

# Module Handbook

B.Eng. AUTONOMOUS VEHICLE ENGINEERING

Faculty of  
Electrical Engineering and Information Technology

Study and examination regulation WS 24/25

As of 2026-03-01

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# 1 Summary

Name of programme	Autonomous Vehicle Engineering
Type of study & degree level	Bachelor of Engineering, full time
Date of first start	WS20/21; start once per year in winter
Standard period of study	7 Semester (210 ECTS)
Study place	TH Ingolstadt
Language of instruction	English
Admission requirements	higher education entrance qualification aptitude assessment
Capacity	40 Students

The following text documents the current status of the compulsory modules in the Autonomous Vehicle Engineering degree programme. In particular, it lists the study objectives and study contents of the individual compulsory modules and the practical courses as well as the time allocation of the semester hours per subject and study semester. It also contains the detailed provisions on the performance and participation certificates accompanying the degree programme.

## 2 Programme Description

### 2.1 Aim of Study

Digitalisation, networking and automation are fundamentally changing the automotive value chains and mobility of the future. Automated and connected vehicles relieve drivers of routine tasks, increase road safety, offer new opportunities and services in individual mobility and can contribute to increasing transport efficiency and sustainability. New fields of technology and expertise are being linked with the classic areas of automotive engineering, mechanical engineering and electrical engineering. Autonomous vehicles are important carriers of technological applications and basic innovations such as artificial intelligence or cloud computing and, increasingly, edge computing, from whose development and testing other branches of industry can also benefit greatly. Automated and connected driving and digital mobility are thus drivers of change.

Like autonomous systems in general, the components of automated mobility systems can be divided into environment detection technologies and core technologies. The environment detection technologies of sensors, actuators and human-machine or machine-machine interaction are required for surrounding area detection, communication, and the execution of instructions. The core technologies of autonomous systems include perception, learning, action, and self-regulation. Based on the raw data from the sensors, an automated mobility system uses technologies of perception to process the environment data. As a result, the system will plan its action based on the technologies of perception. These actions consist for example of planning trajectories or making decisions about driving tactics and strategy. In automated driving, the vehicle's actuator system converts the instructions for lateral and longitudinal guidance into steering movements and braking or acceleration actions. In order for these functions to work reliably even in less structured environments and unknown situations, the core technology of self-regulation is needed. Artificial intelligence is considered to be a promising method compared to rule-based algorithms to cope with the complexity of autonomous mobility, due to the infinite variety of possible traffic scenarios and the underlying non-linear relationships.

The focus of development is increasingly shifting from hardware to software. In addition to sophisticated sensor technology and powerful, software-based driver assistance systems, partially or fully automated driving requires above all the intelligent collection and evaluation of large to enormous amounts of data. This means that the development of systems for automated mobility is increasingly concerned with the question of how these amounts of data can be stored, structured and then optimally used. The development of today's partially automated and later fully automated vehicles requires sound IT and especially signal processing competence. IT components will be just as central to the vehicle as, for example, the powertrain is today.

The Autonomous Vehicle Engineering degree programme in English focuses on the interaction of different technologies in order to qualify engineers for the development of automated mobility systems by teaching scientific and engineering fundamentals and methods. Students acquire specialist and methodological knowledge in the characteristic subject areas for the independent development of components of automated mobility systems:

1. Sense: Sensor technology, sensor systems and sensor data fusion for recognising and recording the environment.
2. Think: Processing the information obtained via sensor technology to create an environment model and situation interpretation as the basis for planning a driving strategy using software and intelligent algorithms.
3. Act: Safe implementation of the driving strategy with the aid of drive, steering and braking forces through actuation and control of actuators.

Laboratory internships and practical phases promote methodological competence. Group projects and seminars strengthen social and personal competence. Later, graduates with a broad interest in interdisciplinary trends in digitalized mobility will find many meaningful fields of activity.

The language of instruction of the programme is English. By bringing students from all over the world together, we prepare them for cooperation in internationally composed teams and for a professional life in internationally operating companies.

## 2.2 Target Group

Technologies developed for connected and highly automated vehicles become more and more prevalent in everyday life. In order to be able to help shape these new technologies, a broad skill set is necessary.

The study programme Autonomous Vehicle Engineering teaches the competences needed and is targeted at prospective students who

- like to think abstract and digital
- are interested in programming, modelling and mechatronics
- would like to understand the full signal processing pipeline (including hardware and software) for complex embedded systems like automated cars from
- have fun to apply their knowledge to find innovative technical solutions from sensor to actor
- would like to get a broad understanding of how to develop complex systems like automated cars
- are interested in new technologies necessary for automated vehicles such as artificial intelligence
- are eager to learn the mathematical concepts, but also want to apply these in order to solve real world challenges on the road to fully automated driving
- would like to develop profound problem solving skills not limited to the domain of automated driving

## 2.3 Qualification Profile

Graduates will gain the following qualifications or competences upon successful completion of the programme:

- **Knowledge and understanding**

Graduates will have acquired extensive engineering, mathematical, and scientific knowledge that will enable them to work in a scientifically sound manner and act responsibly in their professional activities. They will have a solid understanding of signal processing, starting from the mathematical foundations and continuing through the physical layer of signal measurements and digital signal processing, up to the application of signals in machine learning approaches. Additionally, graduates will have developed an understanding of the multidisciplinary context of autonomous vehicle engineering, particularly at the interface between hardware and software.

