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Automated Driving

Safer and More Efficient Future Driving

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require accurate digital representations of their environment at any time, for any weather condition, and in any traffic situation.

Beyond the technical issues, several action items for faster introduction of automated vehicles have to be solved by the governments in order to ensure the full compatibility with the public expectations regarding legal responsibility, safety, and privacy. Authorities have to create the legal framework to remove liability traps, to encourage test regions, to review long-term infrastructure investments, to provide open access, and to set up legal frameworks for inter-car communication.

The challenging technical topics still to be solved and the constant endeavours around the world to drive this exciting technology forward have motivated the creation of this book. In order to get a balanced view on the state of development, the editors have invited authors from different stakeholders including public authorities, car manufacturers, suppliers, and research organizations. Within this book, the state of practice and the state of the art of automated driving building blocks are extensively reviewed and future trends are envisioned. The book encompasses the importance of control engineering, recent advances in environment sensing and perception, in-vehicle architectures, and dependable power computing as well as active and functional safety in automated driving. Furthermore, we have put a strong focus on the validation and testing of automated driving functions. A sampling of relevant industrially driven research projects and industrial initiatives concludes the book.

We strongly believe that this book on automated driving provides an overview of current and emerging technical challenges in that field and gives deep insights into industrial demands. We hope that the reader will be inspired by the different technical articles, selected project summaries, and introductions of renowned national and European initiatives.

Finally, we would like to express our sincere appreciation and gratitude to all authors and co-authors, who made the publication of this book possible. We are grateful to Silvia Schilgerius at Springer for her professionalism and support.

Graz, Austria

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Chapter 3
Automated Driving from the View of Technical Standards

Stephanie Grubmüller, Jiri Plihal, and Pavel Nedoma

3.1 Introduction

Nowadays, assisted driving systems such as Adaptive Cruise Control (ACC) are state-of-the-art. If activated by the driver, these systems support the driver in specific driving situations and control either the longitudinal or lateral vehicle movement. In case of an unstable behavior of the system, a high availability of the driver is needed to take over control. Automated driving systems allow the driver to be absent from the active driving task for a certain duration of time. These systems control the vehicle's longitudinal and lateral movement simultaneously. The degree of automation of a driving function ranges from partial automation and permanent supervising by the driver to full automation and no supervising activity by the driver [1].

The first partially automated functions are expected to be introduced into day-to-day traffic by 2016 [2]. These functions require data from outside the vehicle, which leads to the term of connected driving. Improving traffic information for each traffic participant, for automated vehicles, real-time Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Infrastructure (V2I) communication are mandatory [3]. The further development of automated and connected driving raise new requirements to guarantee a safe system in respect to the reconsideration of the

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technical realization of a vehicle's subsystem as well as consideration of appropriate data sources and communication. This leads to the adoption or establishment of vehicle-related or communication-related technical standards. Infrastructure and vehicles equipped with high-quality data communication components combined with the positive cooperation between the automotive industry, researchers, and the government will result in competent backgrounds for the intended innovation, development, and use of self-driving cars.

This chapter gives an overview of different Standard Developing Organizations (SDOs) related to the automotive domain and automated driving. The levels of automation of different standards are introduced. Finally, the future steps of standardization and requirements on the vehicle systems and environment are summarized.

3.2 Standard Developing Organizations

SDOs are defined by [4] as: "SDOs include professional societies, industry, and trade associations and membership organizations who develop standards within their area of expertise. They may develop standards with their own members or in cooperation with other SDOs and interested parties." There are mainly the following SDOs related to automated driving systems:

- International Organization for Standardization[1] (ISO) consists of a network of national standards bodies which represents ISO in their countries. The central secretariat is located in Geneva, Switzerland. Regarding automated driving, two Technical Committees (TC) are of interest:
  - ISO/TC204 (WG1, WG 3, WG9, WG14, WG16, WG18)
  - ISO/TC22 (SC03, SC32, SC33, SC39)
- European Telecommunications Standard Institute[2] (ETSI) is recognized as a European Standards Organization by the European Union and produces globally-applicable Information and Communications Technologies (ICT)
- Society of Automotive Engineers (SAE) International[3] is an American United States (US)-based professional association and standards organization focused on various transport industries such as automotive, aerospace, and commercial vehicles.
- European Committee for Standardization[4] (CEN) brings together the national standardization bodies of 33 European countries.

