Research and Innovation for Automated Driving in Germany and Europe

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Abstract German and European vehicle manufacturers and automotive suppliers have been at the forefront of developing and commercializing advanced driver assistance systems in the past. They are thus well prepared to proceed towards increasing levels of road vehicle automation, and engage in a multitude of technology development and demonstration actions around the world, now. Nonetheless, serious steps in reliability, security and affordability of the key enabling technologies still need to be taken and solutions for the liability issues and legal requirements have to be found before a broad rollout of automated driving in Europe. Starting from the motivations of automated driving this chapter reviews recent achievements in driver assistance systems and highlights promising paths of future development of automated driving, pointing out the research and innovation needs in key enabling technologies and also considering solutions for non-technical issues. Furthermore, potential synergies between the automation and the electrification of the vehicle are analyzed.

Keywords Advanced diver assistance systems • Vehicle communication • Europe • Germany • Vienna convention • Electrification

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G. Meyer and S. Beiker (eds.), *Road Vehicle Automation*, Lecture Notes in Mobility,
DOI: 10.1007/978-3-319-05990-7_7,

1 Introduction

With striking demonstrations and successful field tests, vehicle manufacturers in Germany and Europe recently drew public attention to their research and innovation activities in highly automated and autonomous driving. In summer 2013 Daimler mastered the 100 km-long route from Mannheim to Pforzheim with a Mercedes-Benz S 500 prototype car equipped with production-based technologies for autonomous driving. It was the same route where Bertha Benz had set out on the first long-distance automobile journey 125 years ago [1]. Researchers at BMW are currently testing applications for autonomous driving in a prototype BMW 5 vehicle on highways between Munich and Nuremberg, giving a spectacular presentation of their achievements at the CES 2014 in Las Vegas in early 2014. The vehicle comprises radars, laser scanners, cameras and ultrasound sensors which are all unobtrusively incorporated in the car's body [2]. Already in 2012, a convoy of various Volvo vehicles including a truck was tried out in mixed traffic on a motorway outside Barcelona, Spain as part of a European Commission-funded research project on the feasibility of platooning [3]. Renault recently demonstrated its autonomous valet parking technology with a Fluence electric vehicle at the premises of their research center near Paris. It runs in auto-pilot mode without passengers from a dedicated drop-off area to a parking lot or wireless charging station and vice versa, and uses mainstream automotive sensor components [4]. At the same time, Valeo presented several solutions for the automation at slow speeds, like e.g. autonomous parking [5]. More and more car models of German and European manufacturers are now equipped with off-the-shelf driver assistance systems that, according to automotive supplier Bosch, will soon allow partially automated driving, e.g. adaptive cruise control and lane keeping assist [6]. Continental predicts that highly automated driving may be ready for the market by 2020, and fully automated driving by 2025 [7]. Despite these successes and announcements, it is questionable whether the regulatory frameworks allowing the driver to hand over the control of the car will be in place on time, and whether liability issues will be solved.

2 Motivations for Automated Driving

Road vehicle automation is expected to provide solutions for major societal, environmental and economic challenges, e.g.

- Emissions reduction through optimization of traffic flow management and reduction of fuel consumption
- Adaption to demographic change by supporting unconfident drivers and enhancing the mobility of the elderly
- Road safety enhancement by avoidance of human driving errors
- Congestion avoidance by traffic flow management and time efficient driving via automation

- Economic competitiveness based on unique selling propositions and technology leadership
- Exploitation of mature technologies by using approved and cost-effective sensors and series production actuators.

These solutions match the strategic objectives of major innovation and technology policies at German national and European levels. According to the High-Tech Strategy of the German Federal Government new forms of mobility are needed in order to transfer people and goods at high levels of speed, safety and comfort as well as efficiency and at low resource consumption in the future [8]. And, one of the major actions mentioned in the Transportation White Paper of the European Commission is a "vision zero" on road fatalities which shall be based on e.g. driver assistance systems, cooperative traffic systems and vehicle to vehicle communication as well as vehicle to infrastructure interfaces. However the topic of road vehicle automation is not explicitly mentioned in these high level strategies [9].