- **Engineering methodology**

Graduates are capable of identifying, formulating, and solving technical problems in autonomous mobility systems using established scientific methods. They can analyze processes and methods of their discipline scientifically and apply suitable analysis, modelling, simulation, and optimization methods. In particular, they will be skilled in signal processing techniques, making them qualified to work with embedded systems—critical in the automotive and other sectors. These skills are highly relevant for embedded software development, especially within the automotive industry, but their application extends to other fields such as railway, aviation, and various industrial sectors requiring deep knowledge of signal processing from hardware to software.

- **Engineering-oriented development and design**

Graduates have the ability to develop mechatronic systems, integrating both hardware and software for autonomous mobility systems, in line with specified requirements. They possess a practice-oriented understanding of design methods and are skilled in applying them, particularly in the context of embedded software development and signal processing. Graduates will be well-prepared to develop robust, safe, and secure software that meets high-quality standards in terms of functional safety and cybersecurity, especially within the automotive domain. Possible areas of activity include the development of autonomous driving systems, vehicle sensor integration, and advanced driver-assistance systems (ADAS).

- **Investigate and evaluate**

Graduates are proficient in conducting literature research and utilizing other information sources to support their work. They can independently plan and conduct experiments and interpret the results. Graduates can transfer new findings from engineering and natural sciences into industrial development, considering safety, ecological, economic, and societal factors. They are capable of planning and controlling development processes while considering the implications of their work in terms of quality, safety, and ethics. Graduates will be equipped to address the growing demand for expertise in software quality, robustness, functional safety, and cybersecurity. These skills are applicable in industries such as automotive, rail, aviation, robotics, and any sector reliant on embedded systems and signal processing technologies.

Graduates also acquire extensive knowledge of development methodologies for both software and hardware in complex systems, with a particular emphasis on autonomous mobility systems and signal processing. They are aware of the non-technical implications of engineering work, such as the social impact of autonomous vehicles.

Furthermore, they are equipped to adapt to the modern job market by acquiring key skills such as time management, learning techniques, teamwork, and communication. They are able to work individually or as part of international teams and can communicate about their field in both English and German.

### **Potential Job Titles and Corresponding Competencies:**

- **Embedded Software Engineer:**

Competencies: Strong knowledge in embedded systems, signal processing, and software development for real-time systems. The ability to integrate hardware and software components and develop safe, reliable software that meets functional safety and cybersecurity standards is crucial for this role.

- **Signal Processing Engineer:**

Competencies: A deep understanding of signal processing from the mathematical foundations to digital signal processing and its applications in machine learning. This role requires expertise in handling signals across various physical layers and applying advanced techniques to improve system performance.

- **ADAS Engineer:**

Competencies: Skills in sensor fusion, signal processing, and embedded system design are essential for developing advanced driver-assistance systems. The ability to analyze and optimize algorithms for safety-critical applications is highly relevant for this position.

- **Test Engineer / Validation Engineer:**

Competencies: Ability to design, plan, and execute testing procedures for complex systems. Knowledge of system validation and the ability to interpret experimental data ensures the reliability and safety of autonomous systems.

- **Requirements Engineer**

Competencies: Graduates are skilled in defining, documenting, and managing system and software requirements. They bridge the gap between stakeholders and technical teams, ensuring specifications meet current quality and legal standards. Their expertise at the hardware-software interface is essential for embedded systems and autonomous technologies.

## 2.4 Graduation Degree

After successful completion of the study programme Autonomous Vehicle Engineering the Technische Hochschule Ingolstadt awards the academic degree:

### **Bachelor of Engineering (B.Eng.)**

## 2.5 Admission Requirements

Prerequisite for admission to study at Technische Hochschule Ingolstadt is either a general or subject-related higher education entrance qualification or the entrance qualification for studies at universities of applied sciences.

The language of instruction of the programme is English. Therefore, sufficient proficiency of the English language is necessary. Individual courses of the study programme (especially within the second phase of study) might be offered in German. The Technische Hochschule Ingolstadt offers students the possibility to learn German or a foreign language.

