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ATZ live

Torsten Bertram *Hrsg.*

Automatisiertes Fahren 2019

Von der Fahrerassistenz zum autonomen Fahren
5. Internationale ATZ-Fachtagung

Springer Vieweg

Proceedings

Ein stetig steigender Fundus an Informationen ist heute notwendig, um die immer komplexer werdende Technik heutiger Kraftfahrzeuge zu verstehen. Funktionen, Arbeitsweise, Komponenten und Systeme entwickeln sich rasant. In immer schnelleren Zyklen verbreitet sich aktuelles Wissen gerade aus Konferenzen, Tagungen und Symposien in die Fachwelt. Den raschen Zugriff auf diese Informationen bietet diese Reihe Proceedings, die sich zur Aufgabe gestellt hat, das zum Verständnis topaktueller Technik rund um das Automobil erforderliche spezielle Wissen in der Systematik aus Konferenzen und Tagungen zusammen zu stellen und als Buch in Springer.com wie auch elektronisch in Springer Link und Springer Professional bereit zu stellen. Die Reihe wendet sich an Fahrzeug- und Motoreningenieure sowie Studierende, die aktuelles Fachwissen im Zusammenhang mit Fragestellungen ihres Arbeitsfeldes suchen. Professoren und Dozenten an Universitäten und Hochschulen mit Schwerpunkt Kraftfahrzeug- und Motorentechnik finden hier die Zusammenstellung von Veranstaltungen, die sie selber nicht besuchen konnten. Gutachtern, Forschern und Entwicklungsingenieuren in der Automobil- und Zulieferindustrie sowie Dienstleistern können die Proceedings wertvolle Antworten auf topaktuelle Fragen geben.

Today, a steadily growing store of information is called for in order to understand the increasingly complex technologies used in modern automobiles. Functions, modes of operation, components and systems are rapidly evolving, while at the same time the latest expertise is disseminated directly from conferences, congresses and symposia to the professional world in ever-faster cycles. This series of proceedings offers rapid access to this information, gathering the specific knowledge needed to keep up with cutting-edge advances in automotive technologies, employing the same systematic approach used at conferences and congresses and presenting it in print (available at Springer.com) and electronic (at Springer Link and Springer Professional) formats. The series addresses the needs of automotive engineers, motor design engineers and students looking for the latest expertise in connection with key questions in their field, while professors and instructors working in the areas of automotive and motor design engineering will also find summaries of industry events they weren't able to attend. The proceedings also offer valuable answers to the topical questions that concern assessors, researchers and developmental engineers in the automotive and supplier industry, as well as service providers.

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Torsten Bertram
(Hrsg.)

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Hrsg.
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ISSN 2198-7432 ISSN 2198-7440 (electronic)
Proceedings
ISBN 978-3-658-27989-9 ISBN 978-3-658-27990-5 (eBook)
https://doi.org/10.1007/978-3-658-27990-5

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Springer Vieweg

Verantwortlich im Verlag: Markus Braun

Springer Vieweg ist ein Imprint der eingetragenen Gesellschaft Springer Fachmedien Wiesbaden GmbH und ist ein Teil von Springer Nature.
Die Anschrift der Gesellschaft ist: Abraham-Lincoln-Str. 46, 65189 Wiesbaden, Germany

Vorwort

Die fünfte ATZ-Fachtagung „Automatisiertes Fahren – Von der Fahrerassistenz zum autonomen Fahren“ 2019 setzt die erfolgreiche Serie der Fachtagungen Fahrerassistenzsysteme seit 2015 fort und zeigt durch die Umbenennung der Fachtagung von „Fahrerassistenzsysteme“ in „Automatisiertes Fahren“ den Technologiefortschritt gemäß der Einteilung der automatisierten Fahrfunktionen nach SAE Level und die Fokussierung der Themen der Fachtagung.

Die Automatisierung der Fahrfunktionen, die Elektrifizierung des Antriebsstrangs, die Vernetzung der Verkehrsteilnehmer und die Individualisierung der Verkehrssysteme charakterisieren die Mobilität der Zukunft. Diese wird sich grundsätzlich von der heute gewohnten Mobilität unterscheiden.

