VDI

Automotive and
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18. Internationaler Kongress /
18th International Congress

EUROPE ELIV

# VDI-Berichte 2299

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**Lichttechnik / Lighting Technology**

## Security



## E-Mobilität 2025 / E-Mobility 2025

# Foreword

Seamless Electronics for Automotive Services

Going forward from the last ELIV - „Electronics in Vehicles“ in 2015 - the most significant Congress in Automotive Electronics has now seen a substantial upgrade.

In line with the feedback given by participants, speakers and journalists we have added new elements and contents to the event, which is beneficial for all involved.

The announcement of moving the Congress from traditional Baden-Baden to Bonn in 2017 has certainly also done its bit to shape the event further. The city of Bonn represents internationality, growth, and easy access and is synonymous with technical know-how at the highest level – all of which does credit to the congress, particularly in light of the turnaround in the car industry driven by the latest electronic developments.

All members of the program committee have been able to convince themselves in person of the capability of the new UN Congress Center, which is located within close proximity of the plenary hall of the former Bundestag. We are planning a new dimension of exhibitions combined with product demonstrations as well as an accompanying start-up market place.

A discussion will be held there along the lines of how the distinct core competences of automobile manufacturers and suppliers can be skillfully combined with those elements that come with the new world. To take account of this and to stimulate the continued debate about mega trends, the offboard elements as part of the extended End2End effect chain will enter the congress as a new major component:

The groundwork for „**Electromobility 2025**“ has to be laid now. We are already „**en Route to Highly Automated Driving**“. Connected Car will become „**Smart & Connected Vehicle**“ and will be enhanced by technologies inherent in the „**Offboard Ecosystem**“, like backend issues, cyber security and neural networks.

To accommodate for the latter, we have invited representatives from IT-related industries to join our program committee.

Likewise, a range of lectures have been planned for the underlying enabler technologies: Vehicle wiring system, methods and test, End2End architectures, security and user interface design.

The proven basic concept of the congress is now entering a new level of sophistication: High-quality specialist lectures are embedded in groundbreaking management talks which will be subject of controversial debates. New trends will be set. Especially Bonn itself is ideally suited to foster the formation of both a technical as well as a human network. This will play a key role for a successful event.

I hope to have inspired your enthusiasm and look forward to the impetus that will be given during this exciting time of change in our industry by the congress.

**Dipl.-Ing. Uwe Michael**

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# BMW 2021: Auf dem Weg zum automatisierten Fahren

Dr.-Ing. **Klaus Büttner**, BMW Group AG, Garching

**Kurzfassung**

BMW hat sich im Rahmen der „Next 100 years"-Strategie auf den Weg gemacht, mit hoher Geschwindigkeit und Ambition den mobilen Wertschöpfungswandel zu gestalten. Neben der technologischen Herausforderung, die mit der Verantwortungsübergabe vom Mensch zum Computer bei Automatisierungsgrad L3 (HAF) einhergeht, wird BMW gleichzeitig das vollautomatisierte Fahren im komplexen, urbanen Umfeld bei Automatisierungsgrad L4 (VAF) in ausgewählten internationalen Städten ausrollen. Die Herausforderungen in der Breite lassen sich nur mit gebündelten Kräften von internationalen Technologiekonzernen meistern. Daher ist BMW eine strategische Partnerschaft mit Intel und Mobileye eingegangen um schnell, kompetent und nachhaltig innovative Technologien im automatisierten Fahren in den Markt zu bringen.

**Themenüberblick**:

– Aktuelle Planung BMW HAF (L3) und VAF (L4) in 2021
– Überblick Technik HAF-/ VAF-Architektur
– Aktueller Stand und Erfolge Kooperation BMW/ Intel/ Mobileye
– Überblick non-exclusive AF Plattform
– Aktueller Stand Ethik und Gesetzgebung
– Überblick BMW HAF/ VAF Versuchsflotte inklusive Vertiefung:
  - Architekturkonzept
  - Sensorsetup
  - Sicherheitskonzept
  - Datensicherheit/ Security
  - Absicherung inkl. Simulation

# Steps towards Highly Automated Driving

Dr.ir. **Rudolf Huisman**, Ir.PDEng. **Thierry Kabos**,
Ir. **Menno Beenakkers**, Ir. **Aart-Jan van Eck**,
DAF Trucks NV, Eindhoven, The Netherlands

**Abstract**

DAF has demonstrated Platooning, Auto Docking and Traffic Jam Assist on prototype vehicles. To realise these features, different reusable “building blocks" have been developed which are illustrated in this paper. For Platooning, measures are taken further decreasing the time gap between platooning vehicles in order to improve fuel efficiency. For Auto Docking, an innovative concept has been developed to determine the trailer position using a 2D or 3D laser scanner mounted at the docking station. Finally, a track-to-track sensor fusion technique has been used in combination with a (gain scheduled) longitudinal plus lateral vehicle control concept for Traffic Jam Assist.

## 1. Introduction

On the route to Highly Automated Driving (HAD), DAF is working hard on automation of those driving tasks which have a clear business case for our customers; e.g. highway driving. Platooning has the potential to decrease the driver dependency on safety, damage, fuel economy and productivity. In addition, it enhances driver comfort (see Fig. 1).


Fig. 1: Main goals and benefits for platooning (Borsboom [1]).

In addition, the feasibility of other automated driving features is investigated, such as manoeuvring at a loading dock and driving in a traffic jam. Auto Docking (AD), for instance, is beneficial for eliminating damage costs and reducing the driver waiting time at the dock. And Traffic Jam Assist (TJA) offers a clear driving comfort improvement and, eventually, a fuel economy benefit, a reduction of road congestion and an improved productivity (as soon as legislation allows traffic jams as “rest time”).

DAF has demonstrated Platooning, AD and TJA on prototype vehicles. To realise these features, different reusable “building blocks" have been developed which are illustrated in this paper. In chapter 2, the high level functional architecture incorporating the main function building blocks for HAD is described. The content of these blocks are illustrated in chapters 3, 4 and 5 for Platooning, AD and TJA respectively. In the current status, these features represent driving automation level 2, 4/5 and 2, respectively [6]. Finally, chapter 6 is on conclusions and the outlook to further research.

## 2. Building blocks for highly automated driving

The main building blocks of the functional architecture necessary for HAD are shown in Fig. 2. See Huisman et al. [5] for more information on the tool which DAF uses to describe functional and E/E architectures. The block ‘driver inputs’ contains all the switches and buttons the driver can use to enable, disable or adjust different features. In the block ‘sensors’, for example, radars, cameras and LIDARs are used to determine distances and speeds from objects around the vehicle. This can be at a low level (i.e. raw sensor data) or at a high level (i.e. by using smart sensors). Other sensors are used to measure ego vehicle quantities such as engine speed, vehicle speed and yaw rate.

The output of ‘sensors 1-n’ and ‘driver inputs 1-n’ blocks are used by ‘sensor fusion & world model’ to create high quality input signals for the nominal functionalities such as longitudinal and lateral control of the vehicle. Parallel to the ‘nominal functionality’ block, a ‘safety supervisor’ is used to monitor the driver inputs and sensors, plus the output of the nominal functionality block in order to switch off some functionalities or go to a degraded mode (by using the ‘arbitration block’). This may be required in case of, for instance, sensor failures. Finally, different actuators, such as the engine, brakes, steering system and gearbox are actuated based on outputs of the arbitration block.

# Highly automated driving (HAD) and parking (HAP)

## Trends and Challenges

Dr. **Stefan Waschul**, Dr. **Burkhard Iske**, Dr. **Christian Raksch**,
**Thomas Führer**, Chassis Systems Control, Leonberg

**Abstract**

The world of Highly automated driving (HAD) and parking (HAP) is evolving at an impressive pace. Traditional vehicle manufacturers are changing their roadmaps and pulling ahead functions by several years. Level 3 functions are now likely to be on the road within this decade. At the same time the race has started for Level 4/5 functions. This accelerated development is a game changer for the automotive industry.

The presentation starts with a brief review of the market requirements for Driver Assistance products. While excellent functional performance of single components is important it is also obvious that only best system performance including advanced sensor data fusion will fulfil the market requirements for NCAPs world-wide, HAD and HAP. An exemplary system architecture including sensors, maps, connectivity and security is being derived and discussed. A selection of concrete HAD and HAP use cases will be presented.

Another important aspect of developing HAD and HAP functionality is the validation concept. The traditional approach to develop and validate full system functionality before vehicle start of production might not work in the context of HAD and HAP. The concept of field based validation will be introduced as a potential solution with some implications.

**Market and requirements**

Research institutes have conducted studies which give insight into the situation of the market as well as the requirements for future advanced driver assistance systems (ADAS).

Surveys [1] from 2012 to 2015 show, that there is globally a great interest of end customers in ADAS with functions like Blind spot detection, Predictive emergency braking for Pedestrians, Adaptive cruise control, Traffic jam assist and finally Construction zone assist.

An analysis of the new car registrations from 2015 [2] shows every 4$^{th}$ new car registered in Germany has an Automatic emergency brake system integrated and 16% of new cars registered in Germany are equipped with Lane assist systems. This is already a reasonable double digit installation rate – see Figure 1.

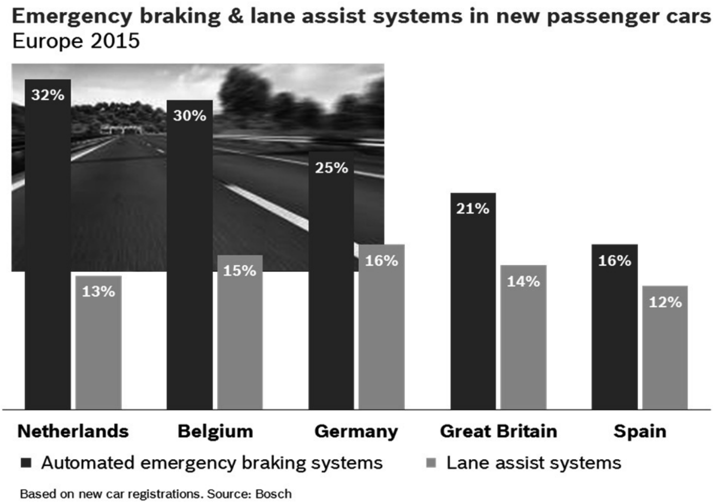


Fig. 1: New car registrations in Europe in 2015 with ADAS functions [2]

And further automation of driving and parking makes a lot of sense. Up to 90% of all accidents with physical injuries in Germany are caused by human errors and a high degree of automation will decrease the accident rates in future significantly – besides the increase in comfort which can be also expected [3]. Therefore every large vehicle manufacturer is working on roadmaps to increase the level of automation as soon as possible. Level 3 functions, especially for highway driving and for parking are now likely to be on the road within this decade. At the same time the race has started for Level 4/5 functions in urban scenarios.

**Highly automated driving**

Besides the end customer acceptance and willingness to use and pay for highly automated driving, there are also some technical requirements to be fulfilled (see Figure 2).

Moreover the proper sensing of the surroundings for possible upcoming obstacles and hurdles based on redundant and orthogonal sensor principles, the system in all its functionality must be safe – following dedicated safety designs of hardware, software and of the overall system. The combination of the sensors (which ensure highly robust environmental modelling in all use cases), intra-connections with the decision making units (e.g. Central Electronic control unit (ECU) including video processing and computing power for deep learning net-

# Artificial Intelligence for Cars – Applications, Technologies and Challenges

## AI will transform the entire automotive industry

Dipl.-Ing. (FH) **Florian Netter**, B.Sc. **Philip Elspas**,
Audi Electronics Venture GmbH, Gaimersheim

**Abstract**

Artificial Intelligence (AI) is an emerging technology that enables unprecedented applications in vehicles but requires a new mind-set for automotive software development. While conventional software development aims to distil expert knowledge into code, AI is data-driven and works best when learning doesn't stop after a product launch. In order to realize this, both vehicles and backend must be empowered to satisfy AI's massive demands towards computational performance and connectivity. This session discusses fundamental key concepts for AI in vehicles, hardware aspects and system requirements.

**Introduction**

Over the last years many innovations were developed in the field of driving assistance. One example is the Audi active lane assist: This system warns if the driver is changing the lane in a risky situation and even gives active support to hold the current lane. With increasing number of software and electronic systems, driving assistance can take more and more tasks from the driver. A further step is taken with the traffic jam pilot in the new Audi A8, presented in July 2017. Activating the Audi AI allows the car to drive automatically in traffic jam situations and up to 60 km/h. Continuing this technological development leads to more and more autonomous driving.

Automated driving needs a full 360-degree view of the close, mediate and far environment. This includes several cameras and sensors for distance measurement. The amount of sensor data and the massive variety of traffic situations make autonomous driving complex. Classical software development, where domain knowledge is used to define a behavior for any kind of input, becomes infeasible. Especially rare situations, like a policeman taking over and overruling other traffic rules, are challenging for classical software development. This can be handled better with AI-based approaches that can learn to handle a comprehensive spectrum of different situations.

Inspired from the human driver and pushed by advantages in this field of research, AI becomes a key technology for intelligent vehicles. Using high performance ECUs, fed with comprehensive sensor data, AI can learn to distill the relevant information to interpret the context. A further enabler is swarm communication. Just like we as humans can learn by taking others as example, smart vehicle can leverage the whole fleet of intelligent cars and learn from each other. Cars that get into critical situations can provide their experience to the fleet improving the AI in a continuous way.

Those and further concepts are described and presented in this paper to give an overview about the state of the art and future challenges bringing AI successfully in cars.

**Overview Artificial Intelligence**

AI is a section of computer science aiming to develop software systems that behave similar to a human intelligence. There are a number of sub-sections, like knowledge-based systems, robotics, Natural Language Processing, Machine Learning and much more. Machine Learning for instance learns from existing data and examples. After the training phase this kind of algorithms are capable to generalize based on learned patterns and can therefore be used in similar situations and use cases.

A popular approach to model AI are neural networks. They are based on a simplified replication of the human brain, significant mathematical elements are neurons and synapses. Neurons are kinds of nodes gathering input data and generate an output signal based on a mathematical function. In addition synapses present a weighted connection between one or more neurons. A simple neural network can be seen in Fig.1.

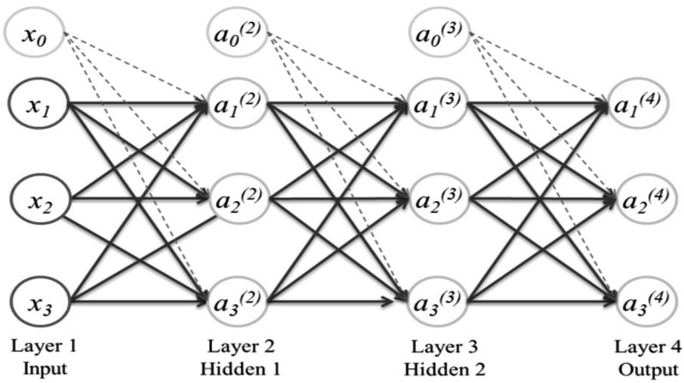


Fig. 1: Simple Neural Network with 3 inputs, 2 hidden layers and 3 outputs

# Teaching a Car to Drive

## Automating the extraction of domain knowledge by observing human drivers

**Urs Muller**, **Lawrence D. Jackel**, NVIDIA, Holmdel, NJ, USA;
**Joachim Langenwalter**, NVIDIA, Munich

### Abstract

We demonstrate that deep neural networks can learn autonomous driving related tasks that were previously thought solvable only by manual decomposition of the problem. Furthermore, we show that learned execution of maneuvers can be performed without relying solely on localization and HD maps.

We teach deep convolutional neural networks (DNN)s to drive a car by observing human drivers and emulating their behavior. The use of hand-crafted rules is kept to a minimum. We found that these networks can learn more aspects of the driving task than is commonly learned today. We present examples of learned lane keeping, lane changes, and turns. We also introduce tools to visualize the internal information processing of the neural network and discuss the results.

This learning-based technology is part of an end-to-end platform ultimately enabling self-driving cars up to Level 5. These solutions include DNN training software and hardware, DNN networks (e.g. object and lane detection), HD mapping integration, localization, path planning and embedded hardware (DRIVE PX2) to deploy in autonomous vehicles. We are integrating these findings with other technology to build a fully self-driving system. We employ the idea of “diversity” of components to mitigate the risk of failure of a single technology.

### Introduction

In this paper, we describe an end-to-end perception and control system for autonomous driving that learns by observing the behavior of a human driver. We have also created additional system components that use a more traditional, modular approach, but which still heavily rely on machine learning.

In our end-to-end system, known as PilotNet, there is no clear delineation between the perception components and the control components. PilotNet optimizes its perception in service of the ultimate goal of vehicle control. To give us insight into the internals of PilotNet, we cre-

ated a tool that provides real-time visualization of the objects in the world that most influence our PilotNet's decisions.
Our modular system includes components that perform mapping, localization, path planning, and obstacle detection. We expect fielded systems will elements of end-to-end learning as well as distinct functional modules. Such an architecture will provide cross-checking, improving overall reliability and safety.

**System Design**
The traditional approach (see, for example, [1], and references cited therein) for self-driving software evolved from years of robotics research and represents what appears to be a rational view of the process:

1. sense the environment
2. extract features
3. recognize objects
4. create an occupancy grid
5. plan a path
6. issue motor commands

This approach assumes we know which objects we need to recognize as well as their correct level of abstraction, i.e. should that object be labeled simply as a vehicle, more precisely as a truck, or even more precisely as a cement mixer? Similarly, the traditional approach needs to specify how much detail and precision is needed in the cost map and what decisions need to be made to plan a path.
With the PilotNet end-to-end system we explore a different approach to system architecture, requiring us to make fewer assumptions.
PilotNet has essentially two steps:

1. sense the environment
2. issue motor commands

This simplicity is possible because we train a DNN [2] to produce the same control commands as a human does when viewing a similar scene. The PilotNet DNN [3] consists of 9 layers, including a normalization layer, 5 convolutional layers and 3 fully connected layers. The input image is split into YUV planes and passed to the network. The first layer of the network performs image normalization. The normalizer is hard-coded and is not adjusted in the learning process.

# Cross-industry cooperation for camera technology standardization

Dr.-Ing. **Frerk Fitzek**,
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Director of Automotive Solutions Architecture,
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**Erez Dagan**,
Mobileye Vision Technologies

**Topic:** Automated Driving and Driver Assistance Systems

"Autonomous driving will change the automotive industry" – statements like this are common sense in the meantime. No one doubts anymore that autonomous driving will change everything. The way we experience mobility, the way we interact with the car and nonetheless how we will live in future.

Besides disruptive future visions and well-looking powerpoint presentations are two simple questions: how does the technical solution look like? And how can we deal with the hardware and development costs?

Hundreds, maybe thousands of engineers in the world around all disciplines are working on this topic. They all think about the best technical solution and are facing the challenge to reach level 4 and 5 of autonomous driving for the customer. From architecture down to industrialization of the sensors and integration platforms, this challenge is one of the biggest in the automotive industry.

One aspect out of that is the sensor configuration which is needed to perceive all objects and obstacles around the car. Different types of sensor technologies like radar, lidar, ultra-sonic and camera are needed. None of them are obsolete, every technology is needed. But one technology has a key role for autonomous driving: the camera technology. The analogy to the human driver is obvious. We are driving our cars (autonomously) with only two single sensors: our eyes. For autonomous cars the camera technology delivers objects like cars, pedestrians, cyclists, detects the freespace or obstacles, and perceives lanes, traffic signs or traffic lights. Based on computer vision algorithms, all important features of the environment are detected and classified by the camera system.

There are two general classes of camera modules: “smart” cameras, which do basic image processing inside the camera and send (often compressed) video across a cable using a technology such as Ethernet, and raw data cameras, which send uncompressed RAW or YUV format video via serializer/deserializer (SerDes) devices to a centralized ECU processor.

The transfer of raw data enables the image signal processing (ISP) function to be moved out of the camera modules into a centralized processor in the ECU. This brings the following advantages:

- allowing the camera modules to be smaller and less expensive
- easier thermal management of the camera concept (with same size requirements)
- scalable centralized computer vision platforms with same camera modules (e.g. level 3-5)
- lowering development cost (e.g. validation synergies or concept development)
- and finally the option to define a cross-industry standard

All signals - high-speed video data, low-latency bidirectional control, and power/ground - are transmitted over a single low-cost coaxial (coax) cable through one small connector. SerDes interfaces have been popular in infotainment display applications for many years, and they are now gaining wide acceptance in ADAS/autonomous driving applications as well.

Additionally, rapid growth in the market is driving the need for more standardized, off-the-shelf camera solutions. Therefore, the authors decided to set up an open cross-industry co-operation to develop a camera module toolbox with the target to focus on the needed specification to meet the common requirements on cameras for autonomous driving. The toolbox includes:

- the optical path: imager and lens
- the geometric integration: size, connector
- the interface: electrical specification, protocol

# Extending the sensor range for highly automated driving: a new approach for environment modelling

Dr. **Nicole Beringer**, **Olav Koska**, M.Sc.,
Elektrobit Automotive GmbH, Erlangen and Brunswick

**Abstract**

This paper describes a novel approach to cope with driving scenarios in highly automated driving which are currently solved only by the driver's control. The approach presented in this paper is currently being implemented as a prototype to be used in our test fleet. It combines techniques well established in robotics like Simultaneous Localization And Mapping (SLAM) as well as end-to-end protection and image compression algorithms with big data technology used in a connected car context. This allows enhancing the positioning of individual vehicles in their Local Environment Model (LEM). This is the next step to overcome current dependencies to in-vehicle sensors by using additional cloud-based sensor processing to gain information.

## 1. Introduction

In highly automated driving (HAD) there are still a lot of driving scenarios where the driver needs to take over control. The reasons for taking over vary from limitations of the range of ego sensors or recognition algorithms to required information, e.g. infrastructure information like traffic lights, which cannot be derived from in-vehicle sensor observations. What all have in common is that any reaction, from the driver as well as from a driver assistance feature, needs to be in time. This becomes clear when looking at the range of ego sensors (e.g., LiDAR sensors about 40m ahead). The driver may want to have the speed reduced in advance before a speed sign is reached or be warned in time to take over control if the autonomous driving road ends. It is quite clear that it needs more than just a high quality in-vehicle sensor processing in order to obtain a wide range of HD information needed for automated driving.

Imagine the following scenario: your car is equipped with all necessary sensors to allow highly automated driving. Your car drives on a motorway which is suitable for HAD while you are asleep. During an overtaking manoeuver, the sensors which are needed for HAD stop working due to some technical defect and you cannot take over. Fortunately, the car is able to bring itself into a safe state. But even if the car manages to navigate to the emergency lane for the safe state it is still dangerous enough for the passengers. That is where our approach

enters the game: By fusing the environment model of our endangered car in the described scenario with other environment information, it can reach a safe state which is also not dangerous for the passengers: For instance, by driving to the next parking lot, even if it is several kilometers away from the position where the sensors of the car stopped working.
The next section gives an overview of current approaches. In section 3 and 4 the underlying algorithms are described. Section 5 presents our current results. The last section gives an outlook for future work.