3 Achievements in Driver Assistance Systems

German national und European public research funding in microelectronics, embedded systems and smart systems integration have triggered innovation in sensor, actuator, control and communication technologies which lead to major achievements in driver assistance systems, recently [10]. European automotive suppliers firstly launched many of these levels 0 and 1 (according to SAE and VDA) road vehicle automation systems for lateral and longitudinal control on the market, or improved them significantly. Furthermore, systems for partial automation (level 2) are subject of current research and demonstration activities.

3.1 Research and Development Projects

In recent years, the European Commission has funded a couple projects for the development and demonstration of road vehicle automation and its base technologies:

The project "Highly Automated Vehicles for Intelligent Transport" (HAVEit, 2008–2011) showed that a higher level of automation is feasible on existing public roads in mixed traffic. As part of the project, three automation modes were developed and implemented in form of (a) an assisted mode by already-available standard driver assistance systems, such as lane keeping assistance or an emergency braking assistance (b) a partly or semi-automated mode where the vehicle drives with longitudinal automation (c) a high automation mode where lateral automation comes into play, meaning the driver no longer has to steer. Despite the level of automation selected, the driver was always fully responsible for maneuvering the vehicle, could take control in place of the system at any time, and had to monitor the vehicle's driving maneuvers. In the partly and highly automated modes, the system observes the driver with the help of a camera located inside the vehicle [11].

The project "Accident Avoidance by Active Intervention for Intelligent Vehicles" (Interactive, 2010–2013) aimed at taking the next step towards the goal of accident-free traffic and developed advanced driver assistance systems for safer and more efficient driving, e.g. driver warnings in dangerous situations, collision avoidance systems, and emergency intervention in the pre-crash phase [12].

The project "Automated Driving Applications and Technologies for Intelligent Vehicles" (AdaptIVe, since 2014) is a consortium of 29 European partners comprising OEMs, automotive suppliers, research institutes and SMEs who aim to make automated driving safer and more efficient [13].

Recently, the project "Interoperable GCDC (Grand Cooperative Driving Challenge) AutoMation Experience" (i-GAME, 2013–2016) started which shall speed up the real-time implementation and interoperability of wireless communication-based automated driving [14].

Moreover, a multitude of EU-funded projects dealt with the communication between vehicles and the road infrastructures, e.g. SAFESPOT, COOPERS, CVIS (Pre)DRIVE C2X, INTERSAFE (for cooperative intersections) and NEARCTIS (for traffic management). The project PReVENT contributed to road safety by developing and demonstrating preventive safety technologies. Advanced driver assistance systems were also subject of the EU-projects STARDUST, and isi-PADAS.

Also the German Federal Government funded a multitude of collaborative research and innovation projects in the field of road vehicle automation during the last 5–10 years.

One of the most prominent activities in Germany are the AutoNOMOS projects (since 2008) that are dealing with autonomous decision making, route planning based on digital maps, user interfaces including smartphone apps and neural signal detection. Two demonstrators have been presented and a multitude of test drives were conducted in city traffic [15].

The project "Forschungsinitiative Ko-FAS—Kooperative Sensorik und kooperative Perzeption für die Präventive Sicherheit im Straßenverkehr" (KO-FAS, 2009–2013) developed and demonstrated driver assistance systems based on cooperative technologies like vehicle-to-vehicle communication, as well as sensor data evaluation, data fusion and active safety systems [16].

Currently, the project UR:BAN is studying the opportunities of using driver assistance systems and car-to-x communication in the complex environments of city traffic such as intersections and narrowing roads, and in lane change maneuvers [17].

Previously, also the projects ACTIV and INVENT were focused on the development of driver assistance systems relevant for automated driving, and recent publicly funded projects on electric vehicles included aspects of automated driving as well, e.g. EFA 2014 II and VisioM.

3.2 Demonstration Activities

The European Union funded research and demonstration project CityMobil (2006–2011) addressed the integration of automated transport systems in the urban environment [18]. It dealt with guided buses in Castelleon, Spain, Cybernetic Transport Systems in the demonstration of Personal Rapid Transit (PRT) at the Heathrow airport of London, U.K., and Group Rapid Transit (GRT) at the exhibition centre of Rome, Italy. Its forerunner NETMOBIL (2003–2005) was a cluster of projects for innovative urban transport systems.