Die angesprochenen Entwicklungen führen zu einer höheren Verkehrssicherheit und einem zunehmenden Komfort, da der Mensch als Risikofaktor bei der Ausübung der Fahrfunktionen beim automatisierten Fahren zunehmend wegfällt und er durch den Wandel vom Fahrer zum Passagier nun die Reisezeit frei nutzen kann. Ein sich damit einstellender gleichmäßigerer Verkehrsfluss führt auch zu einer Steigerung der Verkehrseffizienz und zu einer besseren Umweltbilanz.

Der Wechsel vom manuellen Fahren über das teil-, hoch- und vollautomatisierte Fahren hin zum fahrerlosen Fahrzeug wird sich auf der Autobahn, in der ländlichen Umgebung und in der urbanen Region auf unterschiedlichen Zeitachsen und auch hinsichtlich der beherrschbaren Szenarien verschieden entwickeln, da sich die Komplexität und Kritikalität möglicher Verkehrssituationen deutlich unterscheiden.

Das Themenspektrum der Fachtagung zum automatisierten Fahren reicht 2019 von den erforderlichen Methoden und Kompetenzen bis hin zur Nutzerakzeptanz.

In vier Übersichtsbeiträgen, einer Podiumsdiskussion zum Thema „Reality check for automated driving – how we will drive in 2025?“ und in acht Themengebieten: Methoden und Prozesse, Absicherung, Autonome

Versicherungsvisionen, Haftungsfragen/ Fahrzeugdaten, Künstliche Intelligenz, Umfelderkennung, Daten und Vernetzung sowie Nutzer und Akzeptanz werden viele Aspekte des automatisierten Fahrens beleuchtet und zur Diskussion gestellt.

Die Übersichtsbeiträge geben Einblicke in den Trend beim automatisierten Fahren im Bereich der Nutzfahrzeuge generell und zeigen, wie sich die Mobilität in Smart Cities in China, Japan und Europa aus Sicht eines Fahrzeugherstellers und Zulieferers entwickeln wird. Der Rolle und Bedeutung der künstlichen Intelligenz für das automatisiert fahrende Fahrzeug und die zu schaffenden Voraussetzungen bei deren Einsatz im Fahrzeug wird in einem eigenen Übersichtsbeitrag aus Sicht eines Automobilzulieferers aufgezeigt.

Fahrzeuge mit automatisierten Fahrfunktionen gemäß SAE Level 3 und höher sind in der Lage zu sehen – 360-Grad-Wahrnehmung der Umgebung über Sensoren –, zu denken – vorausschauend und situationsgerecht einen angemessenen Handlungsablauf über Situationsinterpretation, Schlussfolgerung, Planung, Planerkennung, Kommunikation sowie Kollaboration zu generieren – und zu handeln – Handlungen sicher und zuverlässig über Aktoren auszuführen –.

Bei der Selbstregulation (Wahrnehmung und Interpretation, Lernen und Schlussfolgern, Planung und Planerkennung, Kommunikation und Kollaboration) kann die Künstliche Intelligenz einen bedeutungsvollen Beitrag leistet. Mit dem Machine Learning ist dem automatisiert fahrenden Fahrzeug ein Werkzeug gegeben, dass bei einer umfangreichen Anzahl an Messungen aus diesen Daten komplexe Zusammenhänge erkennt. Mit zunehmender Integration der Künstlichen Intelligenz in das automatisiert fahrende Fahrzeug wird dieses mehr und mehr ohne menschliche Steuerung sowie Regelung und durch detaillierte situationsausgerichtete Programme ein vorgegebenes Ziel selbständig und an die aktuelle Situation angepasst erreichen.

Die Beiträge zu den Themengebieten Methoden und Prozesse sowie Absicherung widmen sich der Integration der Verifikation sowie Validierung von komplexen Systemen bereits in frühen Entwicklungsphasen. Daneben stehen die Generierung von Daten der Umweltwahrnehmung sowie deren automatisierte Klassifikation und die Herleitung von Fahrsituationen bzw. Fahrszenarien für die virtuelle und reale Funktionserprobung im Simulator sowie im Fahrversuch.

In den Beiträgen zur künstlichen Intelligenz und deren Anwendung beim automatisierten Fahren werden die Kernaussagen des Übersichtsbeitrages weiter ausgeführt und erhärtet. Ausgehend von der Frage „Ist die künstliche Intelligenz die Lösung für alle Probleme?“ werden die Entwicklung der künstlichen Intelligenz und des maschinellen Lernens im Automotiveumfeld vorgestellt und anhand von Beispielen die Möglichkeiten sowie Herausforderungen beim Training und der Evaluation aufgezeigt.