[1]http://www.iso.org
[2]http://www.etsi.org
[3]http://www.sae.org
[4]https://www.cen.eu/

- Institute of Electrical and Electronics Engineers[5] (IEEE) is the world's largest technical professional association located in the USA.

The key international legislation relating to road safety is based on the two treaties: First, "The Vienna Convention on Road Traffic," and second "The Vienna Convention on Road Signs and Signals." Both were signed by 73 parties in Vienna in 1968.

3.3 Standard Developing Organizations

Depending on the standards, different scales of levels of automation of on-road vehicles exist. The automatic functions will be increased step-by-step and will need to be tested in practice.

In Fig. 3.1 all levels of automation according to the SAE J3016 [5] standard are given. The scale of the SAE level ranges from level 0, which indicates the full-time performance by the human driver, to level 5, which defines the full-time performance by an automated driving system. At lower levels, like levels 0–2, the driver is the main actor and is responsible for making decisions and monitoring

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Fig. 3.1 Levels of automation according to SAE J3016 [5], Copyright © 2014 SAE International

[5]https://www.ieee.org

Level	0	1	2	3	4	5
SAE	No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
NHTSA	No Automation	Function-specific Automation	Combined Function Automation	Limited Self-Driving Automation	Full Self-Driving Automation	
BASt	Driver only	Driver Assistance	Partial Automation	Highl Automation	Full Automation	

Fig. 3.2 Levels of automation defined by the different standards according to SAE J306 [5], BASt working group "Legal Consequences of an Increase of Vehicle Automation" [7], and NHTSA [8]

the system all the time while driving. At level 2 the driver is responsible for handing over control of the vehicle guidance in case of a fault. For higher levels of automation, such as levels 3–5, the system will monitor the driving environment and with increasing levels the number of functionalities and decision-making processes adopted by the system grows.

For levels 0–2 the driver's attention lies fully on the driving task. If a fault occurs, the human driver will have to react within a second. At level 3 the reaction time of the human driver increases up to several seconds. Finally, for automation levels 4 and 5 the vehicle reacts independently during the driving task and the reaction time of the human driver is extended to several minutes [6]. With respect to international standards of automated driving, J306 is the major standard.

Figure 3.2 shows the correspondence between the SAE levels and the levels of automation developed by the Germany Federal Highway Research Institute[6] (BASt) and those described by the US National Highway Traffic Safety Administration[7] (NHTSA) [5]. The NHTSA standard integrates the high and full automation of the SAE standard in one level, whereas the BASt standard defines five levels and the last level is equivalent to Level 4 of the SAE standard.

3.4 Standard Developing Organizations

The introduction of a set of driving functions and increasing automation level requires a set of specifications and requirements depending on whether the vehicle system and/or the communication between the vehicle and other vehicles or the infrastructure are affected. These specifications are not standardized at the moment. As a consequence, an adaption of all related technical standards is needed. Two

[6]http://www.bast.de

[7]http://www.nhtsa.gov/

categories of technical standards may be distinguished: (1) vehicle-related, (2) communication-related.

