processes. COSYM comes with a web-based user interface as standard. Thanks to its service-oriented architecture, the platform can also be incorporated into integrated development environments (IDEs) such as Eclipse, for example.

Market launch

COSYM will be launched in three phases as a part of pilot projects. By the end of 2017, COSYM will be available for ETAS LABCAR HiL systems. This will make it possible to transfer HiL tests into fully virtual environments, for instance on PCs. This can be done using system simulations of the LABCAR MODEL family, for instance. Replacing physical control units requires the presence of virtual control units or suitable function models.

In the second phase up to mid-2018, it will be possible to integrate virtual networks for all standard vehicle buses. In addition, COSYM and LABCAR-MODEL will both support virtual timescales as an alternative to real-time simulation. This makes testing significantly faster than using HiL in real time.

Finally, phase three will lay the foundations for the calibration of

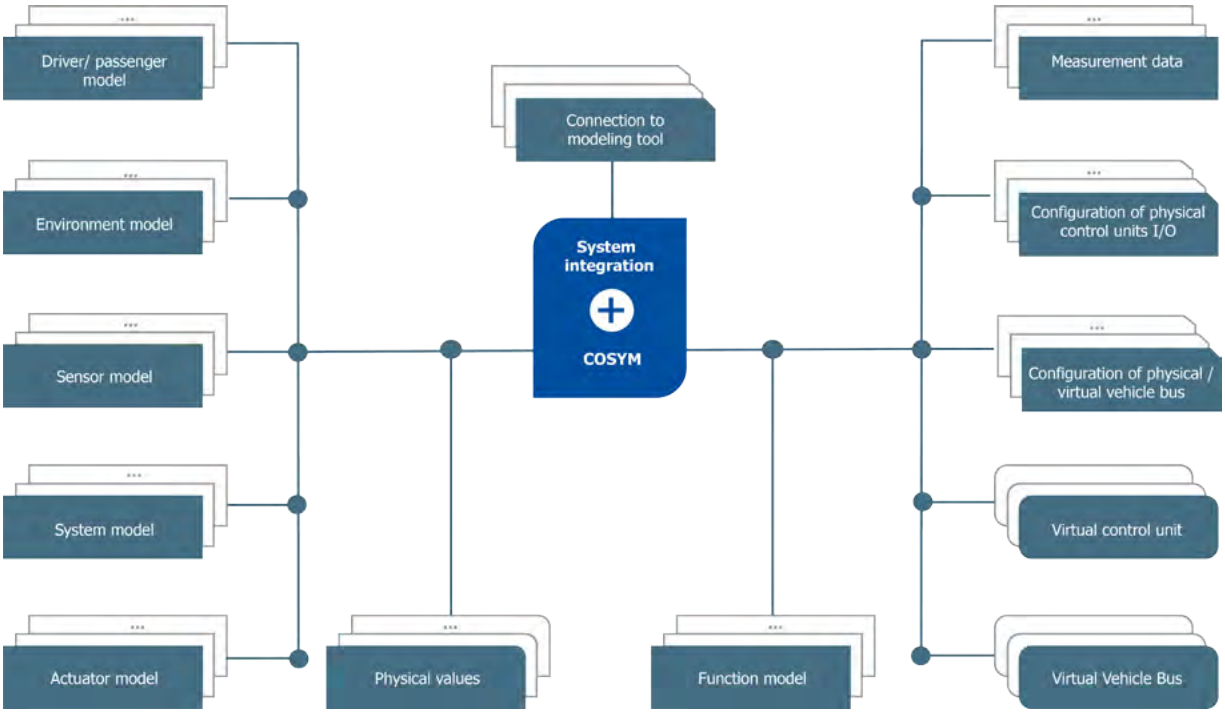

Fig. 4: System simulation modules.

complex systems in virtual environments. The focus here is, on the one hand, on real-driving emissions (RDE) [2] [3]. On the other, it will thus be possible to adapt and train advanced driver assistance systems (ADAS) and driving automation applications in a virtual environment with the aid of measurement data from test drives.

Outlook

In the medium term, the COSYM platform is being designed for use on high-performance server infrastructures either on-site or in an external cloud. To better support the data-intensive development of systems for autonomous driving, the focus is on integrating big-data solutions that allow users to quickly access large data sets for suitable measurement data to compare or combine with simulations.

Authors

Dr. Ulrich Lauff, ETAS GmbH
Dr. Christoph Störmer, ETAS GmbH
Deepa Vijayaraghavan, ETAS GmbH

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