Das Themengebiet der Nutzerakzeptanz wird über eine Einschätzung zum Vertrauen in das System beim automatisierten Fahren eröffnet und erstreckt sich im Weiteren über Fragen zur Überforderung sowie Unterforderung auch im Kontext der Fahreraufmerksamkeit und einer fahrfremden Tätigkeit. Geschehen die fahrfremden Tätigkeiten beispielsweise auf dem Bildschirm des Kombiinstruments, so ist die Aufmerksamkeit des Fahrers zur Übernahme der Fahraufgabe durch Um- bzw. Abschalten des Bildschirms einfacher zu erreichen. Weitere Aspekte im Kontext der Nutzerakzeptanz ergeben sich durch den Fahrer (Mensch) in der Interaktion mit dem Fahrzeug (Maschine) sowie mit den damit verbundenen Interdependenzen.

Das Prozesse im Umfeld des automatisierten Fahrens zu überdenken und gegebenenfalls neu zu gestalten sind, unterstreichen die Themengebiete Versicherungsvisionen und Haftungsfragen auf der Fachtagung.

Die ATZ-Fachtagung Automatisiertes Fahren 2019 dokumentiert den Stand der Technik im oben aufgezeigten Themenspektrum aus Sicht der Automobilhersteller, Zulieferer und Wissenschaft. Die diskutierten Beiträge führen zu Antworten und neuen Fragen, die einerseits grundsätzlich und andererseits vertiefend in der Sache sind, und damit die zukünftige Entwicklung mit beeinflussen.

Die Fachtagung Automatisiertes Fahren 2019 zeigt wichtige Ergebnisse auf dem Weg zum automatisierten Fahren, die in den einzelnen Vortragsmanuskripten oder Vortragsfolien in diesem Tagungsband weiter ausgeführt sind. Der vorliegende Band enthält die Beiträge, die zur Veröffentlichung freigegeben worden sind.

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Validation of level 4-5 functions with a cloud-based simulation

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T. Bertram (Hrsg.), *Automatisiertes Fahren 2019*, Proceedings,
https://doi.org/10.1007/978-3-658-27990-5_1

Validation and verification of Level 4-5 Functions

The validation and verification of level 4-5 highly automated driving (HAD) functions requires a vast number of test kilometers. If real test drives are applied exclusively, it can be safely assumed that the required test scope cannot be covered within feasible limits of time and money [Winner]. This is not only due to the functional complexity of HAD applications, but also due to short development cycles and legal safety requirements.

In addition, the deployment and activation of new vehicle functions is desirable even after the regular “start of production” (SOP). In case of HAD, each of these new functions must fulfill the high demands on functionality and safety of automated driving functions. Validation and verification will thus not end with the regular SOP in the future - it has to be repeatable after SOP as well.

Caused by the high complexity of the automated driving task, HAD functionality is typically implemented by distributed systems consisting of several subsystems, such as ECUs, sensors, and buses. Consequently, validation and verification of the entire system must consider the interaction and communication of these subsystems.

All these factors indicate that intelligent validation and verification strategies are required for HAD testing [Lattemann] [Schöner] [Madrigal], which employ different methods and their combinations, including real driving tests, hardware-in-the-loop (HiL), and software-in-the-loop (SiL) testing [Wagner]. Real vehicle tests or hardware-in-the-loop tests will always stay indispensable as long as real components need to be considered in the test scope. Nonetheless, the validation and verification strategies will remain manageable only, if the majority of testing tasks is transferred from real vehicles on the road to virtual systems. These systems also help to ensure correct system functionality during dangerous driving maneuvers, for situations at the physical limits of driving dynamics, and during accidents – all of which would be impossible to investigate in real test drives.

The required amount of testing clearly suggests the usage of a technology that allows large-scale parallel operation of virtualized systems. It is common understanding that engineers cannot complete the required validation and verification tasks without such a technology. Consequently, cloud computing is a key to master the challenges of HAD validation and verification, because it allows transferring the testing tasks from the road to simulations on a large scale.