3.4.1 *Vehicle-Related Standards*

In [1], an expectation of the introduction of highly automated functions on Germany's market is given. The Traffic Jam Pilot is expected to be deployed to the market first, followed by the Highway Pilot. In traffic congestion driving situations, the Traffic Jam Pilot will provide automated vehicle guidance. The Highway Pilot will be the extension of the Traffic Jam Pilot for higher velocities. Both will be restricted to highway-like environments at first. The authors emphasize that a more complex environment, as in urban areas, demands higher requirements on perception, situation recognition, and decision making than automated driving in a well-defined environment, as, e.g., a freeway. Consequently, whether it is an urban or highway scenario, the adaption or expansion of the vehicle system's architecture by new requirements compromises the vehicle safety. In case an unforeseen event occurs or the system boundaries are reached, the system will be responsible for switching into a safe state and handling the situation. This scenario will raise additional software requirements.

Besides, in case of a hardware fault, the system must guarantee safe operation despite the reduction in functionality. Hence, new requirements on the hardware components of the vehicle system will also appear [9]. Different use cases have to be covered by the automated functionality; for example, special weather conditions such as snowfall, as mentioned in [10], can cause a limited sight of the sensors, which leads to a decision-making based on the surroundings as to how the system needs to behave.

The functional safety standard ISO 26262 [11], published in 2011, offers a general approach for the development of E/E systems. The aforementioned use cases regarding automated driving are not currently covered by the functional safety standard ISO26262. The next version of the standard will be published in 2018. At the moment, the inclusion of the automated driving topic in the standard is under discussion. Concerning the safety of automated functionalities in on-road vehicles, new standards for specification and architecture are needed as shown by the use cases in this section.

3.4.2 *Communication-Related Standards*

Over the years, a range of Intelligent Transport Systems (ITS) will support the driver and finally the system in performing the driving task. ITS covers Advanced Driver Assistant Systems (ADAS), in-vehicle information systems, and roadside

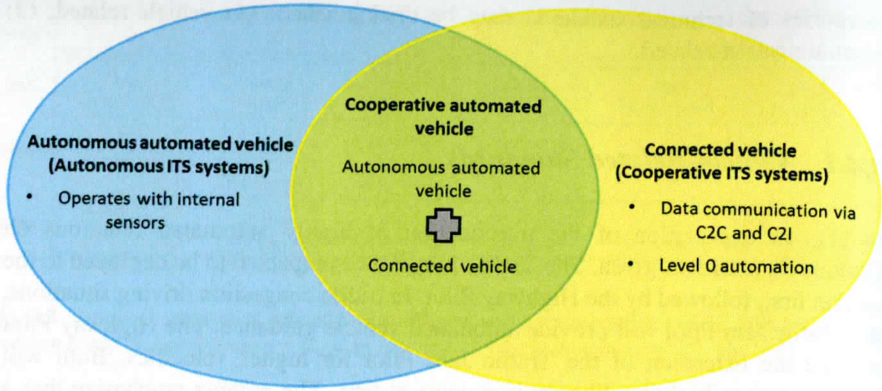

Fig. 3.3 Illustration of relation of connected, autonomous automated vehicles and cooperative automated vehicles according to [2]

telematics [12]. The basis for an ITS are three main technologies: (1) information, (2) communication, and (3) satellite technology.

Autonomous automated vehicles operate isolated from other vehicles and use only satellite data, internal sensors, and radars for guidance of the vehicle, as shown in Fig. 3.3. Without any wireless V2C or V2I, also called V2X, communication technology, the functionalities of the autonomous automated vehicle are limited. This kind of vehicle needs vehicle-based standards. On the other hand, connected vehicles provide such data communication but do not offer any automated functionality. In case a decision regarding the automated guidance of the vehicle is made on the vehicle's sensor data and data provided from outside, the system is called connected or cooperative automated vehicle.

In [3] is stated that V2V data communication improves the traffic information of each traffic participant considerably. As an example, preceding vehicles are able to inform following vehicles about traffic jams in real time. If an automated function is activated, the vehicle can adapt its velocity precisely. Furthermore, due to the V2I data exchange, the automated function is able to align the guidance of the vehicle based on data provided by surrounding information, such as velocity limitations or lighting signals. A cooperative system has the potential to increase the traffic efficiency, enhance the traffic safety, and decrease emissions.