EuroFOT (2008–2012) was a series of Field Operational Tests with the aim of assessing the main Advanced Driver Assistance Systems (ADAS) that have recently appeared on the European market [19].

The project Safe Road Trains for the Environment (SARTRE, 2009–2012) developed and showcased strategies and technologies to allow vehicle platoons to operate on normal public highways where the following vehicles (cars and trucks) operate in dual-mode (fully autonomous within the platoon) with significant environmental and comfort benefits [20]. Its forerunner, Chauffeur, developed new electronic systems for coupling trucks at close following distances.

In Germany, a major demonstration activity for automated driving is the Stadtpilot project where two autonomous cars have been tested in regular traffic in the city of Braunschweig [21].

3.3 Product Developments

Driver assistance systems have greatly advanced in recent years: their two most relevant functionalities for highly automated driving, adaptive cruise control and lane departure warning, are commonplace in high-end automobiles today.

In an adaptive cruise control (ACC) system, the driver selects the desired speed and sets the distance to be maintained to the vehicle ahead. This gap can be set at several distances, adapting to the driving situation and individual driving style. Standard ACC can be activated from speeds of around 30 km/h (20 mph) upwards and can support the driver, primarily on interurban journeys and on highways or motorways.

An ACC Stop and Go system maintains a set distance to the receding vehicle even at very low speeds and can decelerate to a complete standstill. When the vehicle in front accelerates within a few seconds, the ACC vehicle follows automatically. Such system can support the driver in congested traffic at speeds below 30 km/h.

ACC and ACC for Stop-and-Go are provided e.g. by Bosch and Continental. BMW, e.g., is offering a ACC for stop and go situations for its series 5 and up vehicles.

Most German OEMs as well as Continental and Bosch develop Lane Departure Warning (LDW) systems which warn the driver in case the car moves to close to the edge of the lane. Lane keeping assist systems (LKA) actively steering the vehicle to keep it in the lane are offered by Daimler, Volkswagen, Audi and Bosch [22].

3.4 Communication Standards

Automated cars heavily rely on the data connection to other cars and to the infrastructure which cannot be developed without common technical requirements regarding, for example, frequencies used or data management. The European Commission's Action plan for the deployment of ITS in Europe thus aimed at the development of harmonised standards for ITS implementation, in particular regarding cooperative systems. Following a mandate by the European Commission, ETSI and CEN/ISO finalised a first standardisation package which was announced recently [23].

4 Future Development Paths

From a technological point of view, automated vehicles represent the evolution of today's driver assistance systems. It starts with the systematic combination of lateral and longitudinal control, and is further supported by C2X communication and environment perception. A networking with driver information and drive systems is gradually advancing the concept toward its goal. From 2016, partially automated systems may therefore be assisting drivers by combining lateral and longitudinal control in "stop and go" situations on the freeway at low speeds of up to 30 km/h. But this initial step toward automated driving does not relieve drivers of their responsibility to constantly pay attention to what is happening on the road. As well as covering higher speeds above 30 km/h on the freeway, highly automated driving will allow drivers to use the time they would spend driving on other activities. With both levels of automated driving, however, the driver must be able to regain control of the vehicle at all times. Fully automated road vehicles that require neither supervision nor takeover of control by a driver will be the most advanced system. It would have a significant impact on our mobility behavior, road safety and traffic efficiency in interurban (motorway/freeway) and urban applications as it could lead to radically new solutions such as robot taxis.

According to the ITS roadmaps of the European Association of Automotive Suppliers (CLEPA), highly automated driving will be launched into the market around 2020–2025 [24].

The German Association of the Automotive Industry (VDA) expects that partly automated driving (level 2) functions like parking assistant, lane changing assistant and construction site assistant will be available at the short term, whereas functions of conditional automation (level 3), e.g. overtaking chauffeur, traffic jam chauffeur and motorway chauffeur may be on the market on the mid term, and functions of high automation (level 4) will be either mid term (e.g. valet parking, emergency stop) or long term (motorway pilot) [25].