Most existing tools in the area of automotive system development and test are designed for the execution on single computers. In the case of HiL setups, they even run on dedicated real-time systems. This legacy inhibits the fluent transition of existing tools and applications into the cloud and prevents companies from taking benefit of cloud technologies. Hence, one key to cloud-based HAD validation and verification is making the existing, growing and cost efficient cloud resources accessible and available to automotive engineers.

Large Scale SiL Simulations for AD

The present paper focuses on the SiL methodology as a core element of HAD validation and verification strategies. The SiL methodology couples ECU target code, as it is implemented in the real vehicle, with virtual system components and simulation models of the vehicle and its environment. It allows investigating the overall system behavior in virtual test runs, providing full reproducibility, the ability to perform safety critical tests without risks, the test of the system reaction when system components fail (failure injections), system tests under heavy load on the automotive buses, validation of the system behavior in critical driving scenarios, and automated search for critical driving scenarios. These are only some examples for the numerous advantages of SiL based validation and verification.

SiL testing can be applied to different architectural levels of vehicle subsystems. It supports test and validation on the level of individual ECU functions (e.g. the HAD function planning layer), on the level of whole ECUs (e.g. an ECU implementing the driving functionality), or on the network level of multiple ECUs implementing the full autonomous driving function (e.g. integration of perception-, driving function system-, brake- and steering-ECU). While the focus of this paper is to discuss the test of ECU networks, it implicitly covers the other, less complex use-cases as well.

A SiL system for HAD validation and verification needs to reflect the specific requirements that driving automation implicate. E.g., the methodology has to be applied on a larger scale with respect to number of contributors to build a simulation, amount of scenarios or cases to be simulated, and the need to reuse the simulation environment for as many development steps as possible.

Modularity Based on Standards: Fostering Collaboration

The technical challenge of developing HAD vehicles can only be mastered by the cooperation of many parties. The overall task of designing and validating the autonomous vehicle thereby splits into smaller sub-tasks. Different parties take care of these subtasks, acting as component suppliers to the system integrator who builds the overall HAD vehicle. The system integrator also validates the integrated system. Similar to the integration of the real vehicle, the suppliers deliver a “digital twin” of the real components for the integration into the virtual vehicle, which is then used for the creation of a SiL validation and verification toolchain. As an example, virtual ECUs have to be provided by the ECU providers, sensor models are required from the sensor providers, and vehicle model (parameters) are needed from the vehicle chassis designers.

During the development cycle of an HAD vehicle a broad set of user groups is involved, having an even broader set of requirements to the SiL toolchain. Starting with the provision of the different individual system components over data driven open-loop testing to closed loop system integration and large scale parallel execution of driving manoeuvres according to a driving manoeuvre catalogue, the collaboration among different users, teams, and roles needs to be supported.

ETAS tools support these use-cases by consequently following a modular tool architecture based on standards. They can thereby be used as standalone installations, or they are integrated into customer specific toolchains using their powerful API interfaces.

Scalable SiL: From Desktop to Cloud Computing

Creating a SiL environment in cooperation with development partners is typically done incrementally, allowing to manage the efforts and the complexity that are associated with this task. It typically starts in a reduced setup, where a smaller user group integrates components in a SiL environment on a desktop computer. As soon as this set-up works successfully, it is enriched by more accurate parameterization and test-cases, then integrated in a larger virtual vehicle, and so on. When the number of required simulations or the complexity of the SiL simulation increases, e.g. by running virtual test drives over many millions of kilometers, the need for computational power is increased. To satisfy this need, scalable architectures are required, e.g. server clusters or a cloud infrastructure. They are ideally suited to support the demands for computation power of SiL based HAD validation and verification.

Implementation of a SiL Simulation Solution for HAD

As outlined before, the core idea of SiL validation and verification is to couple virtual ECUs *(vECU)* with *plant models*, i.e. a virtual car and its environment. The resulting system simulation is deployed to a *simulation target* to observe the functional behaviour of the objects under test in a virtual environment. Simulation and coupling of plant and vECU is done using an *integration and co-simulation tool*. Since ECUs are connected via automotive busses in the real car, the *simulation of automotive busses* is also required for the overall SiL solution. This “SiL simulation core” can be completed by additional tools, e.g. by test automation tooling to enable continuous testing use cases.