Starting from the year 2014, Fig. 3.4 shows an expectation of the gradual development from connected to cooperative vehicles, from lower levels of automation, and finally to fully cooperative automated vehicles in urban areas by 2030. The ongoing deployment of ADAS, like automated parking or adaptive cruise control, will improve the degree of automation.

On highways, the behavior and diversity of the traffic participants as well as the road course provide good conditions for automated driving, as mentioned in Chap. 15. Since highway scenarios are easier to predict, full automation for that use case is predicted to be available sooner. The driving situation in urban areas is unpredictable

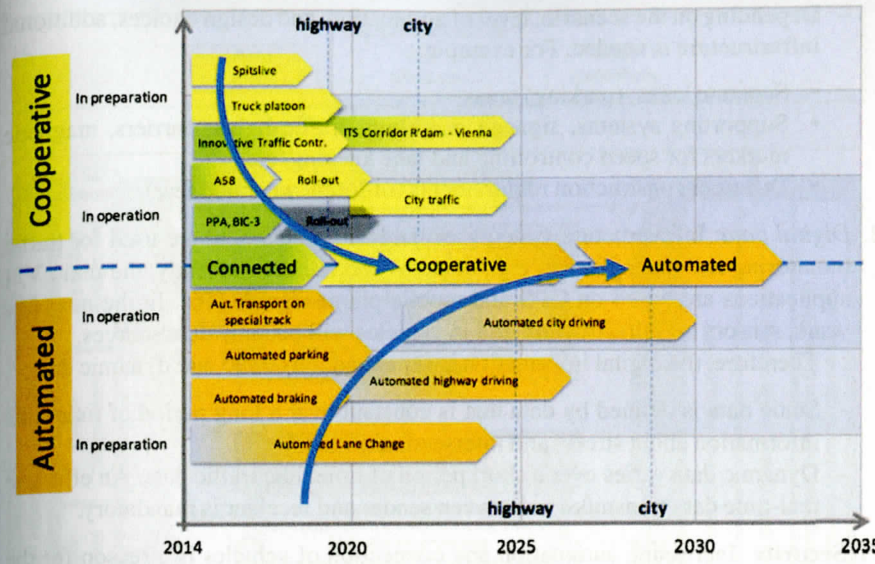

Fig. 3.4 Future development of automated and cooperative systems [2]

due to different traffic participants, intersections, etc. [13, 14]. Deploying automated driving in urban areas, the system will need to be extended, for example with an advanced perception system, traffic rules interpreter, and a decision system [15].

As a result, [3] defined fields of action to deploy cooperative automated driving in Germany. Three of them are important concerning standardization: infrastructure, IT security and data privacy, as well as legislation.

Infrastructure Cooperative driving requires high-speed data transmission. Therefore, sensors on, e.g., buildings which return traffic information need to be updated. Germany's government demands a comprehensive broadband basic supply of at least 50 Mbit/s by 2018. Furthermore, new standards for the digitalization of the federal road network need to be developed.

In [2], the author deals with deploying automated driving on roads in the Netherlands and the new demands on the infrastructure. He divides the requirements into two categories: (1) physical elements and (2) digital data.

1. *Physical elements* of the existing road infrastructure which have to be modified or extended:
   - Roads and road markings: Each type of road, e.g., highway and urban road, needs to be clearly defined and marked.
   - Signs and traffic management systems: All signs and traffic lights are required to be on-line due to the usage of determination of possible acceleration, deceleration, and maximum speed of the automated vehicle.

– Depending on the scenario, level of automation, and design choices, additional infrastructure is needed. For example:

- Separate lanes, (parking) areas
- Supporting systems, signage, markings, traffic lights, barriers, magnetic markers for speed controlling and lane keeping, etc.
- Different construction requirements (different wear and tear)

2. *Digital data*: Infrastructure systems available at the moment are used for traffic monitoring and management, e.g., cameras and radars. Currently, the main V2I applications are based on GPS and mobile phone signals [16]. In the next few years, sensors on infrastructure and in vehicles will become data sources.
   Therefore, the digital information is separated into static and dynamic data:

– Static data is defined by data that is constant over a long period of time, like information about streets and intersections.
– Dynamic data varies over a short period of time, like traffic data. An effective real-time data transmission between sender and receiver is mandatory.