## 2. Current approaches

Within recent years, the trend shifts towards obtaining a wide range of information for HAD from a cloud-based solution instead of only relying on a single-source evaluation of ego sensors, even if the in-vehicle sensor processing is of high quality. In the literature you can find several publications, e.g. [1], [2], [3], [4], [5], [6], [7], [8] as well as webinars (e.g. [9], [10], [11]) dealing with possible solutions.
One major idea is to enrich existing navigation maps with HD information as described in [12] and [13]. This is quite an efficient method to provide highly accurate, up-to-date maps for the development of self-driving vehicles based on map data information in the electronic horizon. For further details on the electronic horizon, please take a look at one of the following references [14], [15], [16].
The described approaches need to meet the quality criteria as follows:

- Up-to-date-ness: Data is continuously transferred to the cloud. Any changes to the road for instance are detected as soon as the vehicle passes by. The sensor quality may need to be confirmed by other vehicles.
- Reliability: Deviations of map contents used in the vehicle are detected by the vehicle sensors and are directly submitted to the cloud. The data is always up-to-date and with this, the probability of unconscious changes is drastically reduced as other vehicles always crosscheck the map content as well.
- Precision: The map becomes more precise with more collected data.

Limitations of ego-sensor ranges and recognition algorithms can be overcome well. Using classic navigation maps as base layer, it is fast to improve on HD features.
Grid-based approaches as in [17], [18], [19] and [20] need to have a general idea about the structure of a HAD system with its components that are required for a dedicated functionality. The current approaches follow the sense-plan-act-principle [21]. To reduce complexity, sensors, components with special tasks (e.g. control), and actuators need to appropriately interact within an HAD system.

# Proposal for standardization of sensor interfaces to a fusion unit

Dr.-Ing. **Thomas Schaller**, BMW Group, Munich;
Dr. **Werner Uhler**, Robert Bosch GmbH, Leonberg;
**Jörg Schrepfer**, Valeo Schalter und Sensoren GmbH, Kronach

**Abstract**

Automated Driving (AD) opens up new perspectives in mobility and is therefore currently one of the main focuses in the development of future vehicles. New technologies will be implemented to ensure the needed degree of system integrity and performance. In particular, environment sensor systems have to work together in sensor fusion units in an unprecedented level of complexity. An automated driving sensor setup includes therefore established technologies like Radar, Camera and Ultrasonic systems as well as new technologies like Lidar.

An important means to meet the challenges of developing automated driving functions, especially automation level 3-5, is standardization: There is a huge potential in reducing costs for development, test and validation by standardizing subsections of the complex hardware and software setup for AD functions. The paper highlights the motivation and advantages of the standardization. As environmental sensors are considered the major enabler of AD, this paper also introduces a generic AD architecture. Based on this architecture, the different potential areas of standardization for environmental sensors will be described. Moreover, a concrete proposal for a standardized logical interface from sensors to a fusion unit will be introduced.

## 1. Motivation for sensor standardization

### 1.1 AD functions need different sensor technologies and a complex setup

In AD functions allowing drivers to at least take the eyes off the road for some time, like planned with Automation Level 3 and above for SOP > 2018, a high grade of coverage and redundancy in the sensor equipment is needed.

In an AD sensor setup, sensors need to observe every direction around the car in close distances up to far distances > 200 m. This leads to cocoon configurations of each sensor type.

The high detection ranges are required due to speeds >120 km/h of the own car and even higher speeds by other cars in combination with delays caused by computational and data transmission systems. Also different environmental capabilities of the sensor types lead to mixed configurations. An example of a redundant sensor setup is shown in Fig. 1.

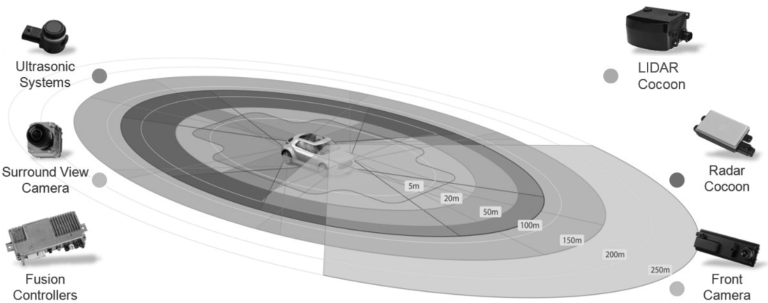


Fig. 1: Redundant sensor cocoons setups of a car incl. detection ranges

The different sensors have different advantages and disadvantages which are highly dependent on weather conditions, illumination and speed. E. g. a Camera is very good for classification of objects at day time but has restrictions at low illumination. A comparison of pros and cons of different sensor configurations is shown in Fig. 2.

| | Ultrasonic | Radar | Camera | Laser Scanner |
|---|---|---|---|---|
| Field of View & Range | O | ++ | ++ | +++ |
| Distance Resolution | ++ | ++ | + | +++ |
| Angular Resolution | O | + | +++ | ++ |
| Velocity Resolution | + | +++ | O | ++ |
| Adverse Weather | + | +++ | O | ++ |
| Darkness / Ambient light disturbance | +++ | +++ | + | +++ |
| Object classification / Semantic information | O | + | +++ | ++ |

Fig. 2: Comparison of different sensor technologies

# Open Fusion Platform (OFP)

## Sensor and Functional Interfaces

Dr. **Michael Schilling**, HELLA KGaA Hueck & Co., Lippstadt

**Abstract**

Within the publicly funded Open Fusion Platform (OFP) project 10 partners and 2 associated partners from science and industry are developing a fusion platform with open interfaces as an enabler for high- and fully automated vehicles [1]. OFP is a generic platform that will support all kind of different automated driving use cases. At the end of the project, the OFP capabilities will exemplarily be shown at the following complex level 5 use case:

"An electric-car autonomously parks (valet-parking) and positions itself directly on top off a parking space with a wireless charging plate. When the car is fully charged, it drives itself to another parking space without a charging plate. "

The generic Interfaces from sensor to perception layer and from the application/function into the environment model are documented in a publicly available Interface Specification [2]. The standardized interfaces will enable project external partners, from universities over research institutes to companies, to use the OFP for their purpose and test their sensors or software modules within the environmental model of the OFP.

The OFP project uses enhanced near series sensors (RADAR, surround view cameras, V2X and HD Maps) to realize the main use case. Again, special attention is given to the standardization of the interfaces between the OFP and the used sensors.

**Introduction**

Highly or fully automated driving functions are very complex tasks, that need at their core a very good environmental fusion model that delivers all the needed information for the use case specific driving decisions. Within the OFP project a generic fusion platform for automated driving functions is developed and implemented. The interface description of the open fusion platform is disclosed to the public in an Interface Specification Document, that enables project external companies, institutes or universities to integrate their own products or prototypes in the OFP. Standardized sensor and function interfaces are very important to accelerate the development of new automated driving technologies. Standardizations for hardware interfaces (e.g. CAN, LVDS, …) and basic Software (e.g. AUTOSAR) are available for many years now and already widely applied in automotive series products. This is not the case for

automated driving specific problems. A few initiatives, like OpenDrive [3], already started a few years ago, but for many issues regarding sensor fusion and environmental modelling, no standards are available yet.
Within the first year of the OFP Project (2016) other new initiatives went public, like the Open Robinos white paper [4] from Elektrobit, the Open Platform initiative [5] from BMW, Mobileye and Intel and the adaptive AUTOSAR [6] enhancement.
Where possible and meaningful, we plan to incorporate other standards and ideas from the automated driving community. If you are working in this area, please contact the main author to add your valuable insights.
The following chapters will start with an Introduction to the basic concepts of the open fusion platform and then go into detail regarding the sensor and functional interfaces used. Furthermore, Data Types, Communication- and Timing-concepts of the OFP will be described.

**Basic Concepts**

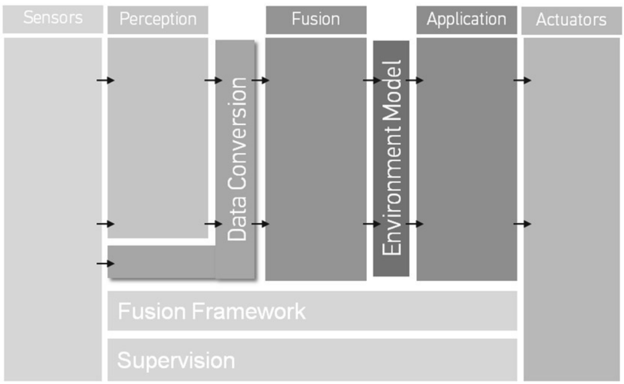


Fig. 1: Functional Layering in the OFP

### *Functional Layering*

The OFP system architecture is formed by a number of functional layers that have well defined interfaces between each other to decouple the functionality from the sensor and functional input. With such a layered architecture, it is the easier to replace or rework layers, without influencing higher and not directly connected components. E.g., if a specified hardware component (e.g. camera) will be replaced by a model with another specification (change of pixel resolution etc.), the immediately connected layer could be influenced either

# Linux in Safety Critical Systems for Future ADAS and Semi-Automated Driving Functionality

**Thorsten Wilmer**, Dr. **Thomas Kopfstedt**,
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**Abstract**

Although intellectual property (IP) of system on chips (SoC) and off-the-shelf software is developed for highest Automotive Safety Integrity Level (ASIL) rating, any integration step can reduce the achievable ASIL rating of the final system. ASIL requirements have to be allocated to components which are able to fulfill the ASIL rating of the final product.

Linux as a QM-rated operating system (OS) can be used in parallel with a Safety Real Time Operating Systems (RTOS, e.g. Classic Autosar, QNX) with a higher ASIL rating on a sufficiently independent core or microcontroller. To qualify Linux for ASIL-B missing work products have to be produced.

Linux and QNX are compared and Linux is found to have higher frames per second, lower network latencies and lower project costs in selected use cases.

A Type 1 HyperVisor can be used to ensure freedom of interference to use Linux and a Safety RTOS in parallel on a modern complex SoC.

## Safety Decomposition of System Functions

Advanced driver-assistance systems (ADAS) and autonomous driving consist of many different requirements which are rated depending on the Level of Autonomous Driving up to ASIL-D.

A central ADAS control unit contains several different SoCs which will implement different functions of the system. The system and software architecture must be iteratively refined to meet all the safety requirements.

SoCs are the building blocks of the system. Some microcontroller units (MCU) are usable for ASIL-D, e.g. NXP MPC5777C (1). Other SoCs are only available up to ASIL-B, e.g. H3-R-Car (2). Parts of a complex SoC can also be only usable for QM while other parts meet ASIL-B requirements, because the development has not followed ISO 26262 or because the subsystem does not implement the required CRC checks or redundancies to meet the required Failure Rate for the ASIL Level.

ARM has published the systematic capabilities of their IP (3). This means that their development process has produced the work products to meet ASIL-D or ASIL-B requirements.
The SoC vendor can then integrate the IP from ARM into the SoC and the resulting system, chip or submodule of the chip can be associated with a failures in time (FIT) rate.

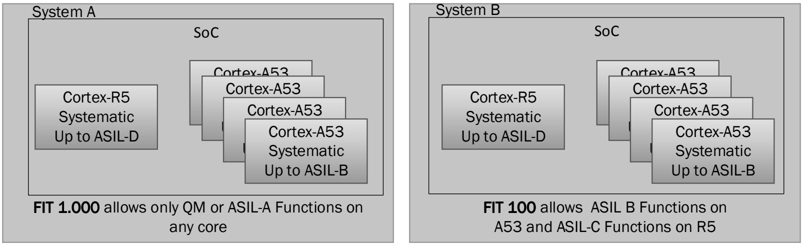


Fig. 1: Example how FIT rate influence the achievable ASIL Level

Applying the ISO 26262 (4) in this example the SoC contains an R5 core and a cluster of four A53. The failure rate analysis has shown for System A 1000 FIT. This means the SoC can be used in System A context only for ASIL-A and QM functions. For System B 100 FIT has been calculated, the same SoC is used. In this case the A53 cluster can be used for ASIL-B software and the R5 for ASIL-C – provided all the other required evidences are met.
This means Linux as QM software would make sense to be used in System A's A53 cores and using a Safety RTOS which is developed according to ISO 26262 on the other cores of System A and B.
Question: Can Linux be also used on the A53 cores in System B?

**Usage of Linux in Safety Critical Automotive Environments**

Linux is already running infotainment, heads-up display (HUD) and connected car systems for several major car manufacturers and demand for its use is increasing. However, one of the major challenges in running Linux in safety critical systems – such as assisted or semi-autonomous driving applications – is implementing functional safety decomposition in the early stages of the system design process.

# AADC – Audi Autonomous Driving Cars

## An open platform for predevelopment and demonstration of automatic driving functions based on model cars

Dr. **Lars Mesow**, Dr. **Florian Knabl**,
Audi Electronics Venture GmbH, Gaimersheim

### 1. Abstract

The setup of test cars for development and demonstrations of new automatic driving functions often takes a long time and requires high cost. We present an open platform called Audi Autonomous Driving Cars that allows to implement, to test and to demonstrate first ideas already in very early development stages. This platform is based on a model car in scale 1:8.

The model cars are equipped with different vehicle like sensors, computers and a vehicle control. As a development tool for the software ADTF (Automotive Data and Timetriggered Framework) is used – an established tool from real prototype and series development. Based on the underlying ADTF framework the model car software can be transferred to the real world as well.

In this paper the technical options of the model car will be explained. Beside the necessary environment detection using on board sensors we present the realization of additional for high automated driving required infrastructure. These are communication options (Car2x), swarm functions and also positioning and map information. The computers of the latest Audi Autonomous Cars were optimized especially for artificial intelligence (AI) tasks. The concept of the model cars is modular and therefore it can be simply adapt or extended for other applications.

Furthermore we explain already implemented applications in development and demonstrations of automated driving functions, based on the example of the swarm data function “on street parking”.

This model car was originally developed for the Audi Autonomous Driving Cup, a student contest for autonomous driving. It is a bridge between teaching and practice.

## 2. The model car

The latest model car (year 2017) is a 1:8 scaled Audi Q2. Its basic driving components like the chassis with damper ,wheels ,motor and steering controller are regular RC components. To make it ready for autonomous driving we added all required electronics for example different kind of sensors, computers and a special power supply. Finally we produced a customized cover in kind of  an Audi Q2 including back und front lights.


Fig. 1: View of the 2017 model car with Audi Q2 cover

## 3. Sensors of the model car

### 3.1. Depth camera Intel® RealSense™ R200

This front view camera provides RGB, Depth and  2x Infrared streams. The RGB stream has a resolution up to 1920x1080 pixels, a field of view of 43° x 70° x 77° (V x H x D) and an update rate of  15/ 30/ 60 fps. The infrared stream has a resolution up to 640x480 pixels, a field of view of 46° x 59° x 70° (V x H x D) and an update rate of 30/ 60fps. The depth stream has a resolution up to 628x468 pixels and an update rate 30/ 60fps. This sensor provides 3D data of the environment in front of the car which is very useful for object detection.

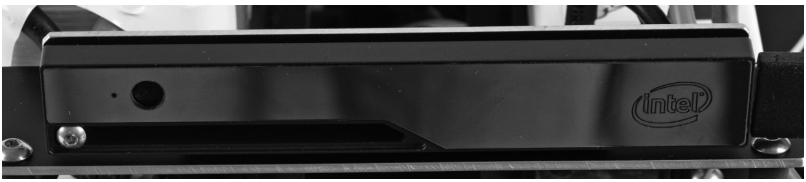


Fig. 2: Depth camera Intel® RealSense™ R200

# FEP – Functional Engineering Platform

## FEP solutions enabling the way to automated driving

**Ralf Belke**, Audi Electronics Venture GmbH, Gaimersheim;
**Gerhard Kiffe**, AUDI AG, Ingolstadt

**Abstract**

The Functional Engineering Platform (FEP) is a software framework built up by AUDI AG realizing a consistent virtual development and testing platform for software based car functions over significant development phases.

The development of end-to-end car functions in a more and more connected car becomes an increasing challenge. Because the car’s interaction with its environment it is necessary that the environment does exist virtual. The following graphic shall show the different aspects of the environment.

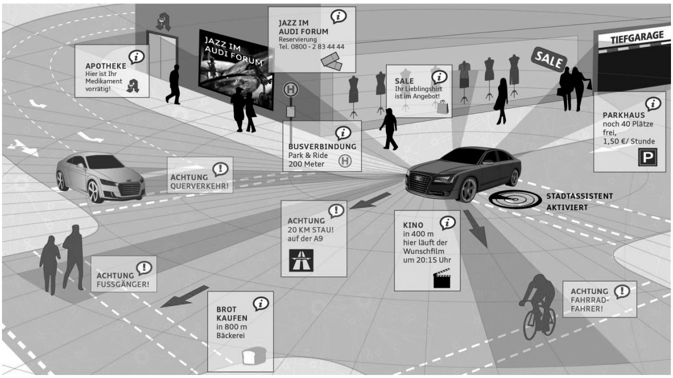


Fig. 1: Overview about environmental communication parties

Because of this facts there have to be the following changes to the development process:

- The development will be more separated
- Different domains have to work together
- The methods, processes, and tools have to be adopted

Since years is predicted that the complexity of the car development will increasing steadily. Now the prediction is reality and the complexity maybe is much bigger than the predictions had expected, so that it is no more possible with the conventional development and releasing

methods to bring car functions on the road. The amount of test kilometers is astronomical high.
The AUDI AG has registered this phenomenon in the year 2014 and has begun to create a development platform which enables different domains like backend and car function development to communicate with each other in early development phases.
Besides the function development the virtual environment plays an important role because functions like intersection assistant is almost impossible to test in reality. The FEP has defined an interchange format for the AUDI AG for the virtual environment data which can be generated by different environment simulation tools. This data can be used by any function which needs environmental data.
Important is the continuity from the early development phase to the releasing using a HIL where FEP is used too.

All this has to be used and realized by humans. So we have established a trainee and support concept which is an important aspect of the success of FEP.

**Motivation**

"As the complexity of automated driving functions rapidly increases, the requirements for test and development methods are growing. Testing in virtual environments offers the advantage of completely controlled and reproducible environment conditions.

However, in order to achieve widespread use of driving simulators for function developers, the connection between the function development framework and the simulation environment has to rely on generic interfaces. To enable easy and straightforward compatibility between automated driving functions and the variety of driving simulation frameworks available, we propose the open simulation interface (OSI)." [1]

This motivation from the OSI standardization project can be used without any constraint, because it fits the technical goals of the FEP project and I think of many other running initiatives all over the world.

But besides the technical aspects to drive highly automated it is also necessary to standardize methods, formats and processes.

# Real-Time-Capable Sensor Models for Virtual Test Driving

## Classification and Application in Development and Validation of Automated Driving Functions

**Martin Herrmann**, **Dominik Dörr**, IPG Automotive GmbH, Karlsruhe

**Abstract**

The increasing range of functions in advanced driver assistance and automated driving systems along with a growing trend toward agile development processes requires efficient testing methods, as ever-larger test catalogs have to be managed within a short period of time. Testing and validation in simulation are indispensable for this purpose since real-world prototypes are not always available and simulation enables repetitive, reproducible driving of the test catalog in automated mode. Virtual test driving requires virtual prototypes which, initially, may consist of very simple models which subsequently are progressively parameterized in greater detail. For the virtual environment in which the prototype operates in the simulation, and for the sensor models that provide the environmental information for the driving function, a similar, multi-level system can be developed as well which, focused on the user, also addresses the tasks of the participants in the development process.

For planning a test, it is necessary to take all three identified sensor classes into account. This is a prerequisite for testing at the beginning of the development cycle even without knowledge of all the parameters. By using the sensor classes of all model levels, large-scale tests can be performed with phenomenological sensor models and even special physical effects be investigated in detail this way, which enables efficient testing and validation in the simulation. Such a multi-level system for ideal and phenomenological sensor models as well as for raw signal interfaces will be presented below.

### 1. Introduction

The environment of a vehicle poses major challenges to advanced driver assistance systems and autonomous driving functions. Neither environmental conditions such as darkness, bad weather, poorly discernible road markings or obscured signs nor dynamic objects or other road users must lead to malfunctions. The environment must be captured and processed fully and error-free by the vehicle as a prerequisite for ensuring the perfect functionality of advanced driver assistance systems and automated driving functions. [1]

The characteristics of the objects are established within the definition of the scenario, encompassing their movement, geometric and material properties. Additionally defined are environmental conditions such as precipitation, wind and lighting, etc.

Depending on the sensor technology used, the respective scene is captured in a way that is typical for the technology involved. For instance, when a camera is used, an image will be created, and when lidar is used, it will be a point cloud. For a precise representation of reality in simulation, all physical phenomena would have to be modeled. However, as this entails a disproportionately high effort, other approaches must be considered in virtual test driving as well.

## 2. Virtual Prototype

Virtual test driving enables reproducible and risk-free testing. Not least, the resulting immense time savings are one of the significant advantages of virtual test driving over conventional road testing on proving grounds or in the field, as it enables millions of kilometers of test driving to be reproducibly performed in automated mode practically overnight. This way it is possible to discover potentially existing negative effects of software or parameter modifications in a cost-effective, efficient manner without any risk to personnel, vehicles and use of proving grounds. This approach not only reduces the number of required real prototypes but also massively shortens a vehicle's time to market. [2]

The automotive systems engineering approach offers the opportunity to meet the complex demands made on the virtual models. According to this approach, all the required systems from the departments involved – both on the OEM and the suppliers' side – are combined in a virtual prototype at an early stage of the development process.

The virtual prototype as a fully parameterized whole vehicle model consists of the models of the same components and systems as the real prototype after which it is modeled and therefore exhibits realistic vehicle dynamics performance. Due to the complete parameterization, all interdependencies and mutual influences of the various vehicle systems can be simulated, thus enabling so-called scenario-based testing. In contrast to the conventional test method, i.e. signal-based testing, there are numerous advantages. To be mentioned first and foremost is testing of the total system (in the whole vehicle) under realistic conditions (in freely definable scenarios).

Another essential aspect is that the virtual prototype is available at a much earlier stage in the development process and can thus be consistently used at any development stage – from early testing of the control algorithm using the model-in-the-loop method through to

# Virtual Homologation of Software Intensive Safety System: From ESP to Autonomous Driving

Dr.-Ing. **Houssem Abdellatif**,
TÜV SÜD Auto Service GmbH, Garching b. München;
Prof. **Bernhard Schick**, University of Applied Science, Kempten

## Homologation and Type Approval: Background

A certificate of conformity (CoC) is required for a product, i.e. vehicle, before it is allowed to be sold in a particular country. It is the grant that the considered product meets a set of regulatory, environmental, technical and safety requirements. Homologation refers often to the process certification and can be classified in two main categories: self-certification and type approval.

Self-certification is a manufacturer's internal process in which the manufacturer is fully responsible for ensuring that vehicles, systems and components comply with the legal regulations. Test methods, responsible persons and proof of the tests must always be documented in detail. The legal authority may, at any time, review compliance with and all relevant documentation, if required. A typical region applying self-certification is the US market [1].

In the case of type approval, the authority the certificates are provided by the local authority based on a report provided by a technical service. For this so called 3rd party principle the authority may be the local government or the ministry, as the Kraftfahrtbundesamt (KBA) in Germany. A technical service is e.g. TUEV.