ETAS provides all the artefacts and supportive tools required to create such a “SiL simulation core”. In the following, we further focus on the integration and simulation platform as well as on tools to generate virtual ECUs. They all have in common that they support the previously described requirements on collaboration and scalability. At the same time, they can be flexibly deployed from local user PCs to servers and cloud infrastructures to support the various setups for HAD validation and verification as outlined above.

Integration and co-simulation platform

The ETAS COSYM integration and simulation platform allows users to integrate virtual ECUs, software and plant model artefacts to simulate the (virtual) HAD vehicle with its environment. It allows users to integrate and connect simulation models (e.g. as FMUs) and virtual ECUs built on different technologies. ETAS COSYM can deploy the simulation on various simulation targets. It supports real-time targets used for HiL testing, SiL simulation on a desktop computer, and the SiL simulation in the cloud. It can either be used as a full stand-alone installation on a desktop computer for interactive usage, or as a simulation backend service as part of a continuous integration toolchain.

Open and Modular Architecture

To support the need for cooperation as described above, ETAS COSYM follows a modular and open tool architecture with interfaces based on standards. This way, the tool can be tailored to the users' needs and be integrated into existing tool chains. As examples, COSYM allows the import of simulation models via the FMU standard, or the coupling to test automation tools using the ASAM standards.

Even more important, COSYM is fully controllable via an API and can thereby be integrated into continuous integration processes – including the execution of COSYM as a backend simulation service in the cloud.

From Desktop to Cloud to Real-time Computing

By its ability to deploy the simulation run into the cloud, ETAS COSYM also allows users to take advantage of the full, highly parallel computation power of the cloud. The simulation results exactly stay the same, independent if the cloud or a desktop computer is used. ETAS COSYM is designed to operate with all major commercial cloud infrastructure providers or, alternatively, on in-house cloud solutions. The user can take advantage from the vivid market of cloud providers, originating from IT dominated applications and offering computational resources at increasingly cheaper prices compared to the costs of operating own computation infrastructures.

Finally, ETAS COSYM also supports to deploy the simulation a Hardware-in-the-Loop (HiL) system operating in real-time. This allows a maximum re-use of artifacts created for the SiL simulation in the HiL based validation steps.

Simulation of Automotive Busses

Autonomous driving functionality is implemented distributed over a network of ECUs. The reasons for this are manifold, e.g. the reuse of legacy from existing EE architectures, modularity to cover system variants, the need for specialization of controllers on one task (e.g. brake controller with specialized circuits to control hydraulic systems), or safety considerations. In the vehicle, this network of ECUs consists of automotive communication buses. In a similar manner, simulated automotive buses are used to integrate virtual ECUs into a virtual vehicle in a SiL simulation. SiL environments therefore also need to provide the capability to simulate automotive bus functionality.

ETAS provides the simulation of automotive busses as part of the integration and simulation tool chain COSYM. This way, numerous system properties of the HAD vehicle can be investigated, e.g. the system behavior under the influence of communication latencies induced by heavy bus loads; the performance of diagnosis algorithms identifying failures in the bus communication; and the system stability if whole ECUs fail and backup strategies in the HAD vehicle are applied. In all these cases, the properties of the inter-ECU communication change dynamically. With COSYM, they can be investigated, since bus communication is an integral part of the overall SiL setup.

Virtual ECUs

To handle both safety requirements as well as functional requirements equally well, hybrid architectures are often used for HAD ECUs. They contain at least one microcontroller, which typically features a software architecture based on the AUTOSAR Classic Platform standard. In addition to that, one or multiple microprocessors take care of high performance calculation tasks. AUTOSAR proposes a software architecture for these microprocessors as well, which is described by the AUTOSAR Adaptive Platform standard [Bechter].