IT Security Increasing automation and connection of vehicles is a reason for the increase in the amount of data. Unprotected access to this data may influence the vehicle safety in a bad way. As an example, fake messages produced during a cyber attack could cause severe damage, which is why data encoding is important. Automobile manufacturers and tier 1 suppliers must ensure secure data encryption and communication. Validation by external organizations and a certain certification of the systems have to be considered. Hence, initiatives for cyber security for cars already exist [17]:

- ETSI TS 102 941:2012—ITS; Security; Trust and Privacy Management
- SAE J3061: Cybersecurity Guidebook for Cyber-Physical Automotive Systems
- Information Technology-Promotion Agency (IPA), Japan: Approaches for Vehicle Information Security

These standards do not, however, consider automated driving. Further, how IT security could affect functional safety is not considered, either. It is necessary to extend the ISO 26262 as a result of the increase of digital data in automated and connected vehicles. Moreover, an improvement and concretization of IT security and encryption standards need to be coordinated permanently.

Privacy Regarding data processing, generation, and linking techniques for data, it will be required that anonymization be employed more and more. The policy of data privacy must always be followed.

Legislation Concerning international legislation, the Vienna Convention implies that only a human being is able to act as a driver. That article must be extended to treat the system driver as the equivalent of a human driver. Also, the increase in the maximum velocity for automated driving up to 130 km/h is mandatory. Additionally, in national legislation, traffic laws need to be adapted to enable automated driving.

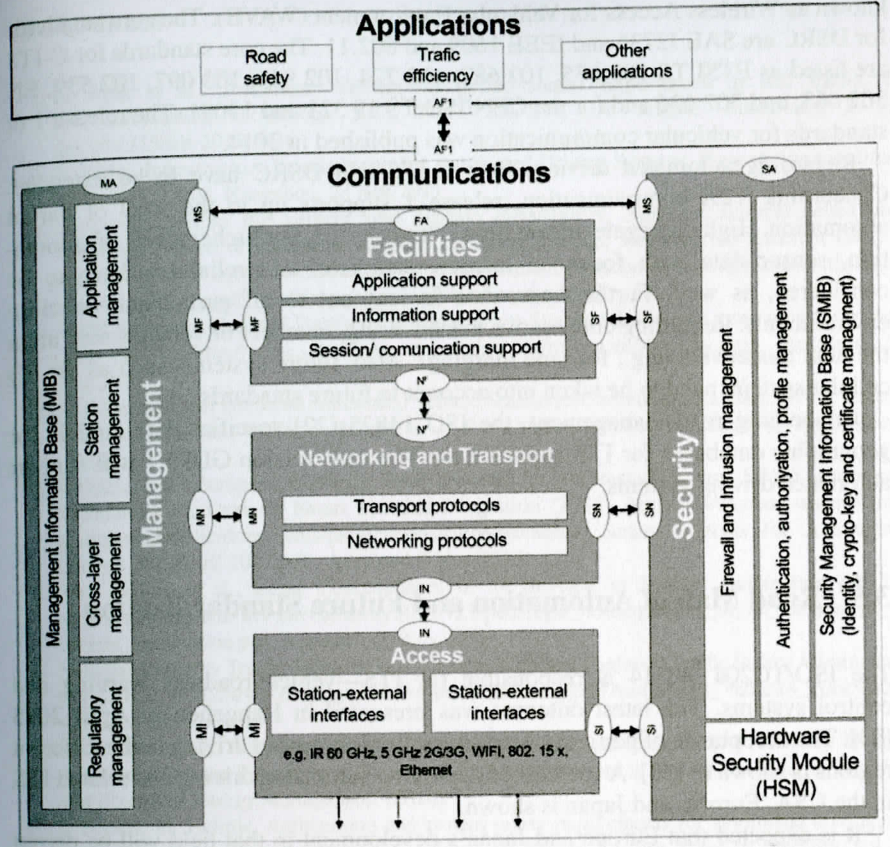

Fig. 3.5 ITS station reference architecture [18]