Basically, a vehicle must be designed in such a way that neither passengers nor the surroundings nor the environment are damaged. This level of damage varies worldwide from market to market and depends on the respective infrastructure, weather and environmental conditions as well as on the socio-economic situation. The rules are as follows:

- European Union: Directive 2007/46/EC Type approval, tests are based on United Nations Economic Commission for Europe (UN/ECE) procedures;

- North America: Federal Motor Vehicle Safety Standards (FMVSS) regulations released by the NHTSA;
- Australian Design Rules (ADR) regulations;
- Japan follows UN/ECE regulations and their own Test Requirements and Instructions for Automobile Standards (TRIAS) regulations;
- Other countries that accept or base their own regulation on those mentioned above.

**Example of Simulation Aided Homologation of ESP Systems**

In November 2007 the United Nations Economic Commission for Europe (UN/ECE) agreed to amend Regulation 13 [5], requiring new truck vehicle types in the most common categories to be equipped with electronic stability control from 2010, with priority given to heavy truck/ and trailer combinations and touring coaches during the phase-in period spanning several years. On March 10th 2009 the European Parliament approved a mandate requiring all new passenger cars and commercial vehicle models seeking type-approval according UN/ECE-R 13H [4] in the EU to be equipped with electronic stability control systems from November 2011, to be followed by compulsory fitting of all newly registered vehicles with ESC from November 2014. Legislators in other regions of the world have mandated similar requirements.

Proposed amendments to UN/ECE-R 13/11, the applicable directive governing the mandatory installation of ESC in commercial vehicles, refer to a “Vehicle Stability Function” as an electronic control function for a vehicle which improves its dynamic stability such as yaw control and roll-over control.

According to UN/ECE-R 13/11 and UN/ECE-R 13H, the stability function shall be demonstrated to the technical service, such as TÜV SÜD, by dynamic manoeuvres at least on one vehicle. This may be realized by a comparison of results obtained with the vehicle stability function enabled and disabled for a given load condition. UN/ECE-R 13/11 for trucks requires a variety of open loop and closed loop test manoeuvres such as reduced radius test, steady-state circular test, asymmetrical one period sine steer and double lane change manoeuver, whereas the UN/ECE-R 13H for passenger cars requires just one - the Sine with Dwell open loop manoeuvre.

# IT-Backend for Automated Driving and Cooperative ADAS

## Functional Safety for IT-Backend

**Uwe Beher**, **Thomas Weyrath**,
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**Abstract**

When driving automated or with cooperative driver assistance the vehicle takes over the longitudinal and lateral control instead of a human driver. Such interventions may be spontaneous and intensive at the same time, that in the case of an error a controlled oversteering by a human driver is not feasible. This especially applies for automated driving, where the human driver is released from monitoring of the traffic.

Both driver assistances have in common, that the kind of intervention depends on the manoeuvers of the other vehicles coordinated by the support of an external IT-Backend. This results in challenging requirements regarding functional safety for the involved electronic control units and the external IT-Backend, which processes the manoeuver information and data flows of all included vehicles. The basis for the realization of driver assistance supported by an IT-Backend is most notably a secured connection of the vehicles, which shows a high level of data security and functional safety.

We present herein the systematically implementation of the required data security and the integration of a functional safe IT-Backend.

### Motivation for IT-Backend Supported Automated Driving

Automated Driving is the replacement of human cognition and sensing by an artificial intelligence that drives the vehicle instead of the human driver. Discrete levels of automation are defined in [1] and classify the manoeuvring performance of the artificial intelligence. The individual levels contain, to which extend the driving tasks are transferred from the driver to the artificial intelligence and to which extend the driver remains involved.

The positive aspects of less involvement of the driver are the more convenient way of travelling and the safer way of travelling, for the driver himself and for the other motorists and cyclists. The higher safety results from an artificial intelligence, which is a software functionality running on an electronic system constantly showing the same system readiness and reaction time during driving without drowsiness or exhaustion.

The higher the rate of automated driving cars, the less traffic incidents and traffic deaths are expected. The commercial competitiveness of automated driving is a key factor for acceptance by the vehicle buyers and the resulting penetration in the worldwide automobile markets.

The overall design of the artificial intelligence, consisting of on-board shares in on-board electronic and off-board shares in the external infrastructure, has a major impact on overall costs. Table 1 gives a rough overview over the major advantages and disadvantages.

Table 1: Comparison of on-board and off-board shares for artificial intelligence

| | On-board device | Off-board infrastructure |
|---|---|---|
| Sensor detection range | Limited to a few hundred meters | Unlimited in range, limited by connected vehicles |
| Sensor system readiness | Continuous availability of traffic sensing | Limited to over-the-air availability |
| Sensor data processing and data fusion | Limited to sensor hardware, limited to known and tested driving scenarios | Sensing capabilities, known and tested driving scenarios increase with operation time |
| Computing power | Fix computing power in on-board device at start of production | Scalable computing power, costs per computing power decrease by Moore's law |
| Environment model | Fix memory in on-board device for fix number of detected objects and trajectories at start of production | Number of detected objects increases with increasing connectivity and computing power |
| Decision model | Decision model limited to fix computing power in on-board device at start of production | Decision model improves as known and tested driving scenarios increase with operation time |
| Maintenance | Timeframe for maintenance from month (over-the-air-update) to years (update during service) | Daily and weekly maintenance depending on update necessity |
| Security | Security degrades continuously after update | Constant level of security by constant updates |

# Connectivity as THE Enabler for Efficiency Improvements in Commercial Vehicles

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**Jörg Lützner**, Continental Automotive GmbH, Schwalbach


## Abstract

Connectivity enables optimization of the key financial levers of fleets, namely fuel, salaries and maintenance. Top priority is the reduction of fuel consumption. The fuel bill usually accounts for over 30% of operating costs. Solutions like Zonar's ZFuel track and rank vehicle and driver performance. Knowing this is key for driver training and reward programs. The transparency and associated rewards can motivate the very important drivers to give their very best as well as improving retention rates. Maintenance is also a key factor. Wear & tear parts like tire must be replaced regularly. Regular pressure and temperature sensor information from the vehicle will be the basis for tire wellbeing and wear analysis. The data can be read out, interpreted and displayed with solutions like ContiConnect, Continental´s digital tire monitoring platform for commercial fleets. The stored information forms the basis for offering tire based comfort and safety as a service. The constant drive for improved efficiency will lead to further exciting connectivity based services for commercial vehicles like dynamic eHorizon and platooning. Both offer attractive fuel savings. All of these services are just the beginning rather than the end of a wave of services designed to support commercial transportation meet society's and industry expectations on sustainable, efficient and safe transport.


## Introduction

Truck makers were the first vehicle manufacturers to fit cellular connectivity in all vehicles. Sure, all services we know today were not there on day one, but no doubt they had good reason to believe that connectivity to and from the vehicles would open the door for far reaching services. The simple fact that vehicles can receive information from outside the truck or the truck owner / fleet operator / vehicle manufacturer can receive a constant flow of information from vehicles clearly leads to an increase of intelligence in and around the vehicle. Quite often this is referred to Intelligent Transportation Systems, the key enabler for improved vehicle efficiency, safety and comfort.

It is obvious that there is not just the one form of connectivity based on the manufacturer fitted telematics module. In addition to this there is the possibility of retrofitting solutions to the FMS or OBD interfaces. These can also access the vehicle and upload vehicle information and data. In addition these solutions can download information into an onboard unit in the vehicle. The main difference to manufacturer fitted telematics is that retrofitted solutions are not allowed to transmit data to the vehicle architecture. Connected tablets can also be seen as in-vehicle connectivity. They already play an important role in fleet telematics. We expect these solutions to coexist in the market for the coming years.

This paper will focus on efficiency improving solutions which already play a key role and new solutions that can be expected in the coming years. All aspects of commercial transportation will be considered; the driver, the truck, the fleet and the OEM. Reduction of fuel consumption will play an important role, since this accounts for at least 30% of the fleet costs.

**Vehicle Performance Tracking**

The more knowledge the fleet manager has on the location, performance and maintenance of its vehicles, the better its precision, agility and quality of the service all of which leads to improved efficiency and customer satisfaction. Vehicle performance tracking is already a key instrument/tool which is used by numerous fleets. Manufacturers often offer solutions providing even more data measuring the performance of their vehicles. Because most fleets have vehicles from multiple manufacturers, “all brands” technology solutions are necessary to track all the same data points for your fleet on a single platform. One of the most successful cross manufacturer solutions is Zonar’s ZFuel. ZFuel is a completely new way to leverage high-density fleet data to go way beyond just Miles Per Gallon (MPG) by taking into account terrain, altitude, weather conditions, routing, maintenance, aerodynamics, gearing and cruise control usage. The fuel consumption figures are normalized so that difference in routes, vehicle load and performance of vehicle are taken into account. The result are numbers which allow a real and fair comparison of drivers so that outperformers can be rewarded, training areas are identified and performance areas in need of coaching in underperformers are highlighted. Customers using this application have seen fuel bill of as much as $300 per vehicle on initial use, easily providing a return on investment in less than 1 year.

The solution comprises an onboard unit which is attached to the vehicle CAN and transmits data to backend. This backend performs the data analytics and presents these to the fleet via a web interface as seen below.

# 5G Automotive Association

## Pioneering the transformation in the automotive industry

**Christoph Voigt**, **Jörg Plechinger**, AUDI AG, Ingolstadt

**Kurzfassung**

Die Telekommunikationsindustrie arbeitet zur Zeit an der Definition des Mobilfunkstandards der 5. Generation (5G). Gleichzeitig sind regionale, europäische und weltweite Bemühungen gestartet, um die Randbedingungen für die zukünftige mobile Kommunikation auf politischer und regulativer Seite zu setzen [1], [2]. Bisher hatte die Automobilindustrie im Bereich der Mobilfunkstandardisierung und Regulation nur geringe Mitsprache. Um die vielfältigen Herausforderungen in den Bereichen Digitalisierung und Urbanisierung sowie gleichermaßen für pilotiertes Fahren unter Berücksichtigung der Anforderungen der Automobilindustrie optimal lösen zu können, sind allgegenwärtige Kommunikation und Vernetzung mit auf die Automobilindustrie angepasster Technologie notwendig. Die 5G Automotive Association (5GAA) bildet hierzu ein weltweit anerkanntes Forum.

**Abstract**

The Information and Communications Technology (ICT) industry works on definition of the fifth generation (5G) mobile radio standard. In parallel regional, European and worldwide activities have been started to prepare the regulatory and political framework for the introduction of 5G in the different markets [1]. Up to now the automotive industry participated in standardization and regulation of mobile radio communication with limited effort. The manifold challenges in areas such as digitization and urbanization in the automotive industry as well as for connected automated driving requires tight involvement to define optimized solutions for ubiquitous communication and connectivity of radio technology suited for automotive use cases. The 5G Automotive Association (5GAA) defines a worldwide fora for all stakeholders.

## 1. Motivation

Telecommunications industry partners currently jointly develop in the 3GPP[1] standardization organization the upcoming new 5G mobile radio standard which will fulfill requirements as defined by the International Telecommunications Union (ITU) for the International Mobile Communications (IMT) System in 2020 [3]. This mobile radio standard targets for the first time industrial applications in the area of massive machine type communications (mMTC) and ultra-reliable low latency communications (URLLC). In the same time automotive industry is at the start of a revolution which is part of the “fourth industrial revolution”, Industry 4.0. To solve the manifold challenges which realizes for the automotive industry in the areas of Digitization, Urbanization and Sustainability communication capabilities will be a key enabler. The automotive industry needs to work together to define end-to-end communication solutions which will work across the automotive industry and will need to integrate in the overall 5G network. The 5GAA builds the worldwide forum for automotive and telecommunication industry to define the automotive world in the telecommunications domain. One of the first automotive specific implementations will be direct communication between vehicles (V2V), pedestrians (V2P) and infrastructure (V2I) based on 3GPP standards. Reusing the existing smartphone HW and SW architecture for automotive does not work for the specific V2V/V2P/V2I scenarios. The automotive industry has to define the use cases and needs to contribute towards defining a mobile radio standard adopted for automotive use. The 5GAA is the incubator and brings together telecommunications and automotive experts such that 3GPP as the relevant standardization body for 5G can define an optimized solution for the industry.

## 2. Telecommunication in automotive world

Today’s use cases for telecommunication in automotive world result mainly in the desire to connect the driver and passengers in a vehicle via voice and data connection to the outside. This can be achieved with acceptable effort in reusing the existing cellular phone hardware and software by transforming verified platforms to automotive standards. Introduction of new services such the emergency call (eCall) or EU wide real time traffic information are a first step towards specific automotive use cases in the communications world. Other services such as software update over the air, vehicle maintenance and also enabling feature-on-demand will follow and will require automotive grade standardized end-to-end solutions. Future applications in the area of shared economy, vehicle-as-a-sensor and autonomous driving all require and assume ubiquitous communication. Traffic management solutions and cooperated ma-

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[1] 3rd Generation Partnership Project

# Component-based Framework for Data Preprocessing within Connected Car Architectures

## Insight of future software development and end-to-end simulation

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**Abstract**

The ongoing development of vehicle-extended communication networks and cross-fleet data storage is driving an increasing focus on connected car functions. The outsourcing of software enables the usage of large and temporally or locally distributed data sets and algorithms. Considering current infrastructures, the quality of service is limited by mobile radio transmission. In order to avoid overload or failure in remote data communication systems preprocessing of car data plays a key role.

The methods for sensor data processing are sufficiently investigated, as there are numerous algorithms and derivatives for various identified forms of problems. Based on this the arrangement and location of functionalities have to be investigated. Beginning by preliminary discussing future architectures for connected cars, corresponding software modularity as well as in- and output interfaces are defined for a reasonable structure of basic services. Furthermore, a framework for data preprocessing is presented by identifying generic tasks. Due to the possibility of arbitrary arrangement in a derivative service, functional restrictions and dependencies are carried out. Finally, the findings of structuration are given by simulating possible localizations of the divisible service.

### 1. Innovations and Challenges for Online Services

According to the European Union's legal requirement for an automatic e-call, all cars registered in the EU from April 2018 will have a mobile radio interface. In current vehicle generations few and simple networked functions can be found compared to the services currently in development. Moreover, the limitations of typical infrastructures and networking will lead to enormous bus loads and well known one to two step function breakdowns with various routing instances.

### 1.1 Distributed Infrastructures

In addition to the classic positioning of functions on vehicle control units, functions that require information outside the direct vehicle environment rely on a connection to external systems. Networked applications can, for example, access network resources of mobile base servers and mobile terminals, such as smartphones or computers of neighbouring vehicles. An overview of distributed infrastructure concepts is shown in Fig. 1 [1].

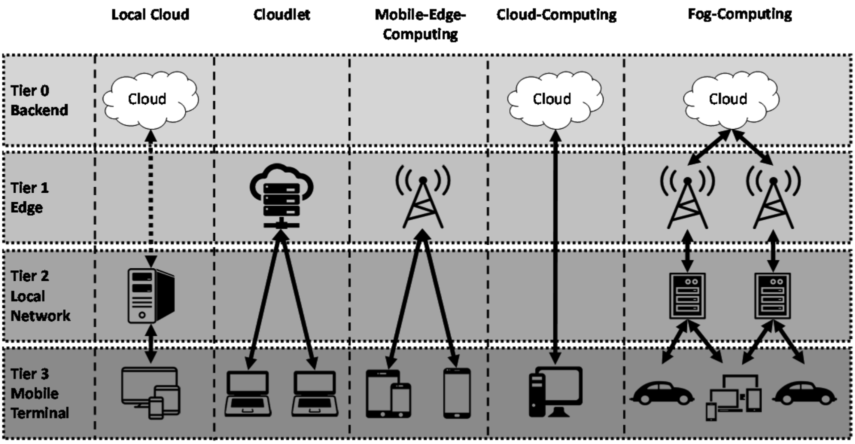


Fig. 1: Concepts of distributed infrastructures

Referring to the cloud computing model, additional intermediate layers are created to increase data security and privacy or enable time-critical and data-intensive applications. In general, decentralized structures make it possible to increase the connection quality and thus the functional reliability. For fully decentralized, geographically distributed infrastructures the term fog computing is widely used [2]. A fog consists of a heterogeneous pool of devices, which are supported by the functionalities arranged thereon. This allows the network devices to transfer data and functions to the node that is most appropriate for the processing.

### 1.2 Data-driven Software Development

Vehicle sensors generate large quantities of heterogeneous data. Those are processed and distributed continuously at high speed via diverse vehicle bus systems. The combined data stream of numerous cars is meant to feed highly precise maps, pursued by various automotive manufacturers. The transferred information, such as road condition, modified course and

# Sense of touch for vehicles

## Smart sensors for vibration analysis

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**Abstract**

In this paper, a very innovative kind of structure-borne (SB) sound sensor for automotive applications will be described. Furthermore, it will be shown that specific state-of-health information of vehicles can be assessed by analysing their SB sound. Relevant information will be forwarded in a C2X system.

At ELIV 2013 the very first results of damage detection in vehicle bodies and the C2X system for information sharing and forwarding has been presented in the talk: “Intelligent monitoring of vehicle body damages for car-sharing applications”. Now, four years later, the maturity of the structure-borne sound sensors raised and multiple functionalities have been added to the damage detection by sensing the vehicle body’s vibration. For example, obstacle detection at touch in valet parking or autonomous driving, knock detection for HMI applications like closing of windows / trunk, crash and pedestrian impact detection and even more.

Hence, the intelligent structure-borne sound sensors provide a “sense of touch” for vehicles. Due to the modular algorithm structure of our sensors, their behaviour can change fully automatically to fit the environmental needs. The paper will deep dive the sensor’s modularity and adaptiveness. Especially, sensor design by finite element simulation and the sensor’s integration in C2X systems will be highlighted.

Furthermore, an overview of the past and ongoing research project KESS (damage detection), COSIVU (gear box monitoring for electric vehicles), TRAZU (crack detection in Trailers) and SEEROAD (road condition monitoring for autonomous driving) will be given to indicate the potential of smart vibration analysis in vehicles.

### Damage detection in vehicle bodies (Research project KESS)

KESS is a short term for “Konfigurierbares Elektronisches Schadensidentifikationssystem” (en.: Configurable electronic system for damage identification). This research work has been funded by the German Ministry of Education and Research during 2012 - 2015. In 2013 the initial idea of KESS, having a fully automatic damage detection C2X system for body damages in car-sharing vehicles, has been presented at the ELIV conference in Baden-Baden [1].

The motivation of KESS based on the growth rate of car-sharing has now been proven right as the megatrend of a sharing community is moving on and on. In 2017 over 1.7 Mio. car-sharing users are sharing 17,200 cars in Germany [2]. Hence, approximately 100 users are sharing one car in average. But still, the damage inspection process is done manually by visual inspection of the vehicle body instead of using a real-time body monitoring with smart vibration sensors. One reason for this might be, that the sensor network integration into vehicles and information sharing between car-sharing operators and OEMs is still an open issue.
In general car-sharing providers would like to have a damage detection system already installed into the vehicle as well as full access to the information. In contrast to that, common OEMs are not interested to install a sensor system for sharing-companies only, as the car-sharing business is still relatively low compared to the TAM (total available market). To overcome this, it will be shown in this paper, that the smart vibration sensors to detect minor damages in vehicle bodies can be used as a gate opener for various functionalities which are of high interest even beyond car-sharing.

Fig. 1: Mounting positions of KESS sensor for damage detection inside the vehicle body

Figure 1 indicates the eleven sensor mounting positions in a car-sharing car which has been used in the research project KESS. Therein, the sensors have been glued from the inside to the vehicle body to be invisible from the outside. Considering the mounting positions and the number of sensors we have investigated that is was necessary to have one sensor on each

# Umfeld Sensorik für alle

## Serienentwicklung von fahrenden Messstationen

**Stephan Max**, **Roman Koch**, **Torsten Büschenfeld**, **Peter Baumann**, **Thomas Ruchatz**, **Stefan Ortmann**, **Andreas Titze**, Volkswagen AG

### Kurzfassung

Die konsequente Weiterentwicklung und Demokratisierung des Fahrerassistenz- und Komfortsystem Angebot auf der einen Seite und die stetig steigende Nachfrage der Systeme auf der anderen Seite haben dazu geführt, dass vielfältige Umfeld Sensoren in allen Fahrzeugklassen zur Serien- oder Sonderausstattung gehören. Ziel ist es, die gewonnenen Informationen außerhalb des Fahrzeugs zur Verfügung zu stellen. Neben der Beschreibung der verfügbaren Umfeld Daten, werden in diesem Artikel die Möglichkeiten und Varianten einer Serienentwicklung dargestellt. Dabei werden die Informationsflüsse von den Sensoren im Fahrzeug bis zum Endabnehmer im Backend aufgezeigt. Ergänzt wird diese technische Betrachtung durch nichttechnische wirtschaftliche und rechtliche Aspekte.

### Abstract

Enhancing and democratizing ADAS and comfort systems and increasing demand for such systems have led to versatile sensors in all car classes as standard or optional fitting. The acquired sensor-data may also be made available outside of the vehicles. The available environmental data and the opportunities and variants of series development are described. The information flow from the sensors to the backend is shown. The technical discussion is supplemented by commercial and legal issues.

### 1. Motivation

„Daten gelten als das Gold im digitalen Zeitalter." (SZ, 10.05.2016) Nach einer Studie von PCW (Pricewaterhouse Coopers) sind 74% aller mittleren und großen Unternehmen bereits im Datensharing aktiv. Die Monetarisierung der Daten hängt im Wesentlichen von drei Faktoren ab: Den Sensoren, welche die Daten erzeugen, den datenverarbeitenden Systemen und abschließend dem Service, welcher dem Kunden angeboten wird (siehe auch Volkmar Denner, Bosch Connected World 2017). Die Qualität der Daten wird hierbei nicht nur die Sensoren selbst, sondern auch durch die Aktualität der Daten entsprechend der Systemlatenz und der räumliche Verteilungsdichte der Sensordaten dargestellt.

In den vergangenen Jahren sind vielfältige interaktive elektrische Seriensysteme zur Unterstützung des Fahrers entwickelt worden. Die integrierten Assistenz- und Komfortsysteme erfassen mit diversen Sensoren das Umfeld des Fahrzeugs, um die Fahrt komfortabler zu gestalten.

Daher ist aus Sicht des Fahrzeugherstellers der Einstieg in dieses Geschäft besonders interessant, da die Fahrzeuge bereits mit diversen Sensorsystemen ausgestattet sind.