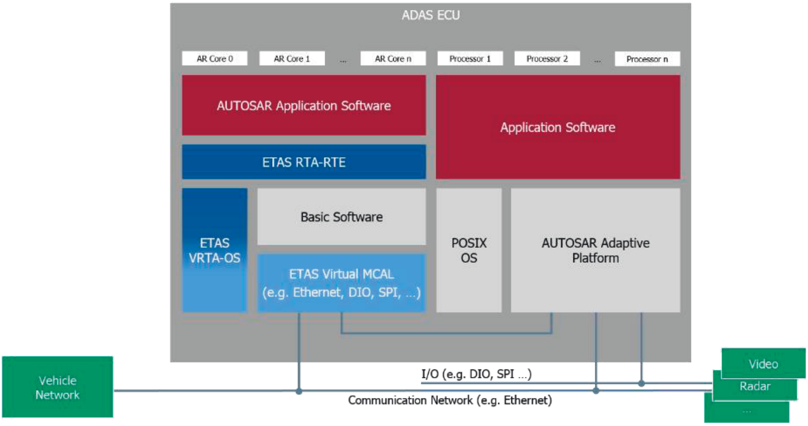

Figure: Possible Heterogeneous HAD ECU Architecture

Virtualizing an ECU, which is based on such a heterogeneous architecture, requires separate consideration of both, microcontrollers and microprocessors, which have fundamentally different properties. The AUTOSAR Adaptive Platform proposes a POSIX based architecture for the microprocessors. For their virtualization, off-the-shelf solutions exist. They are not discussed here.

The virtualization of the microcontroller imposes bigger challenges. Microcontroller architectures are substantially different from PC or server-based architectures. Yet ECU virtualization requires the execution of code, which is intended for a microcontroller-based target system, on a PC or a server. ETAS provides a solution, which allows bridging these differences while at the same time maintaining a maximum possible congruence between the behavior of the virtualized ECU and the real ECU, including aspects of scheduling, multi-core operation, and others: the ISOLAR-EVE product.

ISOLAR-EVE distinguishes carefully between hardware-independent and hardware specific code. All code that is independent from the target hardware platform, i.e. application software (ASW), the AUTOSAR runtime environment (RTE), and large parts of the AUTOSAR basic software (BSW), will be directly reused for the virtual ECU without changes. The remaining code, i.e. the code that is hardware specific, will be replaced with implementations for the PC that provide comparable functionality. In particular, there are specific implementations of the operating system (OS) and the microcontroller abstraction layer (MCAL), which substitute the corresponding microcontroller-specific implementations. While the OS is based on ETAS' production OS implementation that has been proven in hundreds of millions of production vehicles, the MCAL is specifically designed to use the PC platform in an optimal way. ISOLAR-EVE hence allows building virtual ECUs, which contain nearly the complete functionality of real production ECUs and thus reproduce their behavior as realistically as possible. This is because the virtual ECUs contain not only the ASW, but also nearly the complete BSW and large parts of the production OS.

Since the communication among different ECUs represents an essential aspect of the overall system virtualization, each individual virtual ECU needs to support the relevant communication mechanisms of the network. Consequently, including the respective communication stack, which is typically part of the AUTOSAR BSW, in the ECU virtualization, and an interface to the virtual bus implementation, is indispensable for a realistic SiL setup.

Depending on the goal of the virtualization, the required degree of detail may vary from ECU to ECU. In some cases, it may be sufficient to reproduce an ECU's functional aspects without reflecting all details of network communication. ISOLAR-EVE supports functional validation on application software level as well as the verification of individual software components, integration testing, or regression testing on the complete ECU software. For this purpose, the corresponding virtual ECUs provide interfaces on different levels above the BSW, e.g. the Functional Mockup Interface (FMI) for signal exchange on the level of physical signals, or open interfaces for parametrization of the virtual ECU and the manipulation of ECU internal data.

Through its openness and modularity, ISOLAR-EVE ideally supports the integration into continuous integration toolchains. It allows the creation of virtual ECUs for the local PC at the developer's desk over server clusters and cloud architectures to real-time setups. It goes without saying that the integration of virtual ECUs with the ETAS COSYM co-simulation platform and with virtual bus networks is supported as well.

Obviously, a standardized SiL architecture, as mentioned above, will also play an important role for the interfaces of virtual ECUs in the future.

Application of Technology

ETAS participates in a project, in which a large scale, cloud based SiL simulation environment is created supporting the validation of an ECU and its parameterization in virtual endurance runs. The project implements a graphical user interface (GUI) that allows automotive engineers to configure virtual test drives for the validation of virtual

ECUs. The GUI is fully customized to support the workflow and needs of the engineer using the tool. By the click of a button, the engineer can start the virtual test drive. In the background, the tool deploys the SiL simulation to a cloud infrastructure, where, e.g., 2000 parallel simulation jobs are started, executed, and the results are provided to the GUI front-end. The massive parallelization leads to the situation that the simulation time is not limited by the duration of the virtual test drive, but by the general time to start, deploy and finish the simulation – summing up to only a few seconds. The massive amount of simulation data remains in the cloud to perform the data analysis step there.