From the government point of view, the four fields of action give a rough overview of future work in respect to data transmission and legislation. From the technical point of view, communication systems need to be determined.

The ITS system focuses on the vehicular communication. A reference architecture of an ITS station is supported by ISO 21217:2014 [18] and shown Fig. 3.5.

The author in [19] compares different ITS standardization referring to the vehicular communication. Standards have been developed in parallel in the USA and Europe. They are commonly named C-ITS [20] in Europe and Dedicated Short Range Communication (DSRC) [21] in the USA, both relying on the WiFi standard IEEE 802.11. There are significant similarities between both, whereas an ITS communication in Japan operates at a different frequency (700 MHz). In the area of C-ITS, in Europe, ETSI and CEN with their TCs ITS and 278, in strong cooperation with ISO TC 204, are the major SDOs. In the USA, the main SDOs are IEEE and SAE with their working groups IEEE 802.11 Wireless LAN and SAE 1609 DSRC. DSRC combines IEEE 802.11 and 1609 standards, which is also known as Wireless Access for Vehicular Environment (WAVE). The core standards for DSRC are SAE J2736 and IEEE 1609 and 802.11. The core standards for C-ITS are listed as ETSI TS 103 175, 102 687, 102 724, 102 941, 103 097, 102 539, EN 302 663, and 302 636 and for the CEN/ISO TS 19 321 and 19091. The release 1 of standards for vehicular communication was published in 2014.

Regarding automated driving, both C-ITS and DSRC have to be extended. Concerning V2X communication, release 1 supports up to the level of partial automation. High aggregate information is transmitted. For higher levels of automation, sensor data with focus on latency, data rate, and reliability have to be considered, as well. Furthermore, data is sent out to all participants in close environments. Regarding cooperative maneuvering, numbers of vehicles may align the next maneuvers (e.g., for lane merging). Also, future systems, such as the 5G cellular system, need to be taken into account in future standards.

Concerning road management, the ISO 14825 [22] specifies data models for geographic databases for ITS applications. The next version GDF5.1 will support automated driving systems.

3.5 Road Map of Automation and Future Standardization

The ISO/TC204 WG14 is responsible for ITS—vehicle/roadway warning and control systems. The latest outcome was presented in Hangzhou in April 2015 [23]. The acceptance of particular steps regarding automated driving in the different regions is shown in [23]. A forecast of deploying automated driving and related ITS in the USA, Europe, and Japan is shown.

It is expected that Europe and Japan's development in that field will be driven more by automobile manufacturers and tier 1 suppliers than in the USA, where a regulatory process has been initiated [20].

Regarding the EU, serious deployment of V2I communication is demanded as a basis for the Highway Pilot. That system of automation level 3 is expected to be on the market by 2020 and fully automated driving functions, such as the Auto Pilot, by 2025. In contrast, the USA gives only a forecast of level 2 systems, which are expected by General Motors by the beginning of 2017. The whole V2X communication will be available in the middle of 2019, as also expected in Europe. Japan expects the deployment of level 3 automation on roads with intersections by the middle of 2019.

The ISO TC204/WG14 prepared an expectation of the introduction of automated driving functions and the related V2X communication on the international market. According to that plan, first level 3 functions will be deployed by 2017, the Highway Pilot by 2019. Therefore, these expectations are mandatory for future standardization of ISO/TC204 and other SDOs. It represents when standards are needed, namely before relevant systems are seriously deployed.

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Part II
The Importance of Control for Automated Driving