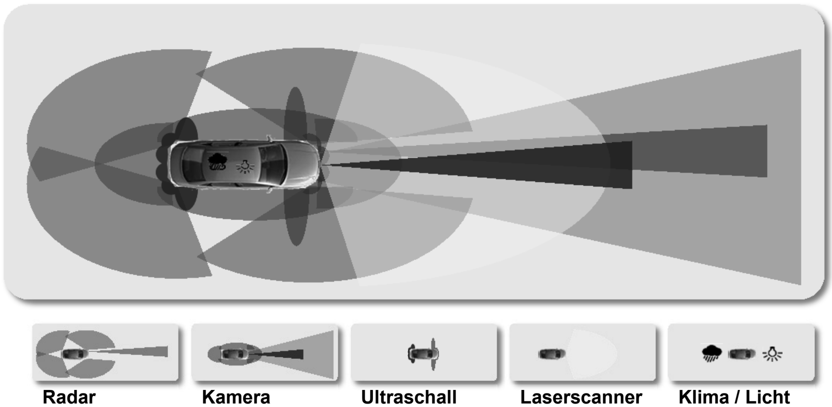


Bild 1: Übersicht Umfeld Sensoren in Fahrzeugen

Verstärkt ist dieser Trend durch zwei veränderte Rahmenbedingungen. Zum einen sind bisher optional angebotene Systeme durch die stetig steigenden Sicherheitsanforderungen von z.B. NCAP zur Serienausstattung geworden. Zum anderen ist durch den Zwang zum elektronischen Notrufsystem (eCall) eine Mobilfunkanbindung im Fahrzeug gesetzlich vorgeschrieben. Daher können die Umfelddaten direkt ortsbezogen und zeitsynchronisiert erhoben und kommuniziert werden.

# Framework conditions for the implementation of backend-based functions in the context of Connected Vehicles

## Sensitivity analysis of Maschine-2-Maschine protocols concerning the robustness of backend-based functions

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### 1 Abstract

In the scope of this contribution, the applicability of cloud systems is examined regarding the future implementation of backend-based vehicle functions. Prospectively, backend-based functions will be integrated as vehicle overlapping tasks with access to embedded vehicle controls. Referred to the typical three-layer architecture for the Internet of Vehicles (IoV) a high-level architecture for the implementation of backend-based functions is given. The potentials of such backend-based function can only be fully utilized if incoming data in the backend is processed immediately and resulting information are transmitted to the vehicle. As a result, backend-based function are exemplary considered as closed control circuits in this contribution. On the basis of Maschine-2-Maschine (M2M)-protocol analysis and a test framework, boundary conditions are derived for such functions. Analysis of the most relevant influencing factors are given. Results show that the end-2-end latency is one of the most important factors. This also makes the chosen message very important. This factor will improve due to developments regarding mobile communication standards, but still have a relevant impact on backend-based functions. This relevancy is outlined in this contribution as well.

### 2 Introduction

Terms such as the “Internet of Things”, “Connected Vehicle”, “Vehicle-2-X” or “Smart Data” describe the current technological trend of digital networking in the automotive industry. Because of the rapid expansion of mobile internet and the spread of cloud serviced, the automotive industry is faced with radical change similar to the introduction of electric control units and their internal connections via the CAN bus during the 1980s [1].

In this context, the Connected Vehicle will support the “Vision Zero” (no accidents, no dead, no local pollution, etc.) with a plenitude of new functions (e.g. traffic light and crossroads assistants, fleet management, smart data-based routing/energy management). Simultaneously, this will lead to a paradigm change in system architecture. The closed system “vehicle” will no longer exist as such, but will be integrated in the environment as one element of an overall function [2]. Hence, the respective vehicle itself will become a service with different states of specification. Initially, in the scope of this contribution, a future architecture is outlined based on the Internet of Vehicles (IoV) in Section 3. Using this architecture, diverse services can be realized. For example a service could be to change the route of a self-driving vehicle because of a detected accident by another vehicle in front of the planned route. To fully utilise their whole potential, the incoming data must be immediately processed in the backend. After this the resulting information must be directly transmitted to concerning vehicles. As a result these services (backend-based functions) are exemplary presented as a closed control circuit. The necessary and if possible interruption-free transmission of data between vehicles and the backend will usually be realized using so-called Maschine-2-Maschine (M2M)-protocols. Based on protocol analyses (Section 4) a test framework with two implemented m2m-protocols is described to choose the best one for IoV-functions (Section 5). In Section 6 boundary conditions are derived for implementing backend-based functions and an outlook is given for relevant influencing factors during the implementation.

## 3 From Internet of Vehicles towards Connected Cars as a Service

Today’s vehicle systems are connected to a cloud system via so-called Brought-In or Build-In technologies using a connection system (cf. Fig. 1). On this the IoV could be divided in three layers but there is no direct relationship between the cloud-system and the client-system over a connection system. This indicates that the data communication is generally unilateral.

# Access to vehicle data

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**Abstract**

The vehicle, formerly a self-contained mobility device, is increasingly integrated into the customer's service world. Thanks to data, the vehicle can be integrated with a number of services. This generates a fast-growing market. The study "Connected C@r 2016" shows an annual growth rate of 24.3%.[1] It projects that the worldwide sales volume in the area of "integrated mobility" will grow from €47.2 billion in 2017 to €140 billion in 2022. The vehicle data-based services associated with integrated mobility are provided by OEMs as well as by independent third parties. This competition will have a positive impact on the product range and choices available to customers.

Therefore, vehicle data must be provided in a way that does not violate the following fundamental framework conditions. Most importantly, vehicle safety may not be compromised under any circumstances. As vehicles become increasingly automated, more and more vehicle actuators are controlled digitally via vehicle buses and safety-relevant vehicle components are becoming highly integrated. This means that any security problem caused by data access may quickly become a safety problem for the driver and the general public. Improperly designed or programmed service applications may not have any negative effect on the vehicle system or cause any safety problems either. Being liable for their products, vehicle manufacturers must take this into account when designing their vehicles.

Here, the OBD interface commonly used today for the provision of data is a security risk. The OBD interface is designed to be used for emissions testing, as well as for diagnostic, repair and maintenance work in vehicle repair shops, where it is used under defined framework conditions by trained personnel. The OBD interface is not designed to be used freely for the provision of data. Such a misuse of the OBD interface can lead to incalculable security risks because it allows for the vehicles bus system to be accessed directly while driving.

[1] Strategy & and PWC and together with the Center of Automotive Management (CAM)

Another challenge is that a lot of vehicle data is proprietary. They differ both in terms of the data format and in terms of their interpretation. Due to the high innovation pressure within the automotive industry, new sensors and methods for sensor data processing are integrated into vehicles all the time, so that the structure of vehicle electrical systems and the data transmitted over them can differ within a manufacturer's model line from model year to model year.

Therefore, the use of vehicle data requires that the data to be used be defined and that this data definition is provided in a reliable manner. This creates a stable database for services. The data can be used reliably over a longer period of time, ongoing troubleshooting and application updates are thereby avoided.

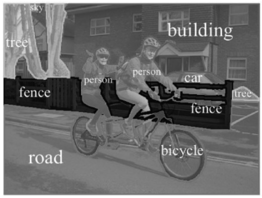
But not all vehicle data can be provided on a general basis. For example, sensors that are installed in the vehicle as part of an innovation supply data that directly enables this innovation. A provision of the data would prevent a refinancing of the innovation and restrict competition between vehicle manufacturers. This would have a lasting negative impact on the innovative capacity of vehicle manufacturers and suppliers. Therefore, some areas require a certain level of protection for machine data. Another example of data that needs to be protected is the internal control unit data for quality control. This type of data is usually available only to the OEM and its directly involved development partners. It cannot be made available to other parties without a special agreement.

If vehicle data includes personal data, it may only be read by the manufacturer and disclosed to third parties with the consent of the person concerned. This means that the manufacturer must obtain the user's consent before providing personal vehicle data to third parties. For a user to consent to this, he or she must be aware of the context in which his or her data will be used.

This must be reconciled with the desire that service providers should be able to develop their services possibly without being in direct contact with the vehicle manufacturer. Here, it is important to find a way for personal vehicle data to reach the service provider while at the same time complying with the declaration of consent for the data for the forwarding of data between the customer and the OEM.

It is therefore important to find a solution that not only ensures the mandatory inclusion of security, safety and product liability requirements but also protects the OEMs' investment and

# Deep End-to-End Learning in Automotive




## … and a platform to facilitate such learning

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**Abstract**

This paper provides a technical discussion of deep end-to-end architectures for automotive use-cases. We discuss various approaches to end-to-end machine learning systems at different levels of abstraction, highlighting the deep learning models. We use the task of automated semantic annotation to showcase the functioning of visual deep learning models on a technical yet uncomplicated level. A general introduction to Deep Learning is provided. While presenting the benefits of Deep Learning, we also consider the limits of systems utilizing such deep architectures as they are often neglected albeit sometimes being significant. In addition, we provide a platform layout that enables us to develop, run and maintain such end-to-end algorithms in a holistic way.

## 1. Introduction

Deep Learning techniques [1] have brought stronger models of Artificial Intelligence to various

industries, such as Finance or Pharma and, with recent successes, to the automotive industry. The applications of such models are usually of analytic or predictive nature. While automotive Deep Learning was commonly used to realize functions, *e.g.* Emergency Breaking Assists (EBA), by contributing the necessary methods such as object detection, they are now used to model complete end-to-end (E2E) systems, *e.g.* by taking sensory input and "translating" this input into steering commands for autonomous driving. In this paper, we consider the task of semantic segmentation as an E2E Deep Learning use-case. We use this specific segmentation scheme to realize automated annotation of image data, *e.g.* stemming from a sensor recording. An example of semantic annotation is shown on top of the page. We strongly highlight that merely being able to create a Deep Learning algorithm to realize such segmentation does not satisfy the automotive needs. While such algorithms require embedded implementation and further integration steps when deployed into a car, they also require an entirely new ecosystem when being used for automated annotation. We provide an exemplary setup of such an ecosystem, integrating development, management and execution of such algorithms into one holistic platform. We believe that the proposed solution allows us to significantly speed up the development of automotive algorithms in the future.

## 2. Related Work

Here we summarize related work on the relevant topics of this paper. Since these individual research areas are vast, we only mention a few key publications.

### Semantic Segmentation

To realize automated semantic annotation, we use a technique called semantic segmentation. This method provides a pixel-wise classification of the image. Previously, Random Forests [3] have been employed to provide semantic labels by classifying the center pixel of an *e.g.* 10x10 patch and repeating this process for all pixels. Since the classification outputs are usually inhomogeneous – pixels in *one* region of the image may have different classifications – these approaches are usually combined with a Conditional Random Field (CRF) [4] to produce a smooth output. CRFs use unary potentials (the pixel classification confidences) and pair-wise potentials (the likelihood of neighboring pixels having the same class) coupled with an optimization scheme, which maximizes the probability of the classes given the neighborhood constraints. Localized pixel-classification has not only been applied to image data alone but has also been combined with depth information [5].

Methods based on Deep Learning usually perform localized classification in the first layer of a deep neural network. In addition, these classification responses are combined in successive network layers to leverage "global" image properties and build dependencies across image regions. Initial deep architectures for semantic segmentation reduced the image to a fixed feature vector using so-called fully-connected layers [11], essentially creating a low-dimensional code of the image. Based on this feature vector (or code) each pixel is classified. Commonly such methods do not use an additional CRF for smoothing but it has been explored as a possibility [11]. This is one example of an E2E architecture. More recent approaches use less complex architectures [6]. In such approaches, the image is pushed through multiple convolution- and pooling-layers – these terms will be described throughout the paper. Instead of creating a code, this approach, however, executes the reversed operations, deconvolution and un-pooling, to output the pixel-wise feature map. Similarly, to the previously discussed approach, this approach is also an instantiation of E2E models.

### End-to-End Machine Learning

End-to-end (E2E) Machine Learning has commonly considered the prediction of one or more structured target variables given an, often raw not-pre-processed, input signal. One early example of such a setup is digit recognition, in which images of digits are directly classified to

# Digital Image for future Location Based Services

## How vehicle sensor data and new data ecosystems will become a major part of the vehicle DNA.

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**Abstract**

Massive changes in the E/E automotive area lead to new technology driven solution stacks that are tackled by a vast number of competitors. Automotive trends now hit key technologies of previous non-automotive-players.

Location based vehicle centric services will play an important role in future mobility. New data-driven business concepts arise and requirements are changing due to ongoing urbanization, changes in regulation and easy access to cutting-edge technology. The technology stack based on location based services becomes a fundamental basis for highly automated driving (HD Map with high-dynamic layers such as local hazards or variable speed limits) and enables highly-innovative services such as real-time parking information or traffic light prediction. In a nutshell, crowdsourced vehicle sensor data will influence the prediction capabilities and the virtual near real time environment around the vehicle far more than onboard vehicle sensors.

Besides the access to vehicle sensor data and superior map assets, the creation of an open location data ecosystem that attracts cross-industry and cross-OEM participants supplying relevant data will be a key success factor.


Fig. 1: Vision Digital Image of the vehicle environment

**Vehicle centric location data will create a digital image of the vehicle environment.**
Today’s vehicles are already equipped with a magnitude of sensors. Data collection, pooling and analytical post-processing will derive new future services with both historical and near real time capabilities. The increasing number of vehicles equipped with sensors, such as radar, camera and LIDAR, and the continuously improving accuracy/richness of such sensors will make it possible to rebuild the environment of the vehicle in a backend system. Given that, we see the possibility to create unlimited context and resulting services in the near future. An exemplary use case is a real time capable HD Map for highly automated driving. With the upcoming fleet generation of 2018, BMW will demonstrate that we will be able to maintain 2/3 of the relevant attributes of a HD Map. We consider this to be a necessary function prior to the launch of our first HAD vehicle.

# VOBES NG – Next Generation of the Volkswagen harness development system

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**Abstract**

In this article, the concept of the new Volkswagen harness development system (VOBES Next Generation) will be presented. At first, the actual VOBES will be described and the motivation for the new concept will be explained. Then we project a vision of the harness development and illustrate the concept of VOBES NG. The key elements of the new system are central database, integration into the IT landscape of Volkswagen Group as well as separation of construction and supporting tool. With the help of these features, the harness development process will become an automated design process.

## 1 Introduction

Fig. 1: Wiring harness VW Passat

The big megatrends in industry, particularly in the automotive industry in areas such as autonomous driving, electric vehicles and digitalization, will provoke a deep rupture in technical development. Even the wiring harness will play a key part in the realization of future car pro-

jects [1]. The new requirements to the harness are a safe and robust construction [2], high-speed data communication, high voltage harness, weight-optimized construction and digitalization. By digitalization, we understand the automation of routine workflows in technical development. All these challenges have motivated the Volkswagen Group to start the development of the next generation of VOBES.
(**VO**lkswagen**B**ordnetz**E**ntwicklungs**S**ystem; Volkswagen harness development system).

## 2 Description of the current harness development process with VOBES

Today VOBES is a toolchain, which has to be applied in the whole group and by all harness suppliers of the Volkswagen Group worldwide. It consists of a harness component library and several construction tools.

At first, there is the library e42 which stores information about all harness components like connectors, contacts and wires with all theirs attributes like color, weight, etc. Besides all electric components with device harness interface and their currents values are managed in our database. The library also provides information about the relations between all components, e.g. which contact fits in which connector. This data will be distributed to the whole toolchain. This way, it is ensured that only approved components are used in our harness worldwide.

The next development step is to work out the system schematic. It describes the logical connections between the used electric components, e.g. ECU1 Pin 6 is connected which component 2 Pin10. In the system schematic, further requirements for special applications (e.g. twisted for CAN-connections) as well as configuration information for electric components can be found. Today, the system schematic of a platform project consists of about 100 single system schematics (such as engine, infotainment and sound system). These single schematics are connected to a project's complete system schematic. Moreover, a single system schematic can be applied to several car projects of the same platform. This system schematic method enables us to describe all Volkswagen car projects of our MQB (Modular Transverse Matrix) family in only one platform system schematic.

After the development of the system schematic the cable schematics are built. Now the logical connections will be translated into wire with real diameter, connector, contacts etc. Furthermore, the modularization of the harness will be described in this plan.

At the same time, the package will be realized in the 3D-Software tool. It includes harness protection, fixing, etc. The final result of these two development steps is a construction of the electric system and of the package.

# Trends Shaping the Future E/E Architecture

## Quo Vadis - Domain and/or Zone-oriented E/E Architecture Pattern

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**Kurzfassung**

Der Artikel gibt einen Überblick über aktuelle Trends und Fragestellungen, die die Entwicklung künftiger E/E Architekturen im Automobilbereich maßgeblich beeinflussen. Anhand der Identifikation und Variation wesentlicher Parameter des Energiebordnetzes und Kommunikationsnetzwerks werden vier exemplarische Architekturmuster aufgezeigt und verglichen. Ziel ist es, mit diesem Ansatz die E/E Systemkomplexität, die speziell durch den Trend des automatisierten Fahrens zunimmt und großen Einfluss auf die Aspekte, Energiebordnetz, Kommunikationsnetzwerk, Rechenleistung, funktionale Sicherheit Konnektivität und Security hat, greifbar und beherrschbar zu machen.

**Abstract**

This paper presents an overview of trends shaping the future automotive E/E architectures. It provides a prognosis and information on architectural patterns and required technologies for upcoming vehicle platforms. To cope with new functionalities such as automated driving (AD) these architectures demand a paradigm shift with respect to power supply systems, in-vehicle communication networks, computing performance, functional safety, connectivity and security.

### 1. The New Automotive Mobility Paradigm

During the last decades, huge changes have taken place in automotive business. New concepts and improvements of existing systems were developed, but mostly independent from adjacent domains. The new market trends automated driving, electrification and connectivity let the complexity and interconnection of our systems, among the established vehicle domains, increase significantly. And the scope of our systems reaches the boundaries of the vehicle including the environment and backend of the car. Future E/E architectures comprising power supply and communication networks need to be designed based on a multi-objective approach to enable new features while preserving basic features with low overhead by a highly scalable architecture.

The introduction of automated driving functionalities Level 3 onwoards shows the most revolutionary influence. In the future, the driver is not considered as a fallback option anymore due to systems like automated driving functions with AD-Level 4 or 5 or due to elimination of mechanical passages in x-by-wire systems. These systems require fault-tolerant sensing, processing, acting and of course fault-tolerant power supply and communication systems in order to fulfill highest Automotive Safety Integrity Level requirements and to meet legislation requirements like ECE-R13h [1]. To do so, redundancy measures on architecture level are necessary. Moreover, failure encapsulation is needed for fail-operations in case of defective components. This is a big change in paradigm: In case of any failure the system has to maintain a degraded AD functionality until the vehicle is in a safe state. New E/E architectures are needed to fulfill these upcoming fail-operational requirements.

## 2. Centralized Computing Platforms

Traditional E/E architectures with a comparatively low or moderate level of complexity are characterized by their strong modularity (Fig. 1). In such architectures, logical functions are distributed in many individual and function-specific electronic control units (ECUs) within the vehicle. Thus each function has its own control unit as one box - one function system. With an onslaught of new features like automated driving, cybersecurity or connectivity, the need for additional hardware platforms increases. With the availbility of higher compute and better availability, an emphasis is made on integrating functionalities into fewer but highperfomance ECUs in order to reduce hardware costs.

This trend is reinforced by cheaper and more powerful electronic devices being available for automotive systems. Not only electronics are getting cheaper, driven by innovations from consumer electronics, they also get more powerful with every day and become more capable of handling several functions in a vehicle. Thus, the trend of integration of ECUs and functionalities will continue enabling ECUs to control domains in a vehicle as so-called

# Seamless Electronics for Automotive Services

## Enabler of the End-to-End Electronics Architecture of the Future

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Abstract

Vehicles of the future will feature new revolutionary functions. Apart from the megatrends such as e-mobility, autonomous driving and connected car, the necessity of networking between car and environment will be the main focus in future vehicle architectures.

Applications in the area of remote updates & diagnostics, vehicle-to-infrastructure, big data, cloud functions and car-for-life will be of great importance when it comes to creating modern functions for keeping the car up to date and delivering functions like the customer would expect from his consumer electronics devices.

In order to satisfy these requirements, the solution needs to be an open, modular architectural framework based on the holistic approach of an end-to-end architecture, with the vehicle backend being an integral part of it.

There are many new challenges regarding the technological infrastructure, such as the central high-performance processing units, new concepts for diagnostics, high security algorithms, consideration of respective adaptions in the environment of the corresponding development processes and collaboration models. All are in the focus of attention.

The trend of moving functions outside of the vehicle and into the vehicle backend requires a continuous and service oriented software architecture – both in the vehicle and in the backend. This enables a cross-domain compatibility between the functions as well as the seamless usability of powerful off-board cloud functions. The vehicle integrates itself, through the end-to-end electronics architecture, into an Ecosystem which provides the future customer a variety of new functions and creates new possibilities regarding comfort and mobility.

### 1. Megatrends change Mobility and Vehicle Requirements

The automobile industry is experiencing a fast change of paradigm. Megatrends, such as autonomous driving, e-mobility, connected car or big data and cloud applications will significantly change the requirements for the future vehicles. The resulting influence will be visible in technological, development, production and after sales processes as well as on the customer side.

While cars where used primarily for transport and mobility in the past, customers will expect the complete integration of their vehicle in the connected environment.
This leads a car manufacturer, like Dr. Ing. h.c. F. Porsche AG, to address the new challenges. On one hand the highly sport-efficient, active drive and at the same time suitable for everyday use character of a Porsche needs to be maintained and developed further, but on the other hand the client should be provided with Porsche-typical solutions for the megatrends of the future.

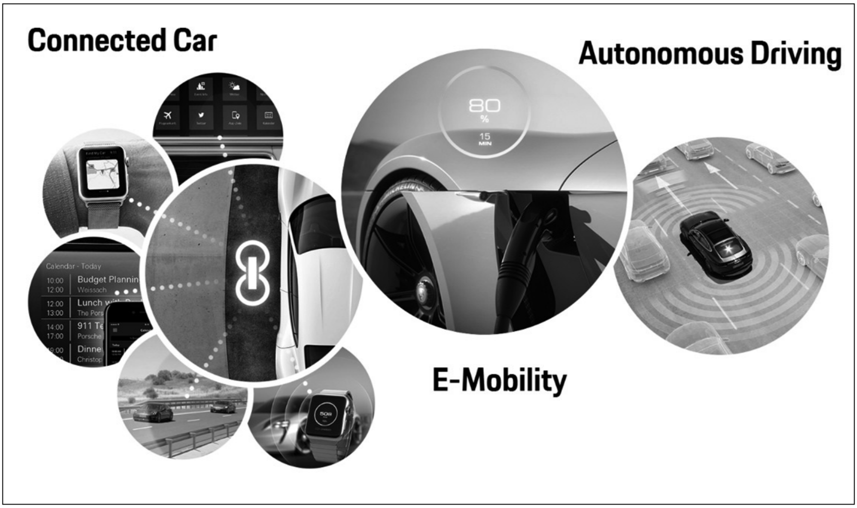


Fig. 1: Megatrends in the Automotive Industry

## 2. Effects of the Megatrends on the Electronics Architecture

Current classical electronics architectures follow a component and domain oriented concept, which puts the vehicle in the focus.
The architecture, i. e. the connected interaction of components and functions, follows a decentralized approach, in which functional intelligence is located on single control units, which are usually coordinated by a central Gateway. Furthermore, classic architectures are mostly configured with a functional set which remains the same over its whole life cycle with the customer. A connection to the cloud or a backend content exists only for very few functions.
However, due to increased customer requirements, expected technology advances and the highly dynamic change cycles driven by associated industries (e. g. consumer electronics),

# Communication mechanism for fail-operational high performance controller

**Rudolf Grave**, **Alexander Much**, Elektrobit Automotive GmbH, Erlangen


## Abstract

The requirements for automotive system design and software development are increasing due to the three most important future subjects of the automotive industry: autonomous driving, software updates over the air, and powertrain electrification. These trends will have a significant impact to the vehicles' E/E architecture. It involves the introduction of service-oriented communication and dynamic operating systems while still meeting the requirements for real-time capability, functional safety, and security. On higher autonomous driving levels we need to build fail-operational and reliable systems while keeping costs in control which focuses on the use of hardware redundancy.