The modular structure of ETAS COSYM is used for a strict separation of simulation backend service and user interface. The cloud and the IT technology used is hidden to the user who can focus on the analysis of the simulation results. He does not have to care about the technical hurdles of operating a cloud simulation. In later stages, the fully scriptable simulation service will be integrated in continuous integration & test tool-chains.

The project also takes advantage from the consequent design of ETAS COSYM for cloud operation. The tools generates code consuming a minimum amount of computational resources only. This is important since cloud payment models are based on resource usage. ETAS COSYM is designed to minimize the costs of operation in the cloud.

Summary

The development of HAD vehicles demands for cloud based SiL validation and verification. By this, the need for cooperation between many parties and the demand for high computational power can be satisfied. To address this, the simulation and integration platform ETAS COSYM and ISOLAR-EVE are designed consequently to operate in the cloud. The use of micro services enables continuous integration and testing approaches, cooperation among multiple engineers working at different locations, and flexible usage of the co-simulation platform. Since COSYM supports the most important cloud infrastructure providers on the market, companies are free to choose the platform of their choice and take advantage of the dropping prices in the competitive market of cloud infrastructure providers.

From the viewpoint of the HAD vehicle development engineer, ETAS tools pave the way to take benefit of the rapidly developing cloud technology. The developers can focus on their core tasks, e.g. system design and function development, rather than handling technical hurdles of cloud operation.

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Handling complex systems: systems design for AD vehicles

Martin Grießer, Maged Khalil and Stefan Dreiseitel

Systems & Technology, Continental Chassis & Safety

T. Bertram (Hrsg.), *Automatisiertes Fahren 2019*, Proceedings,
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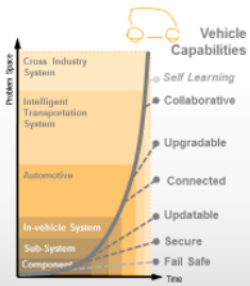
Content

Digitalization requires new Vehicle Capabilities

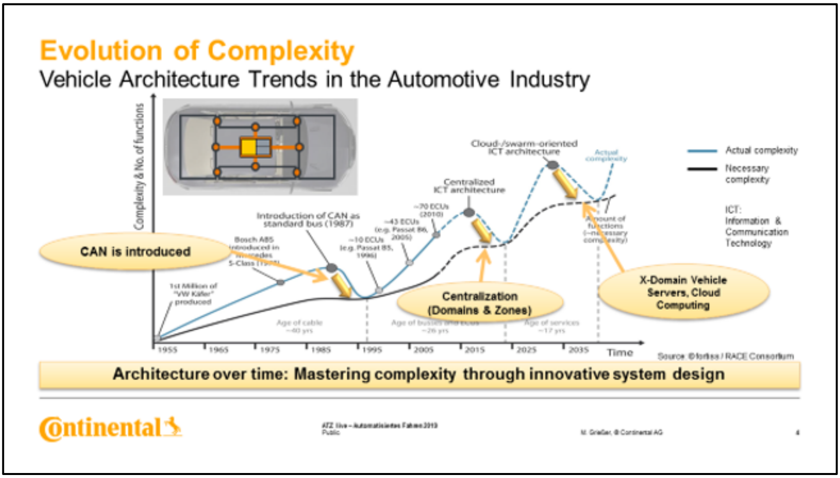


Digitalization challenge

- The vehicles of today **learn ONCE**
- The vehicles of tomorrow will **learn over their life time**