5 Key Enabling Technologies

According to a recent position paper by the eNOVA Strategy Board Electric Mobility and the ITS Roadmap of CLEPA, research and development on key enabling technologies is needed in the following domains.

5.1 Vehicle and Driver Systems Level

The driver engagement and driver re-engagement for various levels of automation in a safe and conclusive manner is important to ensure a safe system as well as user acceptance. In particular, transitions between human and automated vehicle control need to be managed. Therefore, human factors have to be considered as decisive design criteria. HMI (visual, haptic and acoustic) thus must take into account the role of the driver in highly automated vehicles and enable a safe interaction and usage. At the same time, the status of the driver has to be continuously controlled to make sure that he is able to take over control when needed. Furthermore, the user acceptance for partially and highly automated vehicle depends on human factors and the intuitive usability.

Based on environment perception through detection and modeling, driving strategies need to be calculated being fully aware of the dynamic behavior and the intentions of all traffic participants, particularly in complex situations like e.g. crossings and roundabouts. This also requires a use-case oriented fusion of sensor data. Simultaneously, the vehicle needs to be aware of its exact position at all times. Therefore, a passive and active real-time updating of map data is necessary, and needs to be complemented by the detection of physical markings in the road.

Generally, fallback options enabling a safe state in the case of failure or limited performance of the system need to be implemented in order to make drivers and users confident with automated driving and therefore accept it. Thus, a basic technical prerequisite for the implementation of automated driving is system reliability. This calls for fail-safe architecture at board net level that keeps the vehicle in a safe state in the event of a fault.

5.2 Components Development and Integration

In order to enable automated driving functions, the vehicle needs to be able to perceive the environment with very high precision and reliability. Environment sensors and cameras need to be further improved regarding energy efficiency, speed and affordability. Special focus is on false positive detection of sensors. Different sensor types need to be integrated and sensor fusion plays an important role as a main enabler for automation.

As vehicle automation is also based on robotic functionality, actuators are of increasing importance and need to be further optimized regarding their precision and cost.

Furthermore, automated driving requires additional information from other road users and from the infrastructure. Based on this information the vehicle/system can adapt the driving strategy and conclude on the best driving path according to the received information (e.g. upcoming congestion, traffic accident). Enabling this functionality requires the integration of validated communication devices into the vehicles. The security issues for this communication are of major interest for automated driving as unsecure communication may open the system for abuse, criminal or terroristic attacks. Date encryption will thus be needed.

5.3 Methods and Tools

In view of the legal and liability-related challenges to implement automated driving at a broader scale, reliability of all components in terms of functional safety, redundancy and fail-safe performance is required. In order to ensure these requirements, test and certification methodologies need to be adapted for these additional functions. The interaction between all involved automated components as well as the functions needs to be evaluated with focus on automation. In parallel to the use cases, automated driving functions need to be evaluated regarding miss usage/false usage by the driver, e.g. falling asleep or not taking back control functions after a take-over request.

Software methods that need to be further developed include methods for the highly dynamic modeling and simulation of the vehicle environment like e.g. electronic horizon, methods for sensor data fusion and for the communication and processing of big amounts of traffic and operation data, as well as for their fusion with sensor data. Furthermore, dynamic online maps, methods for prediction and decision finding will increasingly play a role as enabling technologies.

Also, criteria for the selection and proper combination of sensors are needed and design standards for software and hardware architectures have to be established.

6 Solutions for Non-technical Issues

The legal implications of automated driving have been analyzed in much detail recently. According to a study by the Federal Highway Research Institute (BASt) the use of high or full automation of road vehicles presently is not compatible with

German law, as the human driver would violate his obligations stipulated in the Road Traffic Code when fully relying on the degree of automation these systems would offer [26].