## Future E/E architecture

The upcoming E/E architecture is strongly influenced by software-driven requirements that are requested by changing driver expectations, like mobile device and social network integration, and driver assistance features combined with rental business models, function on demand, and pay-per-use.

The main requirements are:

- Software updates over the air motivated by function on demand and fast updates in case of functional or security issues
- Dynamic deployment of functions to cover changing software deployment over vehicle lifetime
- Dependable systems with a stronger focus on availability, reliability, and security
- Developer-oriented, middleware-independent development environment including simulation and silent testing functionalities combined with light-release processes to enable faster update cycles
- Remote analytics and diagnostics to get information about used features and analyze problem reports and trends

One key to solve these challenges is to create an information-centric architecture including a virtual information layer where services can consume or produce data (Fig. 1). Basic services produce vehicle-wide unique information like vehicle speed, yaw rates, or seat usage.

The conversion of established signal-oriented communication to service-oriented communication leads to an abstracted vehicle Application Programming Interface (API) that hides details of specific vehicles or variants.
Let's take a blinker function as example: the converted service can be called like a function `TurnSwitch()` taking the parameter "left", "right", "emergency", etc. The abstracted service hides implementation details such as the amount of physical blinkers in the vehicle, specific regulations, etc.

This information can then be requested by other vehicle services like the rear seat infotainment system (only enabled if the seat is used) or driver infotainment system (only enabled if the seat is used and the vehicle speed is zero).

The principle *"Every information is accessible anywhere"* enables the horizontal deployment of functions and the updating of functions including access to new data, but needs to be controlled for safety and security reasons.

This information layer is represented by a set of high performance computers (HPC) communicating via a strong Ethernet backbone. The HPCs are able to start and stop service-dynamically, based on the vehicle needs.

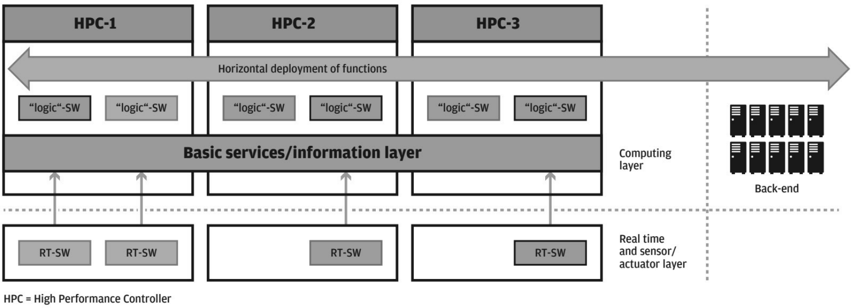


Fig. 1: E/E architecture - information layer

# Modern approach to in-vehicle infotainment architecture

## How to create a sustainable infotainment service landscape

Dipl.-Inform. **Benjamin Gross**, Volkswagen AG, Wolfsburg;
Dr.-Ing. **Patrick Bartsch**, Audi AG, Ingolstadt

**Kurzfassung**

In einer vernetzten Welt redet alles und jeder miteinander über so genannte Web Services. Da das Fahrzeug mit all seinen Sensorinformationen und seiner Vielzahl an angebotenen Diensten für Passagiere, Halter und Flottenmanager ein wichtiger Teil der vernetzten Welt wird, hat der Volkswagen-Konzern entschieden, vernetzte Technologien in das Fahrzeug zu bringen. Mit dem so genannten Volkswagen Infotainment Web Interface (viwi), das im Dezember 2016 veröffentlicht wurde, wurde eine solide Grundlage geschaffen, um eine Service-Landschaft im Fahrzeug zu errichten. Diese Service-Landschaft beinhaltet auch eine der wichtigsten Mobilitäts-Einrichtungen in der heutigen Welt - das Navigationssystem. Dieser Vortrag gibt technische Einsichten in das Volkswagen Infotainment-Protokoll, die Anwendung seiner Technologien und moderne Softwaredesignprozesse für die Welt der Fahrzeug-Navigationssysteme.

**Abstract**

In a connected world, everything and everyone talks to each other via so called web services. As the car with all its sensor information and its wide variety of services offered to passengers, owners and fleet managers becomes an important piece of the connected world, the Volkswagen group decided to bring connected technologies into the car. With the so called Volkswagen Infotainment Web Interface (viwi) that was made public in December 2016, a solid foundation was laid to build an in-vehicle service landscape on top. This service landscape also contains one of the most important facilities to mobility in today's world – the navigation system. This talk will give technical insights into the Volkswagen Infotainment protocol and the application of its technologies and modern design processes to the world of in-vehicle navigation services.

### 1. Introduction

Today's vehicles host widely interconnected devices ranging from engine control units to steering wheel control, driver assistance systems and the passenger entertainment and information center called in vehicle infotainment (IVI). These devices are mainly connected via the so call CAN-Bus [1], some of them with the LIN-Bus [2], for lower end devices and even optical transmission hardware and protocols like MOST [3].

These protocols and bus systems are well established in the whole automotive industry and have wide support in terms of tooling – Hardware and Software – for development, production and service purposes.

The automotive industry sees a lot of benefit in moving the networking infrastructure in the car towards an Ethernet based communication [4]. The Ethernet networking will allow 100Mbit/s in a first and 1000Mbit/s in a second stage on automotive grade wiring, switches, connectors and network interface infrastructures.

For the issues discussed in this article, the Ethernet stack and the available bandwidth come in very handy, as regular TCP/IP connections can be established on the in-vehicle-network. These TCP/IP connections can be routed to any TCP/IP capable device such as consumer electronic devices via wireless technology, within the car or even between software partitions on complex control units that utilize a hypervisor to spin up separate software partitions.

The car basically becomes a shell for a bunch of decentralized services hosted on distributed systems of different computational capabilities. These services shall work together as a whole to give the most seamless user experience (UX), not only on HMI (human machine interface) level such as a graphical user interface or voice assistants, but through the entire vehicle.

Imagine you want to open the trunk from a smartphone connected directly (e.g. Wifi HotSpot) or indirectly (via internet) to the car. For an engineer and also for the customer there shall be no different usability of connectivity – an engineer is of course focused on technology while the customer focuses on overall UX.

## 2. Web technology

In the beginning of the web, a bunch of servers were accessible via their internet address. The domain name service (DNS) made it easier for people to remember the server's addresses because it became easier to digest for a human than a 12 digits dot separated IP address – IPv4. With IPv6 probably just a very small community of people can even remember the actual server address.

The servers hosted a lot of information which was only accessible to those knowing exactly where to look for this information. The web browser made the information accessible in the form of webpages. To navigate from and to the so call homepage of a server, a mechanism called hyperlinks was invented that allowed companies like yahoo to build a big table of con-

# AUTOSAR proofs to be THE automotive software platform for intelligent mobility

Dr.-Ing. **Thomas Scharnhorst**,
AUTOSAR Development Partnership, Munich;
**Simon Fürst**, BMW AG;
**Stefan Rathgeber**, Continental Corporation;
**Lorenz Slansky**, Daimler AG;
**Frank Kirschke-Biller**, Ford Motor Company;
**Rick Flores**, General Motors;
**Tony Jaux**, PSA Peugeot Citroën;
**Thomas Rüping**, Robert Bosch GmbH;
**Kenji Nishikawa**, Toyota Motor Company;
Dr. **Carsten Krömke**, Volkswagen AG

## 1. Abstract

New applications like highly automated driving, Car-2-X, software updates over the air, or vehicles as part of the internet of things raise completely new requirements to a software platform for the next generation of ECUs. AUTOSAR as the worldwide leading standardization organization for in-vehicle software bears this challenge and paves the way making vehicles intelligent and adaptive. Based on a set of selected use-cases, identified by the AUTOSAR partners, the challenges and the approach to master requirements for next generation cars are described. The new platform aims to support dynamic deployment of customer applications, to provide an environment for applications that require high-end computing power and to connect deeply embedded and non-AUTOSAR systems in a smooth way while preserving typical features originated in deeply embedded systems like safety, determinism and real-time capabilities. Built around existing standards such as POSIX, the AUTOSAR Adaptive Platform will complement automotive specific functionalities enabling the platform to run in an automotive network.

## 2. Introduction

Cars continue to turn into real cyber physical systems – just connecting to the internet and exchanging data with smartphones is state of the art. Future cars will be connected to almost everything: Smart homes, roadside infrastructure and even vehicles around them – they become a part of the internet of things.

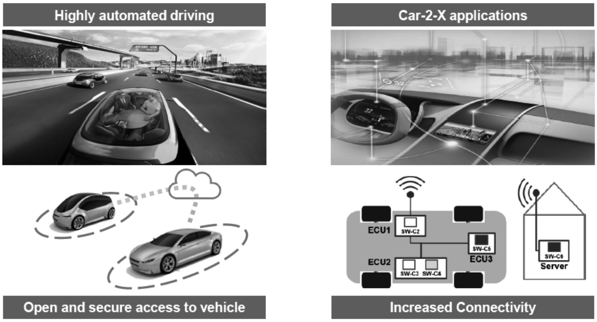


Fig 1: Use-cases driving the further development of the AUTOSAR Standard

Another trend beside the increasing connectivity is the vision of autonomous driving. Further enhancements of today’s driver assistance systems like Adaptive Cruise Control pave the way towards highly automated driving and autonomous parking, see Figure1.

The realization of these new features also adds new requirements on the software infrastructure, hosting these functionalities. Besides the existing requirements such as functional safety and security the software architecture has to support e.g. hardware with high-end embedded computing power, updates-over-the-air, communication with backend-systems or dynamic deployment of applications, as well as dependability to realize autonomous vehicles. An evaluation by AUTOSAR showed that these new requirements cannot be realized by today’s software architectures where almost all vehicle internal communication is done via a deeply embedded controller to meet OEM requirements like startup times or functional safety and where the communication can be described by AUTOSAR means. In general a software infrastructure is required that is much more flexible as today’s. It has to be highly available and capable to adapt itself to specific application requirements at a given point in time. An extension of AUTOSAR’s software architecture for deeply embedded systems turned out not to be feasible. Consequently today’s architectures will be complemented by a new platform that comes along with operating systems designed for high-performance computing which needs to be enhanced by dependability features like e.g. safety, availability, security or real-time. Nevertheless the well-known characteristics of deeply embedded sys-

# Integrated Software Platform for EE Car Architectures

## Solutions for the requirements of a new EE architecture

Dr. **Karsten Michels**, **Timm Drevensek**,
Continental Automotive GmbH, Babenhausen

**Abstract**

In assessing EE architectures in today's vehicles, it is plain to see that new functions are often accompanied by an increase in the number of electronic control units.
This evolutionary development has made the electronic on-board power supply increasingly complex and has led to a number of different electronic control units in several domains.
With the next range of new functionalities, the disadvantages of this traditional architecture will grow and new solutions will need to be found. For example, automated driving, connectivity and new holistic operating concepts will significantly increase complexity. Requirements for safety, security and availability mean that expenditure in development will increase sharply. In addition, over-the-air updates mean that the quality and compatibility of all functions must be ensured across the vehicle's entire service life.
What does the solution look like?
In the future, the many dedicated electronic control units will be integrated into a few central computers in a server architecture that will replace the traditional EE architecture. In line with this new structure, both software and hardware architecture will be tailored to this trend.
The separation of hardware and software, which began with the introduction of Autosar, will be continued and intensified. Significantly more standard and open-source software will be used, which will both create new opportunities and accelerate the development process. However, there are also some conditions that must be taken into account.
This talk explains in more detail how these new approaches will be implemented in an integrated platform and assesses both the advantages and disadvantages, as well as possible variations. This is followed by a description of the solution found, including its implementation.

## Brief history in vehicle architectures and correlating markets

The car, as a daily used product, just hit the first century of existence. It all started as a simple combustion engine on wheels but quickly turned into a complex system forming our personal freedom of mobility. Development took place evolutionary; the overall system was extended through the addition of new features, one after another. Further development merged according to cybernetic logic, from pure mechanical to electronic and later computer based circuits. Each stage of development brought along a new level of complexity.

The required technological expertise for manufacturing these devices were set by the demanded features and dictated reorientation for the involved companies multiple times. Originally designed as a pure mechanical system a speedometer for example required the precision of a watchmaker to handle all the gear wheels obscured behind the display. Later in the evolution, the pure mechanical pointer was controlled by oscillation of analog signals, this required vast knowhow mainly in building electronic circuits. Today with partly or full digital clusters the requirements shift from electronics to the implementation of logical behaviors in software.

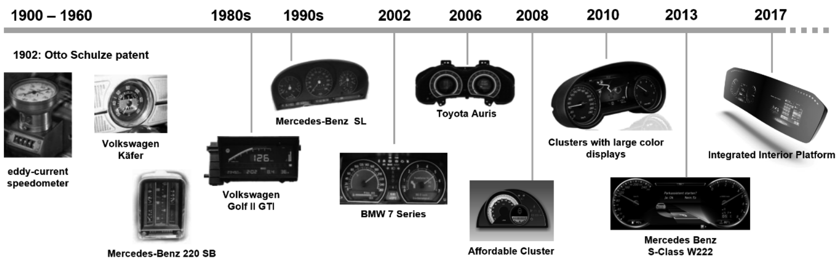


Fig. 01: History of Cluster Instruments at Continental / VDO

During this evolutionary process, former independent functions where merged in order to reduce cost and gain simpler mechanic installation and maintenance. Scaling hardware to integrate new features was done within domain borders.

## Change in framework conditions

The demands coming from customers regarding the functionality of a vehicle have changed over the last decade. Autonomous driving and the expected effects on society are not at least being discussed in the popular media and the race to “who solves it first" is on. What’s influencing this race has to be looked for within the markets for cellular phones and comput-

# Architecture of a complex hardware agnostic high-level function

## Implementing a state-of-the-art AC control

Dipl.-Inf. (FH) **W. Braunstorfer**, Dr. rer. nat. **A. Gegg**,
TKI Automotive GmbH, Gaimersheim;
Dipl. Ing. (FH) **E. Liepold**, AUDI AG, Ingolstadt

**Kurzfassung**

Der Trend zur Hochintegration stellt insbesondere diejenigen Funktionen vor große Herausforderungen, welche eine hohe System- und Applikationsabhängigkeit aufweisen.

Im Rahmen des Vortrages werden zunächst aktuelle Trends und deren Auswirkungen auf die Architektur einer systemabhängigen Funktion wie die Klimaregelung dargestellt. Anschließend skizzieren wir grob eine hierzu in der Praxis etablierte Realisierung. In Kapitel 2 stellen wir die relevantesten Anforderungen und Prämissen dar, welche eine Architektur einer systemabhängigen Funktion erfüllen muss. Wir unterscheiden dabei nach allgemeintechnischen, funktionsspezifischen und organisatorischen Anforderungen. In Kapitel 3 nennen wir Kernelemente einer möglichen Architekturlösung, welche sich so in der Praxis bewährt haben. Der Vortrag endet mit einem Ausblick, in dem die Notwendigkeit und Möglichkeiten der virtuellen Absicherung skizziert werden.

**Abstract**

The trend towards high integration poses particular challenges to those functions which have a high system and application dependency.

The talk presents current trends and their effects on the architecture of a system-dependent function such as climate control. We will then give a rough outline of an implementation about this, that is established in practice. In Chapter 2, we present the most relevant requirements and assumptions that the architecture of a system-dependent function must fulfil. We distinguish between general technical, function-specific and organisational requirements. In chapter 3, we present the core elements of a possible solution, which have been proven in practice. The contribution ends with an outlook which outlines the necessity and possibilities of virtual validation.

**1. Current trends and motivation for high integration of the climate control SW**

Operation using a touchscreen is an example of a modern operating concept for increasing the transparency of the vehicle interior. Taking the example of the new Audi A8, Fig. 01 illustrates that conventional control elements for climate control, such as buttons and keys, are gradually disappearing from the vehicle.

Fig. 01: Tidy and clear interior design in the new Audi A8

In addition, the current megatrend digitalisation is being massively fuelled by the arrival of artificial intelligence and increased connectivity. Personalised vehicle customisation, as well as the remote control of various services via App, are current functionalities that are already in series production. Addition future trends are function on demand, enhanced, networked functions to increase the user experience and online update capability. Software is not only the basic enabler but rather the key technology which is increasingly becoming a unique selling proposition. It is important that the software architecture meets a wide range of requirements. These range from classic basic conditions such as availability in the highly networked vehicle, resource limitations and modularity, to newer restrictions such as the unstoppable trend towards high-integration computers in and outside the vehicle, hardware/software decoupling and the diversity of associated variants to be considered. This diversity of variants is also being enhanced by the expansion and extension of the vehicle product range in both the conventional and, in particular, the (purely) battery-operated drive segment at all OEMs. These developments are clearly contradictory to the economically motivated goal of minimis-

# OPELs IntelliLux LED® Matrix Lights in the new Insignia

Dipl.-Ing. **Frank Langkabel**, Dipl.-Ing. **Torsten Kanning**,
OPEL Automobile GmbH, Rüsselsheim

**Abstract**

In the last few years OPEL has launched several intelligent lighting features, including the new LED matrix glare-free high beam system in the Astra and the Insignia

This paper describes and characterizes key technical aspects to introduce the latest lighting technology on an existing electronic architecture, the new OPEL Insignia.

It deals with new software-controlled lighting features, which need to be established, evaluated and validated to offer an improved performance for a midsize vehicle.

## Introduction

In the past, the OPEL exterior lighting strategy has been to offer intelligent lighting features at affordable costs and make them available to more drivers. So far, OPEL has offered its Adaptive Forward Lighting (AFL) system in High Intensity Discharge (HID) technology in most of its car lines. These systems provide different Low Beam patterns such as town, country, motorway, adverse weather light combined with a static cornering light (Figure 1). To improve the drivers' visibility in curves, the OPEL AFL HID system is equipped with a swiveling module. Simple sensor inputs (steering angle, vehicle speed etc.) are used to control headlamp lighting functions while AFL headlamps have been usually connected to a camera system to provide a high-beam auxiliary function which has been launched by OPEL in 2009 in the first Insignia generation.

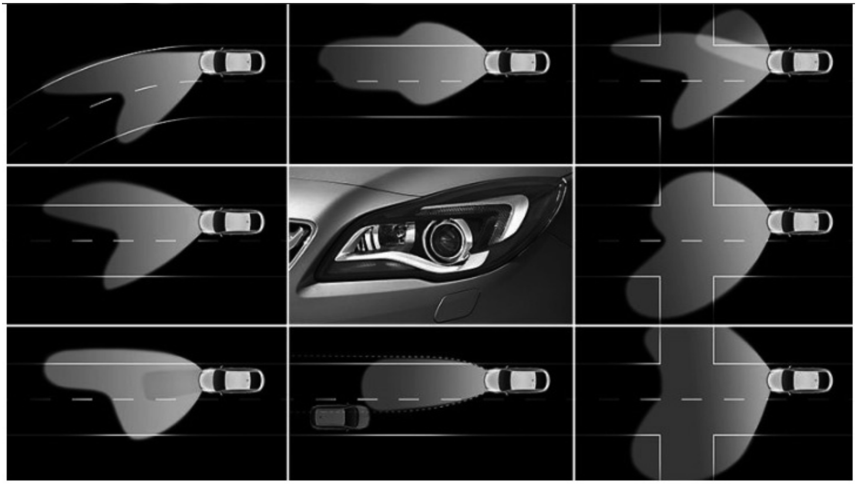

Fig. 1: OPEL AFL HID beam patterns

With the launch of the Intelligent Light Range (ILR) functionality in the OPEL Zafira and the Astra GTC in 2012, OPEL introduced its next generation AFL lighting system. It is the first step to offer an exterior lighting system which is adjust by camera information.

The camera records the distance to oncoming and preceding vehicles and also the difference in altitude (Figure 2). With this information from the camera, the ILR system dynamically adapts the low beam width and improves the driver visibility at night under low beam conditions.

With this first camera based ILR feature, OPEL could assure one's position in offering leading lighting technologies.

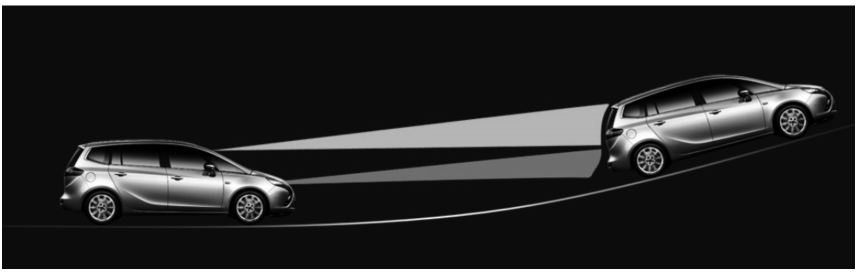

Fig. 2: OPELs Intelligent Low Beam Light Range

# High Resolution Headlamps

## Challenges for Electronic Architectures

**Jacek Roslak**, **Carsten Wilks**, **Boris Kubitza**,
Hella KGaA Hueck & Co., Lippstadt

### Abstract

High-definition headlamp technologies such as µAFS, DLP and LCD have been developed extensively for a few years now. Series production of these systems is expected to commence in 2020. These HD technologies open the door to new headlamp functions and thus increase the added value for drivers in the categories of safety, customization and emotionalization as well as communication.

Thanks to the large number of pixels, high-definition headlamps offer nearly unlimited variations for the distribution of generated light. Thus, it does not make sense to limit the functionality of an HD headlamp to the conventional light distribution such as low beam or high beam.

This paper focuses on the new challenges for electronic vehicle system architecture when it comes to implementing a high-definition headlamp system. First, a technology-neutral functional architecture is created. In the next step, two possible solutions are derived from the electronic system architectures based on the example of an LCD headlamp. One of the solutions pursues the approach of processing information centrally in the vehicle and the second system architecture pursues an approach for which the functions are distributed. The advantages and drawbacks of the respective solution are discussed and demonstration vehicles are used to present the results from the investigative study. This contribution also deals with new challenges such as high-frequency data transmission, real-time calculation of HD light distribution, data compression, as well as the interaction of the pixel data and output control. It provides a good basis for discussing the requirements for future electronics architectures of HD headlamp systems.

### 1. Introduction

The introduction of glare-free high beam in 2010 revolutionized the automobile lighting world. By mechanically swiveling the high-beam modules, areas that might cause glare, for example for oncoming cars, can be changed such that glare cannot occur. This makes it possible to increase driving time with high beams and thus significantly increases traffic safety at twilight, dawn and night.

Since 2013, mechatronic headlamp systems have been gradually being replaced by LED matrix solutions, initially with around 30 individually switchable segments. The 80 LED matrix headlamps brought to the market in 2016 can achieve even more variability in realizing their adaptive lighting functions [1].