Key driver

- automated driving
- electrification
- integration of the environment
- time to market of new features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Actual complexity
Necessary complexity
ICT: Information & Communication Technology
Centralization (Domains & Zones)
X-Domain Vehicle Servers, Cloud Computing
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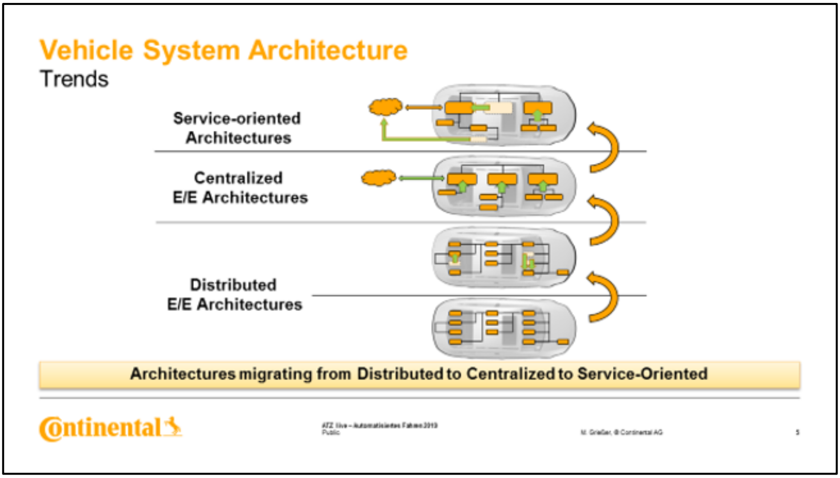
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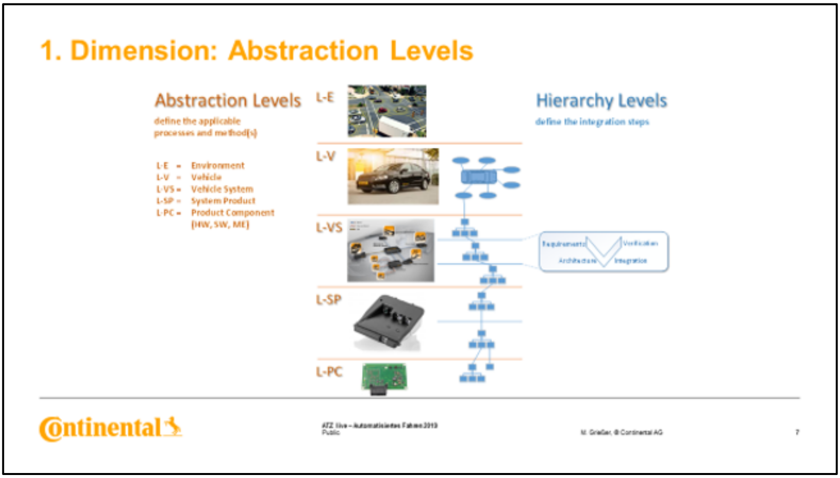
1. Dimension: Abstraction Levels
Abstraction Levels
define the applicable processes and method(s)
L-E = Environment
L-V = Vehicle
L-VS = Vehicle System
L-SP = System Product
L-PC = Product Component (HW, SW, ME)
L-E
L-V
L-VS
L-SP
L-PC
Hierarchy Levels
define the integration steps
Requirements
Architecture
Verification
Integration
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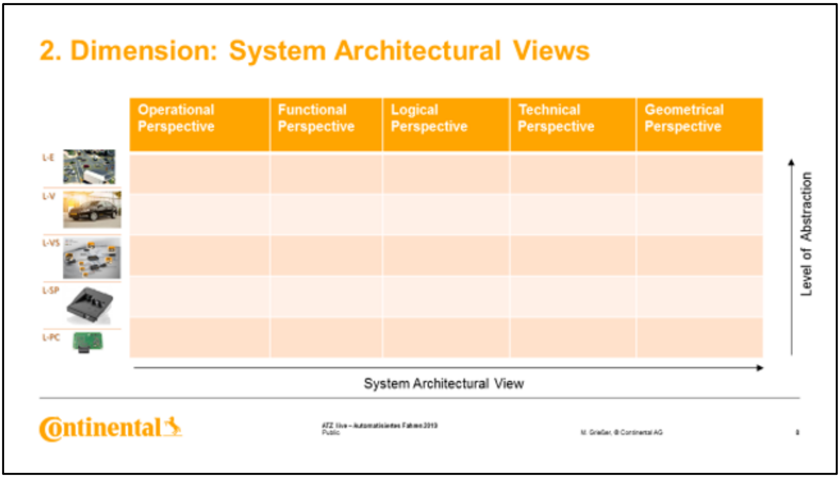
2. Dimension: System Architectural Views
Operational Perspective
Functional Perspective
Logical Perspective
Technical Perspective
Geometrical Perspective
L-E
L-V
L-VS
L-SP
L-PC
Level of Abstraction
System Architectural View
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