The underlying regulatory hurdle is the Vienna Convention of 1968, which is implemented in national road traffic regulations everywhere in Europe and in many other countries of the world—however not in the United States. It clearly states in its Article 8 that “Every moving vehicle or combination of vehicles shall have a driver”, and “Every driver shall at all times be able to control his vehicle or to guide his animals” [27]. Assisted and partially automated driving (up to level 2) complies with this convention; conditional or highly automated driving (level 3 and higher), where the driver is not monitoring the system permanently, do not. The only exception is an automatic emergency stop system that steps in if the driver is not able to take control.

According to many stakeholders of the European automotive industry, the Vienna Convention of 1968 should be amended and clarified in the sense that the use of driver assistance systems including highly and fully automated systems does not contradict it, and the national road traffic regulations should be adapted. Furthermore, amendments of the vehicle regulations (e.g. of the UNECE) would be needed.

A comprehensive European study makes further suggestions for solving the non-technical challenges of automated driving [28]: In order to deploy the automated driving applications cost-effectively and at the right time, a short- to long-term plan for gradual introduction in certain categories should be established and supported by mandatory measures. According to that study, serious solutions at the legislative level would make it possible to break the chicken-and-egg problem of infrastructure creation and vehicle technology deployment. Beyond legislative measures, an appropriate standardization program would help the industry, the regulators, and the road infrastructure owners to take the right decisions in due time and avoid thereby undesired costs introduced by uncertainties in their business models. The technical in-vehicle environment that remains safe for the entire exploitation phase should be defined across company limits in order to avoid issues due to differences in innovation cycles in electronics compared to automotive industry.

7 Synergies of Automation and Electrification

According to a recent position paper by the eNOVA Strategy Board on Electric Mobility, automation can significantly benefit the energy efficiency, and thus increase the range of electric and plug-in hybrid vehicles [29]. Through sensors and IT-services, highly automated vehicles are able to collect data about their environment and autonomously choose routes and driving styles that minimize the energy and fuel consumption as well as ensure the best use of the battery capacity; resulting in an increased and better predictable range. These advantages are well applicable for conventional vehicles, yet for the electric vehicle even more so as they increase acceptance by counteracting the biggest shortcoming of its technology—the limited range.

At the system level, automation in combination with cooperative driving ensures that traffic flows are optimized in congestion areas both in the city, the primary area of electric vehicle usage, and on the highway where it can greatly increase the usefulness of electric vehicles for longer distances. Synergies can also be found even in slow traffic: highly automated electric vehicles can reduce time searching for a parking space and, in combination with inductive charging, simultaneously find the proper position on the charging-coil as well as charge automatically. An electric delivery van that slowly follows the driver when he walks from door to door was recently presented by Volkswagen [30]. Self-organizing fleets of electric vehicles could also coordinate their local availability and charging level with one another, thus increasing the reliability and efficiency in using car sharing services. Driverless electrified taxis, which represent the highest level of automation, play an important role as a long term vision.

From a technical perspective, the electric drive and the accompanying redesign of the electrical and electronic architecture enables the intelligent integration of electronic controls, communication modules and sensors that are the basis for the automation of vehicles. Higher levels of automation facilitate the synchronization of drive components and can thus, for example, improve the driving dynamics. Optimized decision-making processes and redundancies guarantee a safe and reliable operation of the vehicle, even if the automobile malfunctions. The cross-linking with the environment and the usage of maps and navigation data, which partly already can be found in electric mobility, can be further developed to implement automation. Simultaneously, the liberty with regard to the interior design that electric vehicles offer can be consequently used due to higher degrees of automation.

8 Outlook

Automated functionalities are on the agenda of German national and European Union's research and innovation funding programmes, e.g. in the context of the new Horizon 2020 framework and the Joint Technology Initiative on Electronics (JTI ECSEL) therein. It can thus be expected that European vehicle manufacturers and automotive suppliers will further strengthen their competitive advantages in developing and implementing the key technologies of automated driving in the next few years. The modification and renewed international harmonization of the regulatory frameworks as well as the establishment of solutions for reliability issues that would allow the deployment of highly automated driving in Europe will be a massive effort though, and require the involvement of many relevant stakeholders beyond vehicle manufacturers and car owners, e.g. insurance companies, and road authorities.

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