The current trend in automobile lighting development is toward even higher numbers of switchable segments. Solutions using thousands to even several hundreds of thousands of individually switchable segments are being discussed. Four different concepts are currently being intensively studied for HD headlamps [2]:

1. Laser scanner
2. High-resolution LED matrix
3. LCD technology
4. DLP technology

This contribution explains exemplarily the LCD and DLP technologies in more detail. Innovative approaches for HD lighting technology are introduced for the categories of safety, customization and emotionalization as well as communication. The core of this study focuses on the challenges for electronic vehicle system architecture when it comes to implementing a high-definition headlamp system. Two opposing potential solutions for the electronic system architectures are derived and analyzed.

## 2. High resolution headlamp technologies

### 2.1 LCD

The basic idea of using a liquid crystal display (LCD) for realizing an adaptive headlamp system is not new. The first reports on inventions using this idea started appearing 20 years ago. The use of halogen or HID with a high IR light component, however, resulted in a high thermal load on the LCD display. This problem is minimized today by the use of LEDs.

The essential challenge in using LCDs for automobile lighting was increasing the optical efficiency. If polarized light is used for LCDs in conventional solutions with a polarizing filter, the working principle leads to losses greater than 50%. Thanks to the idea proposed in [3] of a two-stage optical system using two wire grid polarizing filters for each polarization direction, for the first time the efficiency necessary for a headlamp application could be achieved. The light patterns generated in the two optical paths are superimposed on each other by a secondary optical system to generate a homogenous light distribution with the required illuminance values on the road (see Fig. 1).

# Intelligent lighting improves driving safety and comfort

## Electronics and networking pave the way for new use cases

Dr. **Maximilian Austerer**, Continental, Wien

**Abstract**

Vehicle lighting has come a long way since the days of “electrics only” when filament headlamps just offered a choice between parking light, low beam and high beam. In retrospect, the biggest single change was the introduction of LED technology to the front lights. By using and controlling an LED matrix, the light distribution can be given multiple shapes and lengths, which improve lighting under varying traffic or weather conditions. Initially LED lighting was understandably often employed to facilitate new visual light designs mostly (“light signatures”) which help to differentiate between brands and to communicate emotional qualities. However, as LEDs always require an electronic control, the shift to LED technology has paved the ground for a much more profound change that has begun to happen: Once there is a light control unit (LCU), its electronics offer completely new functional possibilities. The key to exploiting these new possibilities lies in networking the LCU with other vehicle systems and with the data that is processed by them. Considering that advanced driver assistance systems (ADAS) and highly automated driving (HAD) are based on an increasingly large (sensor) data pool in the vehicle and in the backend, there is great potential in connecting lighting to this growing data pool. *New* information and *more precise* information about the vehicle environment can thus be used to improve the level of support which lighting can offer to the driver – or the automation. Continental is using its decade of expertise with developing and manufacturing LCUs to advance lighting to intelligent lighting by giving lighting a similar quality like ADAS. Via expanding the list of potential inputs for lighting control, new use cases become feasible and the driver will get better and more situation-appropriate support. The ultimate goal is to increase the performance of vehicle lighting so that the driver no longer needs to make manual adjustments. Instead of using hard thresholds to activate limited fixed options, intelligent lighting facilitates a new level of performance, which can include predictive lighting. Among the new intelligent lighting functions portrayed below are glare-free lighting, homogeneous lighting, high-definition lighting, and lighting tuned to the needs of HAD.

## 1. Where lighting comes from

Historically, lighting was one of the first vehicle systems to "turn electric" around 1910. However, there it remained for almost a century. Admittedly, modern halogen (1962 onwards) or xenon headlights (1991 onwards) compare to the old 6 volt lighting like a jet airplane compares to a double decker. Light intensity, light color and range have been massively improved and bending or cornering light has improved illumination in a demanding driving situation. But still, at the end of the day, the driver's choice – until quite recently – was either ON/OFF or HI/LO. Even fog lighting is an optional feature.

Roughly ten years ago this began to change with the introduction of the first LED low beam in 2007 and the first full LED headlamp in 2008. Soon after, the need for LED control units provided the starting point for the first steps up the control quality ladder: In 2010 the first LED headlamp with Advanced Front Lighting System (AFS) was introduced, followed by an LED headlamp with glare-free high beam (GFHB) in 2013. The same years also saw the first glare-free pixel light high beam system. A year after that the first laser high beam application was introduced to the market. Already in 2015 the first C segment car was offered with LED matrix lighting (Opel Astra), which marks a breakthrough. By 2016 already more than 250 vehicle models across all segments had some kind of LED lighting. The short time distance between recent lighting innovations points the way: Once LED technology and electronics are in place, there is ample room for innovation.

Continental has been an active part of these innovation activities for around a decade now, and has been delivering LCUs (currently 3rd generation) to many OEM LED (and laser) headlamp applications already. This focus on LED (and laser) lighting technology from day one is owed to the deep and long corporate background in chassis and body control units which Continental has been advancing for several decades. The necessary background in electronics, miniaturization, higher integration levels, thermal management, sensor fusion (ADAS, HAD), electric/electronic architecture (EEA), software development, post-manufacturing function download via the Internet of Things (software over-the-air, SOTA), connectivity (IoT, V2V) and networking was pivotal in developing LCUs and intelligent lighting technology. It is to be expected that LED technology will continue to gain market share and will spread wider across vehicle models and brands, **Fig 1**. What is more, over the next four years the LED fitment rates are expected to rise in *all vehicle segments*.

# On the path towards intelligent headlights

## Concepts for high-resolution light sources

Dipl.-Ing. **Thomas Liebetrau**, Infineon AG, Neubiberg;
Dipl.-Ing. **Stefan Grötsch**, Osram Opto Semiconductors GmbH, Regensburg

**Abstract**

High resolution front lighting systems for ADB (adaptive driving beam) or AFS (adaptive front lighting systems) are capable to create light patterns with small pixels and high dynamics. Systems based on active LED arrays (µAFS [1] [2]) already contain the required driver electronics. Passive projection systems like DMD (digital mirror device [3]) or LCD (liquid crystal display [4]) require light sources with high luminance.

In addition, there are further challenges to supply and control these light sources in the harsh environment of a headlight system. This paper introduces a system concept based on fast dynamic power supplies and automotive qualified microcontrollers suitable for high temperature applications and capable to drive high density light sources. This concept provides an efficient and powerful setup compatible with automotive proven interfaces like CAN or Ethernet to tie this system to the vehicle's network.

### 1. Motivation

It is discussed for quite a while that night time driving goes along with 80% higher accident risk versus daytime use. Also one third of fatal accidents of vehicle passengers occur at night. Overall the rate of fatal accidents for passengers per driven distance is about four times higher at night compared to well-lit situations during day light. Adaptive vehicle front lights improve visibility and can therefore contribute to night time driving safety. [5]

Systems with high resolution light sources provide an image intended to generate an adaptive, but in addition smooth and dynamic driving beam. With increasing number of pixels the graphical computation effort rises to the range known from graphics processing units in display applications. In order to manage an appropriate control it is beneficial to place this unit next to the light sources, dealing with the extended operating conditions of a headlight system. Typical graphics controllers derived from consumer or industrial applications do not fulfil these requirements.

## 2. Illumination vs. Visualization

Looking at a complex night time road situation, driving with low beam to avoid glare for other traffic participants as shown in Fig. 1 goes along with discomfort by the lack of viewing range.


Fig. 1: Complex night time traffic situation, illuminated with low beam pattern

In the past adaptive front lighting was done with mechanical shutters. Modifications of the light distribution are covered in the UN ECE regulation no. 123 [6], e.g. motor way light. Adapted beam pattern widths of the low beam for different scenarios of inner city or country roads were also implemented. In the first half of this decade LED pixel systems were introduced. Fig. 2 shows how addressable LED segments form an adaptive driving beam.

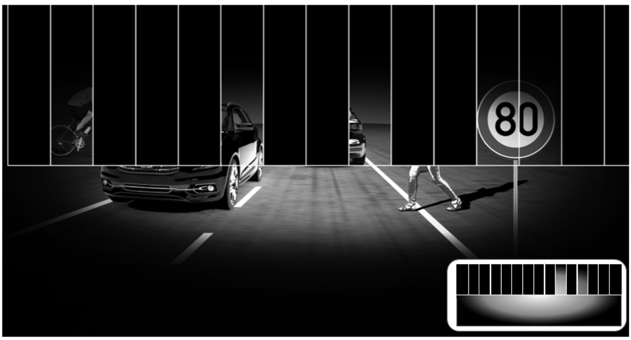


Fig. 2: Situation illuminated with fixed low beam and adaptive driving beam by addressable LEDs

In order to better distinguish the pixelated forward lighting developments we introduce the terms illumination and visualisation to differentiate the functional headlight beam from displaying information in the beam pattern. Fig. 3 illustrates the current vision to improve the illumination scenario by introducing a high resolution two-dimensional (2D) pixel array.

# Intelligence-Driven Offensive-Defense (I-D O-D)

## A new methodology for Cyber Security

**Yuval Diskin**, CyMotive Technologies Ltd., Herzlia, Israel

### <u>Current situation</u>

The cyber security solutions today are mostly focused on the network activities. They monitor, detect, and sometimes prevent attacks on the IT infrastructure of the organization.

Most of the Technology solutions aim to block the attacks mostly inside the virtual territory of the organization. It happens because Cyber Security experts and developers almost ignore for many years the important dimension of the Human Beings behind the attacks.

That made the solutions to focus on the network (It is reflected by the life cycle of Lockheed Martin that starts in the **Reconnaissance Stage** of the attack:

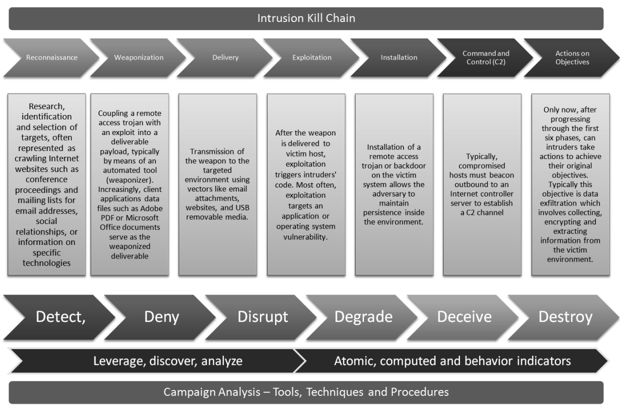


Fig. 1: Intrusion kill chain by Lockheed Martin

**What really happens in the real world?**

But what about what had to happen before the **Reconnaissance** started? **Who** - and not less important - **Why** executed the attack? What could be done if we knew it before the attack?

Before the **Reconnaissance** stage the attackers should have **Motivations** for the attack**,** then their **Motivations** became somehow into **Intentions**, then they **Assembled** together to **Conspire** or in other words they started planning the attack**,** and only then… the **Reconnaissance stage** started. These stages and behavioristic are detectable.

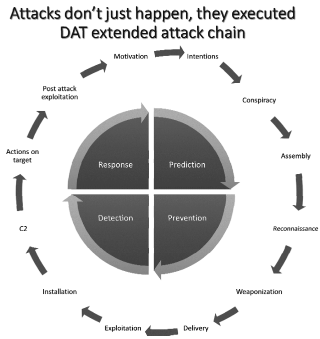


Fig. 2: The real world Kill Chain of Cyber Attack of Diskin Advanced Technologies

**I-D O-D**

The lack of Technology solutions focusing also on detecting these behaviors before the Reconnaissance stage, leaves Cyber Defense with not enough time to get really prepared for the attack, and with much less opportunities to preempt the attack.

The Automotive Industry is experiencing a dramatic revolution by connecting the cars to the Internet and by making the Cars more and more autonomous. It is a great challenge which encompasses both opportunities and threats. Thinking "out of the box" means also investing in new dimensions of Cyber Defense to protect this great opportunity.

Mr. Diskin will demonstrate how **I-D O-D** will be what he believes - the next horizon of Cyber Defense by connecting the external world to the internal world of the organization, and by providing more time to get prepared for attacks, and by adding more layers of Defense.

# (Cyber) Security / Over-the-air software updates

## Protecting and empowering the connected vehicle

Dipl.-Ing. **Stefan Römmele**, Continental, Frankfurt

**Abstract**

In the foreseeable future most new vehicles – and in the course of time a continuously growing part of the vehicle fleet – will be connected. Because of this, the car has the potential to become a major element of the expanding Internet of Things (IoT). The age of digitization opens up new possibilities for consumers' user experiences. While industry participants seek new business models and opportunities to monetize the connected car, the age of digitization opens up new possibilities for the user experience of consumers. Given these immense possibilities, the automotive sector is facing a development leap unlike anything ever seen before.

One key trend and enabling technology within the overall changing environment is over-the-air software updates. There are multiple market drivers resulting in a continuously growing market demand for over-the-air updates. On the one hand over-the-air offers a huge potential to reduce warranty-related costs by reducing the number of software-related recalls, and safety- relevant updates can be performed much faster. On the other hand a trend towards post-build functional upgrades and the ability to download new functions is becoming visible. Despite the vast number of opportunities which over-the-air offers, its biggest requirement is (cyber) security. Ensuring the highest possible level of security will be the enabling factor to permit the success of the above mentioned technological developments. In the end, it's all about trust: Trust of the end consumer in the eco-system including assurance of data privacy and trust among all industry participants. This presentation explores over-the-air security challenges and explains Continental's contribution on how to overcome them. Continental has worked on single ECU over-the-air software updates for many projects in series production since 2005 and is in the development phase for various projects covering multiple ECU over-the-air updates.

## 1. Main Pillars of security

Building and refining cyber security for the connected vehicle is a complex task which needs to be addressed on at least three levels at least. One of course is technology. A connected vehicle will need to have an “anti-virus” system on board and it will definitely require software over-the-air in order to keep up to date with new elements of security such as software patches. At the same time the right processes must be considered to achieve the intended security level. There will be no secure vehicle without processes tuned towards security. This begins with the engineering (Security by Design) of the vehicle architecture and all components which together bring security to a car. This engineering must be extended to detect attacks or vulnerabilities, logging them and communicating anomalies within the SW or data communication in the In Vehicle Network (IVN) or between car and the digital world (V2X, cloud, backend). There must be no influence on vehicle integrity by unauthorized, unidentified communication or software. Unintended system behaviour must be detected, reported and managed in a bidirectional exchange between the vehicle and the cloud. And finally cyber security requires a vast portfolio of know-how and skills, including encryption, defining security processes, and revealing system vulnerabilities even by scientifically-motivated hacking.

## 2. Future demands and challenges

In the past, vehicles had a very limited access to outside data. The global positioning system (GPS), the radio, and short-range interconnection technologies such as Bluetooth and WiFi defined the scope of networking and entertainment. Currently this limited horizon is already being expanded via vehicle apps for the smart phone, which, for instance, help to find parking space or a parked car, or offer driver support via concierge functions, or apps which unlock the car without having to fumble for a key. The first steps to connecting the vehicle to the Internet have been made. In the future, this process will accelerate and take on a whole new dimension.

Once the car itself becomes an integral part of the Internet of Things (IoT) it will turn into the ultimate mobile device. This trend is motivated by an overriding goal: To make individual mobility safer, to make it more environmentally friendly by increasing the efficiency of the vehicle and of traffic as a whole, and to make driving more comfortable. One key requirement to achieve all this is to extend the driver’s and the vehicle’s horizon beyond the line of sight. More data on the road ahead mean more options and a longer timeframe for objectified decision-making (e.g. for safe and/or efficient driving/operating strategies).

# Ransomware Against Modern Vehicles
## Feasible Attack Paths and Effective Protection Measures

Dr.-Ing. **Marko Wolf**, ESCRYPT GmbH;
Dr. **Robert Lambert**, ETAS Inc., Canada

**Abstract**

Ransomware on vehicles has the potential to become a real threat to vehicles for the same reason that it has become a significant and persistent menace to IT infrastructure in institutions and businesses: there is a compelling business model behind. Victims of ransomware on vehicles will also have compelling reasons to pay the ransom demanded to regain access to their vehicles, or to restore their vehicles to a properly functioning state. We assume, this would be particularly relevant for commercial vehicles, public vehicles, and for large vehicle fleet owners, since they often serve critical and urgent tasks with high damage potentials and since they have the financial power to pay high ransoms. With this article, we will explain how ransomware might be used to attack vehicles and extort drivers or vehicle owners. We will demonstrate that vehicle ransomware can be readily created and deployed, showing that that threat of ransomware on vehicles is real and present. In fact, we believe, that with the growth and importance of interconnected information technology in vehicles together with its continuous standardization, the security threat through ransomware will become even larger. Hence, we will also give several practical recommendations for preparing ahead against the ransomware threat with holistic multi-layered protections, but also extending vehicles and vehicle organizations with the ability to react on potential ransomware attacks with updated defenses and responses

**Introduction**

Since the recent, prominent attacks of *CryptoLocker*, *WannaCry*, and *Petya* against several critical IT systems, ransomware, which means any kind of cyber extortion malware, has become very popular topic in industry, academia, and the media. Today's ransomware effectively capitalizes on the increasing digitalization and connectivity of virtually every area in our life, together with our increasing dependence on such connected IT systems. Ransomware has already successfully attacked personal computers, public and private enterprise IT systems, websites, smartphones, and industrial control systems. However, one very prominent connected device used every day by billions of people has not been affected yet – the modern connected vehicle. Hence this work will provide a deeper look at possible attack scenarios, possible attack paths, and on effective protections against ransomware in modern vehicles.

**Critical Vehicle Security Attacks Are Still Rare in Real Life**

Since modern vehicles have become increasingly software-driven, connected, and complex, they have also become increasingly susceptible to new cyber security attacks. Increasing software deployment widens the number of potential attack targets, increasing connectivity widens the potential attack surface, and growing complexity increases the chance for an exploitable security vulnerability. On one hand, virtually all known vehicle security attack patterns have already been successfully demonstrated in practice, including remote cyber security attacks on safety-critical driving functionality, such as vehicle steering and braking [1]. On the other hand, except for some prominent alertness attacks such as [3] and [4], critical vehicle security attacks with a real safety impact, that is, attacks which effect the safety of driving the vehicle (a *driving safety attack*) are not (yet) a real-life issue. Hence, the most common vehicle security attacks today are unchanged from yesterday, meaning vehicle (component) theft, odometer manipulation, (chip) tuning, and counterfeit part production.

**Serious Cyber Security Attacks Do Scale to Significant Profits**

To our understanding, there are at least two reasons that safety attacks have not yet developed. First, creating a driving safety attack requires a lot of time and money (i.e., many person months and >100 k$), but yields an attack which is applicable only on a certain type of vehicle. Attacks are not easily transferable from one vehicle to another due to the heterogeneity of most vehicular onboard IT architectures and software. Second, successful driving safety attackers are, up to now, rewarded only with some (academic) fame but no real financial gain for the attackers. However, looking at other IT domains (e.g., business IT), the most successful attacks are exactly those which do (i) easily scale and (ii) have a “business model” that works, such as software piracy, phishing, and ransomware. Could these attacks also become serious security threats for modern vehicles? Software piracy and the physical equivalent: theft, are serious, but currently well-known and at least already tackled security threats within the automotive domain. Phishing in turn usually tries to exploit careless behavior which people from time to time will exhibit when interacting with their applications or devices. However, vehicular IT usually has to be highly automated without many direct user interactions such as password entry, which could be attacked by social engineering attacks. Ransomware, however, has not really been tackled by automotive security engineers yet. However, this could change quickly.

# The path to a global EV charging system – How to harmonize the customer interface

Dipl.- Ing. **Fabian Grill**, CharIN e.V., Berlin and Porsche AG, Weissach


## Abstract

As an international standard of a reliable, safe and powerful charging system to support basic charging as well as long range E-Mobility a significant number of companies support the Combined Charging System (CCS). To harmonize and further develop the holistic system approach of charging, the CharIN e.V. was initiated by various OEM and suppliers of the value chain. The association with over 80 international members is continuously growing and fostering CCS as the global charging standard.


## 1 The Path to High Power Charging

Due to the current design of EVS, which are typically used in urban areas and their surroundings with less than 10.000 km travelling range per year, the limitations of electrical range and charging power are almost acceptable. The extension of the electrical range with model year updates and new car models offers more range stability in all climate und traffic conditions and gives flexibility to the customers. EVs which will be launched during the next years will additionally support long distance travel.

In combination with a high power charging infrastructure the charging time at a certain charging spot can be reduced to a maximum of 4 minutes for 100 km electric range. These long range EVs open the opportunity of driving purely electric for new user groups like business travelers, driving up to 50.000 km per year.

Therefore, the CharIN e.V. focuses on the requirements specification of a reliable, safe and powerful high power charging system to support long range E-mobility – the Combined Charging System (CCS). The challenge in charging is to do it as fast as possible that means the charging power has to be increased without ignoring the AC aspect and the overall one system approach of charging.

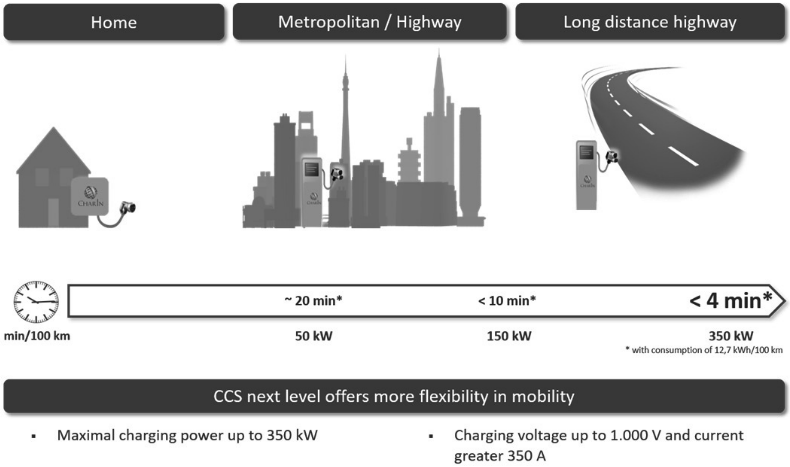


Fig. 1: Overview CCS – Charging Performance

## 2 International Initiative

The Charging Interface Initiative e. V. - abbreviated to CharIN e. V. - is a registered association founded by Audi, BMW, Daimler, Mennekes, Opel, Phoenix Contact, Porsche, TÜV SÜD and Volkswagen in 2015 to promote CCS as a standard worldwide. By mid of 2017 the association has grown to over 80 international members along the whole value chain; this is an increase by over 50 members during 2016. The current members are from Australia, China, Denmark, Finland, France, Germany, India, Japan, Korea, Portugal, Spain, Sweden, Taiwan, the Netherlands, UK and the US. 15 out of the top 20 car brands are already represented within CharIN.

# Challenges of a 48 V Drive System with 20 kW continuous mechanical power

**Karl-Martin Fritsch**, M.Sc., Dr.-Ing. **Christoph Schmuelling**,
**Tobias Binder**, M.Eng., Dipl.-Ing. **Markus Cramme**,
MAHLE International GmbH, Stuttgart

**Abstract**

MAHLE developed a high power electric drive system with 48 V supply voltage. By means of a large number of city test drives with a C segment vehicle 'real world' customer demands were examined. A continuous power of 20 kW is found to be sufficient driving around town. Using a 48 V boardnet offers a cost benefit of about 30 % compared to a 400 V system, however a drive system with 20 kW continuous mechanical power at 48 V supply voltage also comes with many challenges to overcome, especially for the electronics. The power inverter uses MOSFETs, rather than IGBT technology, due to their advantages in switching losses. With a special power electronics design, up to 600 A rms can be realized for the drive system. To achieve high efficiency, MAHLE developed a Permanent-Magnet-Synchronous-Machine (PMSM) which has a high power density due to a specific rotor design with a high amount of reluctance torque. To ensure both durable high efficiency operation and high power density, a thorough thermal analysis of the electric machine combined with the electronics was performed.

## 1. Introduction

A growing ecological awareness, air pollution and statutory requirements are leading to a demand of high efficiency mobility solutions with low fuel consumption and low emissions. In metropolitan areas, the decrease of the air quality leads to a growing demand for urban mobility. Bans of ICEs (Internal-Combustion-Engine) in city centres are already in public discussion. A solution for keeping the individual transport is the hybridization of existing platforms by Plug-in-Hybrid-Vehicles (PHEV) or the usage of dedicated urban Battery Electric-Vehicles (BEV). For the transfer of the customers demand "driving electric in the city" to an e-drive specification, MAHLE has collected a comprehensive set of data.

The tests were executed using a C segment vehicle with a total mass of 1670 kg. According to [1], a continuous power of 20 kW and a peak power of 30 kW is sufficient for driving a vehicle at city speed which can be seen in Fig 1. The required maximum axle torque should be up to 1600 Nm for short time and 1200 Nm continuous. To achieve low system cost, several boundary conditions are considered.

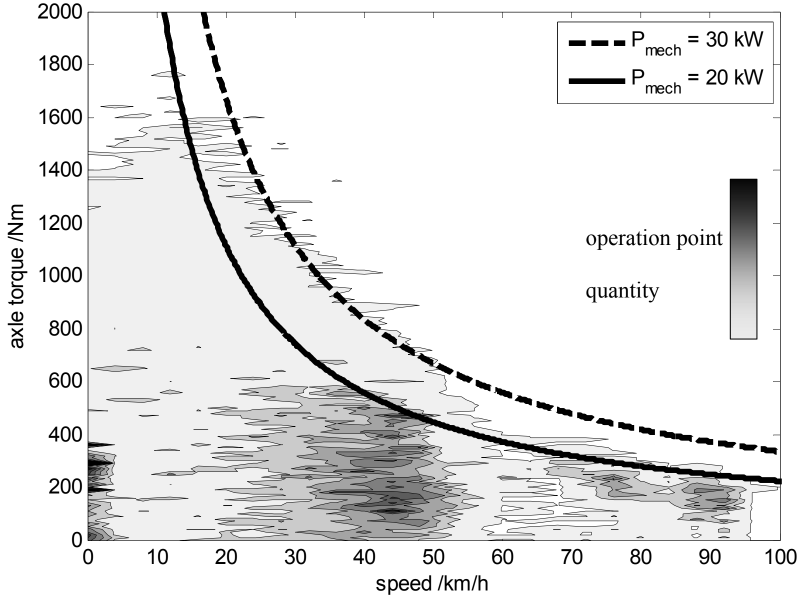


Fig. 1: Required torque and speed of the city test drive, mechanical power lines for 20 kW and 30 kW [1]

## 2. The reason for driving with 48 V

For the evaluation of the appropriate supply voltage, a study of the electric drive system cost for different power levels and supply voltages is made. Active parts, like the design of the electric machine, the electronics design with the required amount of parallel MOSFETs or IGBTs or the type of connections were considered. Different low voltage (≤60 V) solutions were compared to high voltage drives.

Cost can be saved by using a low voltage level. On the one hand, with a lower supply voltage, for the same power level, the currents are increasing proportionally and with this the copper wires cross sections. Due to the limited current-load-capacity of the switching elements, additional cost-intensive parallel paths are needed for high power applications. On the other hand, there will be no demand for any safety features like insulation observer or service disconnections for maintenance. A breakeven exists, like it can be seen in the result of the relative cost comparison for 48 V and 400 V (Fig 2).

# Combined Charging System (CCS)

## High Power Charging and current activities in international standardization

Dipl.-Ing. **Matthias Kübel**, Volkswagen AG, Wolfsburg

**Abstract**

The existing offer of Battery Electric Vehicles (BEV) equipped with the Combined Charging System can cover ranges up to 300 km according to the New European Driving Cycle (NEDC).

Additional burden caused by secondary loads, way of driving or ambient temperature decreases the range. Therefore BEVs are the ideal means of transport for urban and commuter traffic. The breakthrough of e-mobility with BEVs will only be achieved if BEVs can cover ranges of more than 500 km. These vehicles can then fully replace vehicles with combustion engine. Vehicle manufacturers realized this and are working on the development of long-distance BEVs. A variety of long-distance BEV models from different manufactures has already been announced to be available until 2020.

As charge durations of up to 30 minutes are accepted by the customer, fast charging is considered as a key enabler for long-distance electric vehicles. With the current DC charging standard for electric vehicles – the Combined Charging System (CCS) – these charging durations will not be achievable. Hence, OEMs and electronic industry partners from the USA and Europe are working together on an extension of the CCS charging standard with charging currents up to 400 A.

This has already been announced on the ELIV convention in 2015 where a concept was shown how a DC EV charging station with a conductor cross-section of less than 50 mm² can solve the challenge of delivering up to 400 A. Without any exceptional measures the conductor cross-section for a charging current of 400 A would increase up to 120 mm². Charging with exceptional measures leading to a reduction of the conductor cross-sections is called High Power Charging (HPC).

The purpose of this paper is to provide an overview of the standards which are affected by HPC and to point out the current status and the road map of these standards. Furthermore, the requirements and corresponding test cases for HPC vehicles and HPC DC EV charging stations as well as their complexity regarding interdependencies between the affected standards are explained to ensure that products which are currently under development will comply with future HPC standards.

## 2 System definition

The definition of the system is based upon the functional description of High Power Charging considering the described framework (preservation of the established vehicle coupler geometries, assurance of handling by avoiding increased conductor cross-sections, compliance with temperature limits of the involved components). Here, a new subsystem for thermal management has been integrated in the existing charging system (see Figure 1). This subsystem consist of the functions necessary for HPC, i.e. thermal sensing inside the vehicle connector, thermal transport from the cable assembly and thermal exchange inside the DC EV charging station.

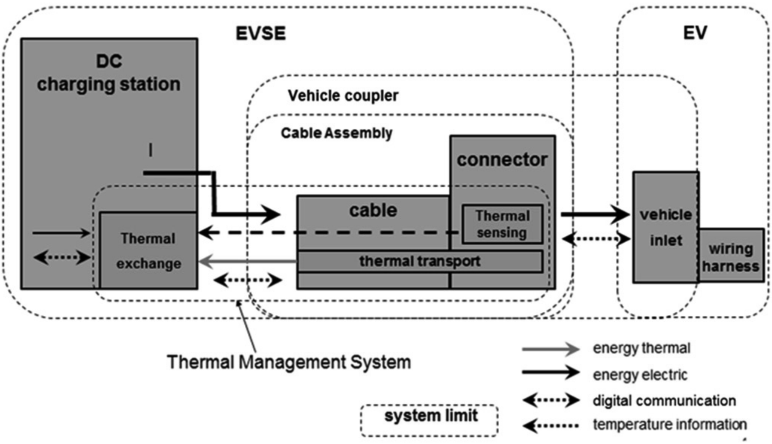


Fig. 1: System definition of High Power Charging

# SoC-Swing based Optimization of Automotive Batteries using Simulations

**Felix Frank**, M.Sc., Dr.-Ing. **Jörg Wilhelm**,
Robert Bosch Battery Systems GmbH, Stuttgart;
Prof. Dr.-Ing. Dr. h.c. **Dieter Schramm**,
Universität Duisburg-Essen, Duisburg

## 1. Abstract

The design of an automotive battery for an electric vehicle is subject to a lot of boundary constraints. Technically, the chemical system of a battery is described by its electric and thermal performance. It is impossible to determine the electrical configuration without regarding the batteries thermal performance. However, the thermal performance is neglected often, at least in a first approach. Normally, to find the optimal solution for this trade-off between determination of the electrical/thermal battery-structure and an expensive first build-up of a prototype to test with, a lot of iterations, including experts of every domain involved, are conducted. To overcome this issue, a model-based approach is described in this article. Based on two models, an electrical cell model and a heat-transfer-coefficient thermal model (cf. [1]), a mathematical optimization is done to find an optimal configuration, given a set of boundary conditions. These boundary conditions are e.g. a maximum average battery temperature, a maximum and minimum system-voltage and a desired amount of usable energy. The mechanical structure of the battery cells, assembled into a battery pack, as well as expected production costs will not be regarded.

One key factor for the electrical design of a battery is an appropriate location of the SoC-Swing (SoC: State of Charge). It determines the usable energy, as well as the maximum and minimum system-voltage. In contrast to a usually used parameter to describe the loss of energy caused by the need of operating the battery cells within safe conditions, the SoC-Swing is placed exactly in this work and arousing influences are analysed. Additionally, the operation condition, more precise the current-profile the battery is exposed to, has a major influence on the usable energy and therefore on the driving range of e.g. an EV (Electric Vehicle). With reference to the location of the SoC-Swing the current profile combined with the internal cell-resistances result in a varying electrical and thermal performance.

The method used to find an electrically and thermally optimal battery design, is a combined optimization, consisting of an electrical pre-optimization followed by a global optimization for which a genetic algorithm is deployed.

## 2. Initial Situation and Requirements for Automotive High-Voltage Batteries

At the beginning of each battery design procedure there are requirements. From a battery manufacturers point of view these are technical and economical customer requirements and a set of technical boundary conditions derived from battery-pack and electrical powertrain components. As derived in [2], they can be denoted as electrical, thermal, mechanical and economical requirements (see Fig. 1). None of these main influencing factors can be considered completely isolated. This fact leads to the high complexity in battery design. A change of one requirement can have impacts on each of those influencing factors.

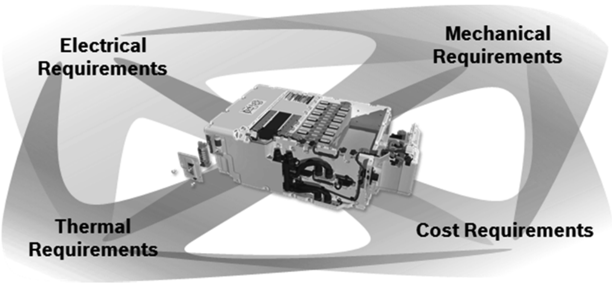


Fig. 1: Main influencing factors and requirements on high-voltage battery design.

The technical and economical customer requirements usually contain the following information:

- Desired energy content/usable energy (or driving range on specific cycle, vehicle type or energy consumption)
- End of Life (EoL) or Begin of Life (BoL) criteria
- Usage case (driving profile, temperature distribution, power requirements)
- Lifetime
- Installation space
- Cost requirements

They are supplemented by technical boundary conditions originating from the electrical powertrain and battery components:

# Challenges in Battery Development: The Best Fit

**Benedikt Frieß**, **Thomas Soczka-Guth**, **Florian Hofbeck**, **Franz Nietfeld**, Daimler AG, Sindelfingen


### Abstract

The ongoing transformation from conventional combustion engines to battery-powered electrical vehicles imposes demanding requirements on the battery as its key component, such as high energy density, performance, long lifetime, fast charging ability, safety and affordable costs. State-of-the-art battery technology fails to meet all these requirements in a single device, leaving engineers with the dilemma of finding a good balance between competing properties. This article provides an overview on the challenges faced in today's battery development and ends with an outlook on Daimler's strategy for the future.


### Introduction

The company Daimler has been one of the leading protagonists in the field of mobility early on, proudly tracing its roots back to the early childhood of automotive development. The companies pioneering spirit is also reflected in the long-lasting endeavor to promote alternative propulsion methods like fuel cells and battery-powered vehicles, paving the way to a future beyond conventional combustion engines. Already in the early 70s the first electric van with an innovative battery exchange system has been introduced by Daimler-Benz. Back then, battery design was based on a sodium-sulfur technology, which requires high temperatures for operation. It was the starting point to a succession of various electric research vehicles with different battery designs and chemistries in the following decades. Nevertheless, for long, the maturity of the battery technology was not sufficient to compete with highly-optimized and customer-friendly conventional cars for market share. Only in recent years, when the lithium-ion battery technology has entered the stage, this seemingly irrevocable principle slowly seems to crack. One of the key events was the introduction of the world's first series hybrid with lithium-ion battery by Mercedes-Benz in 2009. Establishing a successful integration of the temperature sensible lithium-ion chemistry into the frontend of a traditional vehicle with a battery environment showing peak temperatures above 100 °C, it was proven for the first time that lithium-ion technology had reached a maturity level acceptable for automotive applications.

In subsequent years, a multitude of different hybrid and electrical cars were developed by car manufacturers around the world, rendering lithium-ion technology the primary enabler for the breakthrough of electro mobility on a global scale. Yet, this stunning development obscures the technical challenges developers and scientist are facing to establish electric vehicles as future means of transportation. This article aims at providing insights into the complexity and challenge of contemporary battery development.

**Key performance indicators**

The usability of batteries in electrical vehicles poses stringent conditions on various aspects of battery performance. Fig. 1 illustrates the main set of characteristics used to evaluate the performance of battery systems. It comprises the following key indicators:

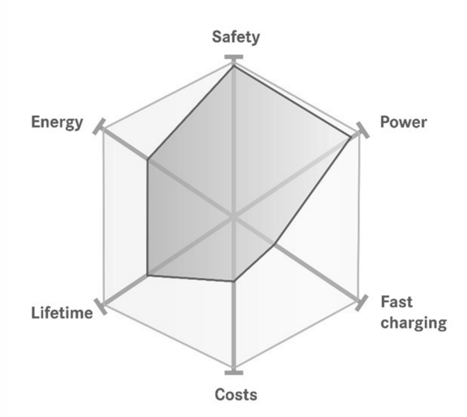


Fig. 1 Illustration of key indicators used to highlight performance and potential of battery systems

- **Energy density** ─ One of the defining features of any battery system is of course the amount of energy stored inside of the batteries' cells. As it determines most of all the traveling distance, it has strong implications for the practical usage of cars. However, considering the demanding constraints in space and weight of today's modern cars, the gravimetric and volumetric energy density is often the more relevant number for engineers to look at. It has far-reaching consequences for the development of traction batteries and asks for a sophisticated solutions concerning the integration and layout of battery components as well as the usage of light-weight materials.
- **Power** ─ Having identified a battery system with large storage capacity, the next important quantity to think of is the rate at which this energy can be stored or released. For traction batteries, the power determines the acceleration of the vehicle and, in case of a braking event, how much of the vehicle's kinetic energy can be recovered by the battery system. In this regard, high power seems desirable, but unfortunately

# Digital Readiness

# Virtual Integration and Validation in Volkswagen Development's SimLAB

Dr. **Peter Oel**, **Florian Pohl**, Dr. **Julian Timpner**,
**Benjamin Aschoff**, Volkswagen AG, Wolfsburg

**Kurzfassung**

Die Automobilindustrie befindet sich in einem, die gesamte Wertschöpfungskette umfassenden, rasanten Wandel. Hochintegration statt Einzelsysteme bedingen gänzlich neue Architekturkonzepte und Technologien in der Entwicklung und Absicherung. Anstehende Innovationen wie updatefähige, lernende und auf ihre Umwelt reagierende Funktionen stellen signifikant neue Anforderungen an den abzusichernden Umfang. Die Integration des E/E-Gesamtverbundes, also das Zusammenführen aller Elektrik-/ Elektronik Hardware- und Softwaresysteme zu einem Ende-zu-Ende-Gesamtsystem, wird zunehmend Fehlerschwerpunkt und muss daher als eigenständige Entwicklungsaufgabe wahrgenommen werden. Die Entwicklungs- und Freigabefähigkeit kann ausschließlich durch Verwendung neuer digitaler Integrations- und Simulationswerkzeuge realisiert werden und führt zu einer Gesamtverbund-Simulationsplattform, die sowohl für die Funktionsentwicklung als auch für die Absicherung verwendet wird. Ziel dieser Plattform ist es außerdem, durch Verknüpfung simulativer Technologien mit traditionellen Absicherungstechniken den Hardwareeinsatz in der Entwicklung schrittweise zu reduzieren.

Vor diesem Hintergrund implementiert die Marke Volkswagen Pkw im Kontext der Absicherung des E/E-Gesamtverbundes zwei wesentliche Digitalisierungsinitiativen. Das Framework zur Virtuellen Absicherung ist ein Simulationsbaukasten, der die gestufte Integration im E/E-Gesamtverbund ermöglicht. Das „SimLAB“ ist ein fachbereichsübergreifendes Projekthaus, in dem mittels agilen Zusammenarbeitsmodellen Entwicklungspotenziale optimal ausgeschöpft werden, um virtuelle Technologien in die Simulationsplattform zu integrieren und die Absicherung neuer Funktionen durchzuführen.

**Abstract**

The automotive industry is undergoing a rapid change encompassing the entire value chain. Highly integrated systems are replacing rather simple distributed ECUs, necessitating entirely new architecture concepts and technologies for the development and validation of vehicle functions. Upcoming innovations, such as over-the-air software updates and self-learning systems, pose significant new challenges to validation of the vehicle functions. The integration of the complete E/E package, i.e. the unification of all electrical/electronic hardware and software systems into a complete end-to-end system, is increasingly becoming the main source of errors and must, therefore, be regarded as an independent development task. The capacity for development and approval can be realized only through the use of new digital integration and simulation tools and leads to a complete simulation platform package, which is used not only to develop but also to validate vehicle functionality. The aim of this platform is also to gradually reduce the use of hardware in development by combining simulative technologies with traditional validation techniques.

In light of this, Volkswagen Passenger Cars is implementing two main digitalization initiatives in the context of complete E/E package validation. First, a virtual validation and verification framework provides a building block system for simulations that enables incremental integration in the complete E/E package. Second, SimLAB is a cross-departmental “project house” in which development potentials are utilized optimally by means of agile cooperation models to integrate virtual technologies in the simulation platform and to perform the validation of new vehicle functionality.

# Software test methods being used at Opel

## Seamless testing from C-Code to high level feature requirements

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**Abstract**

At Opel, software which is integrated into Electronic Control Units (ECUs), is developed using a top-down approach. The development starts with high level feature requirements, continues with low level software requirements, and ends with the software itself. In most, but not in all cases, the software is modelled in Simulink® [A] and the C-Code is derived using an auto-coder. The verification of the software is performed using a bottom-up approach. In software engineering this approach of modelling top-down and verifying bottom-up is known as V-Model. This paper discusses, which test methods are utilized at Opel to verify the developed software throughout all the levels of software development, from C-Code to high level feature requirements. To ensure this, using a single test method is not sufficient. We need multiple test methods with different scopes and the set of test methods discussed in this paper is sufficient for seamless testing.

**Overview**

Because of the complexity of the software in a vehicle, a modern fully equipped vehicle approximately consists of 100 million lines of code [1], the software is split up into so called software components representing features or common functionalities. Those software components are developed individually and are combined using a bill of materials, a list of components which are required to represent the feature set for a given vehicle.

When it comes to testing, the C-Code of the software components is verified using functional code unit tests against the low level software requirements. If the C-Code of a software component is derived from a Simulink model, that model is tested against the low level software requirements using functional model unit tests. Subsequently, equivalence tests prove that the derived C-Code fulfils the low level software requirements as well by proving that the behaviour of the Simulink model equals the behaviour of the C-Code. Next, the individual software components are combined as defined in the bill of materials and the resulting model is tested using a Model-in-the-Loop environment to verify that the interaction with other software parts is working as desired and that the feature level requirements are met. These

Model-in-the-Loop tests are done for parts of the bill of material instead of testing the complete set of existing software, which is helpful for testing a given feature (e.g. Lane Keeping Assist). Using rapid prototyping methods the same model is tested in a vehicle. This is necessary because it is not always possible to test all high level requirements in a Model-in-the-Loop environment due to the fact that the simulation of the environment (vehicle, road, etc.) does not exactly match the real environment. If all mentioned tests passed, the software is integrated into the final ECU and a Hardware-in-the-Loop setup is used to prove that the integration has been done correctly. The described test sequence is sufficient to verify that the developed software matches the high level requirements, not considering influences such as sensor accuracy or bus latencies, and that the software fulfils high software standards. A second verification of the high level requirements is done later in the development cycle of a new vehicle including hardware components and other impacts such as bus communication latencies. That verification is not discussed in this paper.

In *Fig. 1* all test methods are shown. Left-hand-side the different artefacts of development are shown (high level feature requirements to integrated software), and in the columns the different test methods are shown. The arrows indicate what is tested (start point of the arrow) and against which level of implementation (end point of the arrow). It can be seen that, if one of the test methods is not executed, it is no longer guaranteed, that each artefact adheres to what is "specified" with the next higher artefact, and therefore the consistency between integrated software and high level feature requirements is not guaranteed.

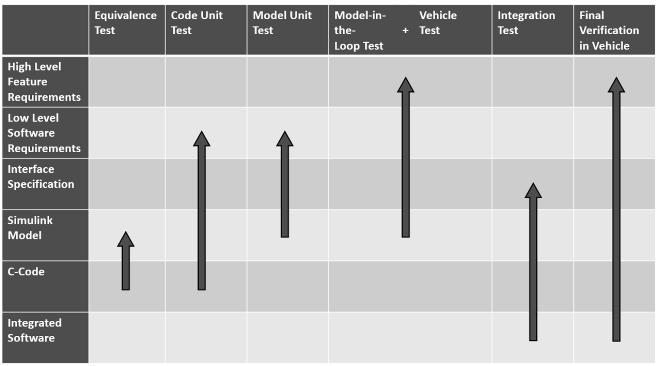


Fig. 1: Overview of test methods

# Accepting Uncertainty

## Applying proven methods for quantifying test results and test coverage to ensure safety compliance of self-learning systems

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### Abstract

The field of advanced driving assistance systems (ADAS) and autonomous driving (AD) system has seen an increase in applied test coverage in line with the increase in functional complexity and safety relevance.

With the advent of SAE Level 3 and higher systems – Conditional, High and Full Automation, and the introduction of advanced self-learning systems for automotive use, designers, OEMs and homologating bodies alike are confronted with two main questions: Firstly, how can we assure a reasonable test coverage for a system that has to operate properly and safely in any conceivable environmental condition? And secondly, how to properly test a self-learning system, which may completely change its behavior long after testing has completed?

We are showing that both questions can be solved using the same solution: any self-learning system in our scope, including those with non-deterministic portions, can be identically transformed thusly that the aspects of self-learning and non-determinism can be considered identically to the problem of the unknown use case population.

Next, we explain how established and proven approaches from different domains (experimental physics, mathematical statistics, data analysis) can be applied to achieve a measure for test coverage in the situation of populations where only basic knowledge about their properties exist.

### Novelty and Innovation

We solve the hitherto unsolved problem of test and validation of self-learning/non-deterministic systems for safety-critical applications by transforming it into an already-existing effort problem.

We then tackle the effort problem and replace guesswork in estimating test coverage with quantitative results, thus allowing for an optimization problem.

These results allow to optimize for TCO over the entire development cycle by considering previously separately considered domains together. This step is however not considered within the scope of this paper.

**Nota Bene:**

In cases where a formal, equation-based description is used in this document, we will describe a time-discrete system without loss of generality, as other realizations may be reached via bilinear transforms.

## 1. Introduction

Software, and thus software development, does not differ from purely physical products in that one aims to properly test goods before shipping a product. This is the case for software deemed uncritical with regard to functional safety and availability; it is especially relevant for safety-critical systems, for example systems where human lives depend upon flawless operation of software. A faulty operation could not only endanger lives, it could also result in large losses of a company's reputation or revenue (material or immaterial damages). These concerns have led to a rigorous practice of software reviewing and testing. The procedures are standardized in e.g. ISO 16142 (medicine), the aerospace industry (AS 9100) or the automotive industry (ISO 26262 in Europe).

A theoretically working, brute-force approach for testing would cover every possible scenario in which the software would be used in. The tests would contain the correct response of the software in every situation the system may encounter in the field.

For certain small and simple systems, it is possible to have a full coverage of every possible scenario. As the system becomes larger and larger, covering the system in whole in testing will become an insurmountable task. It will also get overly complicated to even find every possible scenario in the input space.

Automated systems (e.g. Polyspace) will struggle to design tests with high coverages of all thinkable scenarios.

The advent of artificial intelligence (AI), especially the disciplines of Deep Learning / Neuronal Networks, worsened the problem: In neuronal networks the number of paths the information could flow through in the network is several magnitudes above the number of paths that can be found in conventional software [3] [5]. The paths are crossing each other and the signal flow is processed in neurons with a nonlinear transfer function. These nonlinearities make it impossible to decompose the problem using proven and established analysis methods valid for linear systems.

Apart from the formal description of the problem, there is a question that presents itself intuitively with regard to AI systems: how would I test the reaction of a system after it has gone

# Test Automation at Valeo Siemens eAutomotive in Practice

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Dr. **Heiko Dörr**, Model Engineering Solutions GmbH, Berlin

**Abstract**

In the dynamic field of e-mobility, agile software development is needed in order to adapt and deliver products that fit the customer's growing needs. At the same time, quality assurance must keep pace with the velocity of the development. Hence, Valeo Siemens eAutomotive introduced the *agile mbD Suite* as an enabler for rapid prototyping of e-drives. In collaboration with Model Enginering Solutions, Valeo Siemens eAutomotive combined agile development activities and automated quality safeguarding. As a result, design changes can be realized faster while at the same time product quality is improved.

**Introduction**

Delivering safe software products is a challenge for all manufacturers, in particular in regulated environments - such as the automotive domain. Here, standards such as ISO26262 and ASPICE specify requirements on, e.g., processes, methods, work products, and tools. Although these requirements shall support and ensure the development of safe software, they impede realization of competitive advantages by preventing the introduction of innovative and advanced techniques in software development. However, customers demand short development cycles and regular releases to establish and exploit competitive advantages in trending fields such as e-mobility for themselves.

These demands can only be satisfied by modern processes, methods, and tools, such as agile development, continuous integration, and automated quality assurance. As a supplier of e-drives, Valeo Siemens eAutomotive (VSeA) strives to satisfy these demands, while at the same time, safe-guard the quality of their products. For this reason Valeo Siemens eAutomotive partnered with Model Engineering Solutions (MES) to identify and support the necessary transformations and transition into agile development for safety-critical devices.

This goal is achieved by developing an environment that allows rapid-prototyping and early validation of design models. At its basis serves a continuous integration server that builds, integrates, tests, and evaluates the current software status. This process insures that at any point in time during the development phase a working product is available. Additional setup routines initialize templates and interfaces for this environment such that developers can immediately start modeling and testing assigned requirements. The standardized and template-based approach also facilitates outsourcing of individual activities such as testing. Results from third-parties can easily be integrated into the present environment. The process is further augmented by a quality monitoring system that evaluates and visualizes incoming data on the basis of a tailored quality model. This way, one can easily see whether the current revision complies with the selected quality standard.

The remainder of this contribution is structured as follows: In Section 2, we present the initial situation and the goals to be achieved by the end the transition. In Section 3, we show how the agile process is supported by roles and infrastructure, while in Section 4, the safe guarding activities and their integration into the infrastructure is presented. In Section 5, we discuss the capability of this approach for dynamic outsourcing of test activities. We conclude this contribution in Section 6 with a summary of the lessons learned and future tasks to leverage the efficacy further.

**Agile MBD Process**

Before transitioning to agile model-based development, Valeo Siemens eAutomotive had introduced model-based development. The introduction of model-based design then did solve many problems at the time. The two main benefits of this approach are: First, it enabled simulation and test of the system to be developed by using the model. This allows for the early validation of the requirements. Second, it is possible to translate the graphical model into source code by using a code generator such as dSPACE TargetLink or Embedded Coder from The MathWorks. As a consequence, the development cycle can be shortened consider-ably.

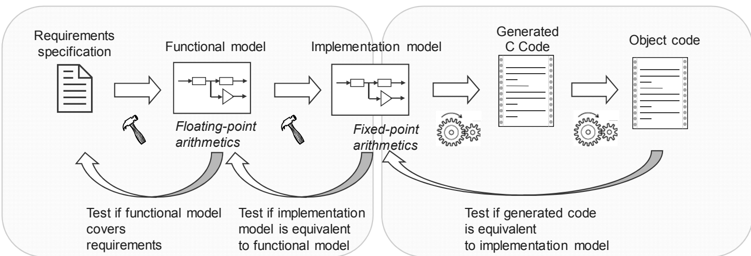


Fig. 1: Model and code verification in model-based development

In more general terms, the model-based development process consists of two main phases. Figure 1 illustrates this process in a simplified way. In the first phase, a model is devel-

# Interactive Specification and Validation of Highly Automated Driving Functions in a Mixed Reality Environment

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**Abstract**

As digitization progresses, new virtualization methods are making it possible to simulate function concepts and currently implemented functions in any traffic situation long before a costly physical prototype has been constructed. In this context, the following paper describes the development of a mixed reality simulation application on the basis of Microsoft HoloLens which allows users to immerse themselves into a simulated traffic situation with the aim of observing it as a pedestrian and interacting with its elements. All components, from pre- to post-processing the process chain of mixed reality simulation, are available by seamlessly linking the mixed reality application with IAV GmbH's Scene Suite traffic simulation tool. Featuring the scenario modeler and two-dimensional result visualization, this tool already offers a broad scope of different functions. On the basis of test person studies, this new methodology can be used for evaluating the effect of a virtual prototype in its environment at an early stage of the development process.

## 1. Introduction

The trend towards autonomous driving is shifting responsibility from the driver to the vehicle. Besides the actual tasks involved in driving, however, this also includes the interaction between drivers and their environment. As an actual example, let us assume the following situation: an autonomous car approaches a pedestrian crossing while a pedestrian is walking across it. Usually the human driver instinctively controls the vehicle and uses non-verbal communication, such as hand gestures, to signalize to the pedestrian that s/he can cross without risk. An autonomous vehicle, on the other hand, follows the defined specification which is preceded by numerous system tests, involving real persons and, for example, a physical prototype. In practice, studies of this type are very costly, only possible at a late stage in the development process on account of the prototype needed and, depending on the situation under test, simply too dangerous for the test person.

The function development process in this field is complex and sometimes not transparent. In the course of progressive digitization, development methods, such as virtual integration, are permitting the integration of new processes and technologies that complement the classic development process based on the V model. Even today, for instance, the complex function development process is assisted by scenario-based function development which makes it possible to define specifications and verify them on the basis of two-dimensionally modeled and visualized scenarios. Following on from this, upgrading two-dimensionally described scenarios into a virtualized three-dimensional environment would appear to be the next logical step. New technologies, such as the Microsoft HoloLens, permit the generation of a mixed reality in which the user perceives virtually generated objects in the same way as the environment that physically exists. This paper describes the development of mixed reality simulation using the Microsoft HoloLens to assist the process of developing functions for highly automated driving. Particularly in early development phases, this aims to offer the capability of evaluating the effect of the development vehicle on its environment before a physical prototype has been constructed.

## 2. Mixed Reality

Augmented reality, as a sub-domain of mixed reality, assists the perception of real-world situations using additional information. Unlike virtual reality, which largely screens users from reality and offers them a synthetically generated environment, augmented reality is embedded in the real-world physical environment rather than replacing it. According to Azuma, the aim of augmented reality is to give the user the feeling of having virtual and real objects existing together in the same space [1]. In a general definition of augmented reality, he also quotes the following three characteristics:

- Combination of real-world and virtual content
- Real-time interaction
- Registering information in three dimensions

# PST – Powertrain system test: A new test element in a holistic test strategy for hybrid vehicle powertrains within the product development process

# PST – Powertrain System Test: Ein neues Testelement einer ganzheitlichen Erprobungsstrategie für hybride Fahrzeugantriebe im Produktentwicklungsprozess

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**Abstract**

The validation branch of the v-model has a major importance as it significantly influences the time-, cost- and quality- amounts within the product development process. In the field of powertrain engineering, longstanding empirical knowledge was gained for testing conventional vehicle powertrains. The hitherto used test strategies here were more focused on the subsystems of the powertrain than on the powertrain as an integrated system. Through the electrification of the powertrain, the topology, the range of functions and even the usage behaviour have changed. Also the complexity of the powertrain system increased and must still be validated and tested regarding its functionality and durability. This leads to new challenges for the validation and requires not only adjustments of the test strategies for hybrid vehicle powertrains but establish and develop integrative tests for the powertrain as an integrated system in order to meet the increased complexity. This paper presents a concept for a new developed test element within a holistic test strategy for hybrid powertrains, called the powertrain-system-test (PST). For this purpose, an introduction to the used holistic test strategy for hybrid vehicle powertrains and the therefore established nomenclature is given. This is necessary in order to avoid misunderstandings of used terms. Subsequently the concept and the test content for the PST within the product development process is presented. The aim of the PST is to test the interaction of all subsystems of the powertrain in each vehicle-charge before entering the vehicle-level to increase the overall quality and maturity of the powertrain as

an integrated system. Finally, an outlook is given on the current results within the framework of the implementation of the PST concept.

## 1 The nomenclature as the basis

The basis to develop and describe a holistic testing strategy is to determine a standard understanding of used terms in the field of powertrain engineering.

Because this field enclosures a big area of studies, it leads to the current fact, that same terms have different meanings depending on the viewing angle of the professional focus, as [1], [2] and [3] expose. The research literature exhibits a gap here [4]. Therefore, a nomenclature is defined and described. A part of the full nomenclature is illustrated in Fig. 1 and listed below.

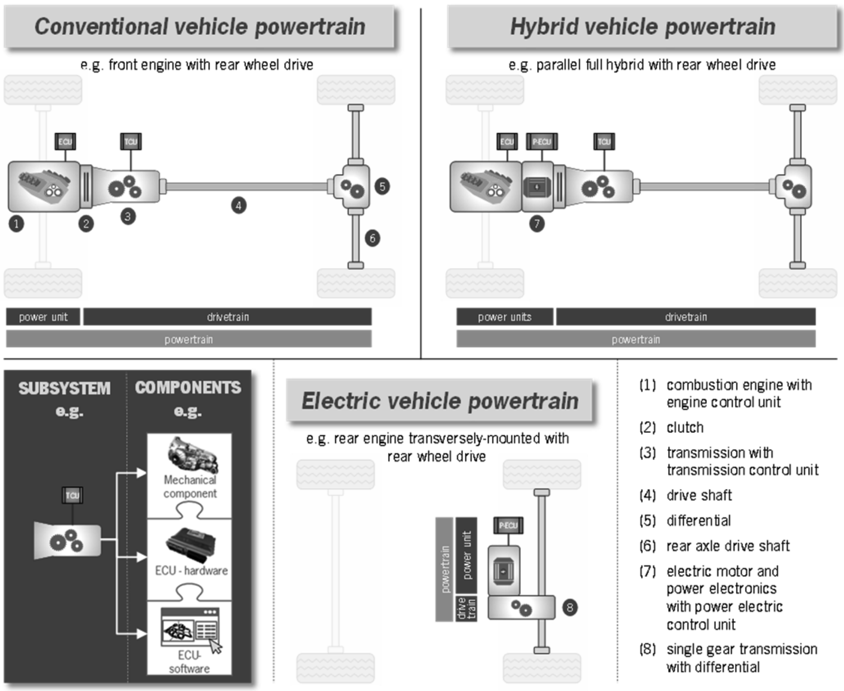


Fig. 1: Illustration of the nomenclature

# Augmented Reality Head-up display

## System requirements and solutions concerning precise augmen-tation of information within the road scene

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**Abstract**

Augmented Reality (AR) is the next evolutionary step for head-up displays (HUD) in passenger vehicles. Especially, for the transition phase between manual and automated driving mode an augmented-reality head-up display can be used to establish trust between passengers and the automated driving system.

The requirements for the optical and projector components to create the visual impression of augmented reality are very different compared to classical head-up displays. Detailed models of the vehicle environment and the movement of the vehicle are obtained by intelligent sensor fusion algorithms. Very important is the precision of the overlay of visual context into the road scene. Together with beneficial graphic design concepts deviations of the augmented reality objects from the real world background are minimized. An important factor for a precise visualization is the compensation of latencies. Those are created from the vehicle sensors signal transmission and the duration of the augmented scene creation. In order to eliminate high frequent image oscillations caused by road disturbances these latencies are compensated by prediction algorithms implemented in a so-called augmented reality creator.

### 1. Contact Analogous Augmented Reality Head-up display

Head-up displays are more and more becoming standard equipment in modern passenger vehicles. They are used to project essential driver assistance and vehicle related information (e.g. velocity, speed limit, guidance, adaptive cruise control) directly into the driver's field of view. In conventional HUDs this projected information, so-called virtual image, can be seen typically two meters in front of the driver, just above the engine hood.

Such projections are proven to be less distractive to the driver than traditional displays [1], [9]. Especially for elderly drivers the larger projection distance of such devices reduces the accommodation effort of the eyes significantly.

A future trend for HUDs is contact analogous augmentation (cHUD), i.e. information is placed in time and space such that it is associated with background objects (road scene) in the driver’s field of view. Scientific research shows that many driver assistance functionalities will benefit from augmentation of information [4]. Guiding a vehicle is a mainly visual-based task, therefore assistance information should be placed in the primary field of view (FOV).

Bergmeier [3] published research on night vision systems to warn the driver under poor environmental conditions in case of obstacles (e.g. passengers, animals). He concluded that the utilization of any secondary display would lead the driver to focus on that display instead of looking out of the wind screen. Only an augmentation of the obstacle in the primary field of view by a cHUD would give the intended increase of driver awareness of where the obstacle is located and how it moves.

For guidance a direction change information is traditionally indicated by an abstract symbol, usually an arrow. Research by Israel [5] indicates especially in complex environments (e.g. multiple lanes at in-town complex intersections) the driver's perception may be improved best by augmentation. He suggests that the actual turn sequence should only be shown 2 – 3 seconds before the maneuver execution, while in the time before a maneuver pre-indication seems to be appropriate.

Many drivers find it difficult to navigate in narrow space like construction sites. Israel [5] showed that the augmentation of lane keeping significantly increases the accuracy of the lateral guidance by indicating the vehicles position in the next 1.2 -- 2 seconds based on the current steering angle.

With upcoming technology of automated driving the cHUD technology will be used to visualize the environmental perception of the vehicle (e.g. indicating the intended driving path, recognized third party traffic participants including potential criticality). Especially in situations where a takeover by the human driver is required, this technology will support to focus the driver's awareness to the essential information (such as traffic situation), which enables him to take back the control.

### 1.1 Human Perception sets Requirements for Augmentation

To generate the impression of contact analogous objects, the human perception of depth is essential. It is based on different mechanisms:

- Superposition: Obviously, the virtual content needs to be aligned with the background. In the dynamic environment of a driving vehicle the motion parallax affects the depth perception. Running at some speed, nearby objects appear to glide rapidly past us, while more distant objects appear to move more slowly. Likewise moving sideways, the occlusion of objects changes. Therefore, humans conclude different depth for objects that appear with different relative speed [6]. Due to this fact the per-

# Cognitive driver take-over capability after piloted driving – method development and interaction with a side task

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Technical University Braunschweig, Braunschweig

**Abstract**

Within the context of highly automated driving, where the automated system takes over the dynamic driving task and supervision activity from the driver is no longer required, new challenges must be considered, like an increasing likelihood for the driver being out of the loop. This might result in a higher engagement in non-driving related (NDR) tasks or a higher relaxation correlated with a reduced level of arousal. The cognitive absence and the possible effects on the take-over ability of the driver are rarely studied so far in the case of the take-over situation, but it seems to be an important factor for the take-over times.

Based on these assumptions a two-step procedure was conducted to identify an additional measurement for assessing the cognitive aspect of the take-over ability of the driver beside the already known objective variables for the visual perception or the behavioral reaction of the driver. These processes of situation processing and decision-making are more implicit and therefore more difficult to measure but have to be integrated in an overall model of the take-over ability.

The first step consisted of the development of a methodology, for which four pilot studies were conducted at the Wuerzburg Institute for Traffic Sciences (WIVW GmbH) in collaboration with Volkswagen Group Research. The drivers performed different highway trips with a highly automated system in the same route. During the highly automated drive the scene projection was switched off (occlusion of the visual scene) to promote the feeling of being completely out of the loop. While take-over requests the projection turned on again and the driver had to change lanes either to the right or to the left depending on the surrounding traffic. Results showed that in a controlled environment besides the typical reaction time measures a speech output as verbalization of the decision process for the direction of the lane change before the actual performance of a motoric reaction proved to be a good indicator for the cognitive take-over ability of a driver and for the definition when he/she is back in

the loop. In a second step, the method was used for an additional study (N=64) in the static driving simulator at Volkswagen Group Research. Besides situation complexity, different parameters w.r. t. NDR tasks (performance, position and interruptibility of the secondary task) were varied. The results showed that the situation complexity as well as the performance and position of the NDR task had an influence on the cognitive take-over ability. The interruption of the secondary task in the take-over situation by the system did not have any influence in this study.

The studies help to understand the underlying psychological constructs of decision making in the take-over process.

## 1. Introduction

### *1.1 Effects of an increasing automation on the cognitive attention state of the driver*

Increasing automation level, like a highly automated system, which takes over all aspects of the dynamic driving task [1], allows the driver temporary to be a passenger and offers new degrees of driver's freedom. A permanent supervision is not necessary and the driver will be explicitly allowed to focus on non-driving related (NDR) tasks [2, 3] or to relax. The driver has only to be aware of possible mode transitions in which he/she has to respond correctly to a take-over request within a time frame of a few seconds. So the driver might lose situation and mode awareness and might be cognitively "out of the loop" [4]. Banks & Stanton [5] identified a more detailed model of the engagement of the driver. This results from the combination of the dimensions "active/passive" and "in the loop/out of the loop" (see figure 1).

| | **In the loop** | **Out of the loop** |
|---|---|---|
| **active** | **Driver in full control of the vehicle and actively engaged in the driving task** | **Driver in full control of the vehicle but showing characteristics of "being out of the loop", e.g. driving without attention** |
| **passive** | **Driver no longer in control of the vehicle but remains vigilant to the driving task** | Driver no longer in control of the vehicle and becomes desensitized to the driving task |

Fig. 1: State classification of the driver in "active/passive" and "in/out of the loop" (based on [5])

For this work, the concept „out of the loop" is defined as a state where the driver is no longer in control of the vehicle (technical definition of out of the loop) and simultaneously in a passive state, meaning having a low attention and arousal level (see figure 1, grey mark). What can be assumed is, that the stronger the out of the loop phenomenon before the take-over request is and the more demanding the take-over situation, the longer it takes until the driver

# User-centric HMI considering behavioral aspect of driver

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## Abstract

Keywords – HMI, User-Centric, User-experience, moods and emotions, voice, usability.

With the growth in number and complexity of the systems in the vehicle cockpit, came the need for the driver to interact with much more complicated HMI. Driver's response to a situation is impacted by a variety of factors, such as the surrounding environment state (e.g., weather, road conditions, and traffic) and the driver's physical state (e.g., his age, character, fatigue level, and his driving habits). Most of the HMI development processes consider only the visual appeal and user input mechanisms, but not psychological and physiological needs of the user. The above factors necessitate the adaptation of the HMI design and development process to take into account, the human factors also, which make the vehicle system interaction and driving experience an easy and pleasant one. This can be made possible, if users are involved not only in the usability tests and concept assessment, but also in the other aspects of the HMI development process.

This paper provides methodologies on how the HMI can be made more effective and more user-centric, so that it minimizes the impact of such factors. These methods include user involvement right from the development of Design Strategies, Information Architecture, Scenarios, and Task Analysis. The objective of this paper is to evolve methods to develop an HMI, with characteristics such as Effectiveness, Ease of learning, Efficiency of use, Memorability, Error Prevention and Satisfaction, collectively called as Usability, through involvement of the users.

With these user centric methods, OEMs will be able to provide better HMI, which understands the moods and emotions of the driver, so that Driver can interact with the vehicle as a buddy and not as an object.

## 1. Introduction:

With the tremendous growth in automotive technologies, HMI is getting complicated day by day. Driver commands HMI through various mediums like touches, voices, gestures etc. But do HMI understands drivers or the situational factors like surrounding environment state (e.g., weather, road conditions, and traffic) and the driver's physical state (e.g., his age, character, fatigue level, and his driving habits)? Maybe answer is No or Yes in very fewer scenarios. With current maturity level of HMI technologies, now the time has arrived, when HMI need to understand drivers, their psychological and physiological behaviours and adapt itself to serve for best user experience. So that HMI can be a face of your vehicle and Vehicle be your buddy and not an object.

Development of personalized HMI is one of the significant challenge for HMI at the moment. The paper highlights a way to achieve a solution, with the combination of User centered Design principles, Artificial intelligence and personalization.

## 2. User centered Design principles:

"Human-centered design" is characterized by, the active involvement of users and a clear understanding of user and task requirements, an appropriate allocation of function between users and technology, the iteration of design solutions, multidisciplinary design [ISO 13407] [1]

User-Centered Analysis: The goal of user centered analysis is to collect and analyse data, to make, informed interface design decisions based on:

- Who the users are
- How they think
- The stakeholder goals and objectives.

The user-centered analysis need to collect data on:

- User profiles
- Work environment
- Scenarios of how users will use the interface
- Task analysis.

## 3. Need of user centered design and analysis in automotive infotainment HMI:

Driving is one of the most complex activities which human performs, so usability is the most critical part while designing HMI for automotive infotainment system. Every user has its own mental model, so same UI design and information architecture is not suitable for all. To get an efficient user feedback, UI design must be compliant with user's mental model. HMI interfaces