In an aptitude assessment procedure (see admission regulations), the applicant must also prove that he or she has the aptitude for the special requirements of the Bachelor's degree programme listed below, which leads to the expectation of a successful course of study:

- strong, solid knowledge of mathematics, in particular the ability to think abstractly, logically and system-oriented and to formalise approaches to solutions;
- competences in the field of natural sciences, computer science and technology

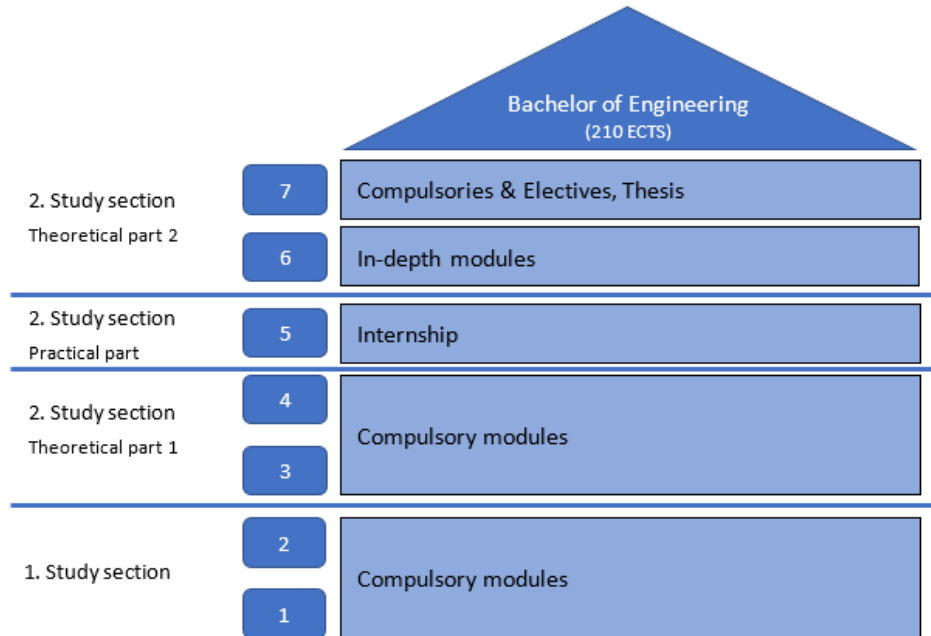
The aptitude test is carried out by evaluating the following criteria:

- average grade of the higher education entrance qualification and
- subject-specific individual grades

The individual subject-specific grades in mathematics and the two highest-scoring subjects in the natural sciences, including computer science, which were acquired in the last four semesters prior to the acquisition of the HZB, are used as subject-specific individual grades. In order to be able to treat grades from foreign grading systems in a uniform manner, the grades are converted into points and a total point value is calculated as a weighted average from the above-mentioned criteria. If the total point value is above a threshold value, the aptitude is deemed to have been established.

## 2.6 Programme Structure and Content

The programme Autonomous Vehicle Engineering starts in the winter semester only. The standard designated period of study comprises seven semesters and 210 ECTS (credit points, CP).



The university bases one CP on a workload of 25 hours. The study programme is divided into two phases of study. The first phase comprehends two theoretical semesters. The second phase comprehends two theoretical and one practical semester, which is scheduled for the 5th semester. The 6th semester is reserved for a student project and specialized subjects. The study programme is completed with the 7th semester, which is reserved for elective subjects and the bachelor's thesis:

1st study section: Semesters 1 and 2

Teaching of basic theories, methods and skills of engineering sciences, mathematics/statistics as well as technical and practical computer science.

2nd study section

- Theory part 1: Semesters 3 and 4

Teaching of subject-specific basics and skills in processing information for the purposes of vehicle guidance. A general elective subject offers either the opportunity to expand German language skills or to take a compulsory elective subject in which social aspects of mobility are dealt with.

- Practical part: Semester 5

Semester 5 is a practical semester, 20 weeks of which are spent in companies. A final report and a final presentation serve to reflect on the internship on the following levels: on the level of personal learning processes, the development of the supervisory relationship, the attitudes gained towards the profession in general and the field of work in particular, and further study planning.

- Theory part: Semesters 6 and 7

Teaching of in-depth subject-specific theories and concepts of automated and networked driving; Bachelor's thesis: Proof of the ability to analyse a complex task from practice/research and to work on it with the inclusion of specialist knowledge and the aid of scientific sources. The results are to be presented in written and oral form to show that the task can be presented in a structured manner and defended in terms of content.

The degree programme is modularised and fully complies with the European Credit Transfer and Accumulation System. The following study structure is planned in detail:

- Basic modules (60 CP): imparting the necessary methods, techniques and content-related fundamentals of a mechatronically oriented engineering education, which focuses on the field of computer science.
- Advanced modules (52 CP): imparting knowledge about components and development methods for modern mobility systems
- Specialisation modules (37 CP): imparting knowledge and methods for the development of components of automated mobility systems
- Key qualification modules (20 CP): Development of personal and social competences that are required for the aspired technical and management tasks in companies.
- Practical phase (24 CP): Shifting the place of learning from the university to a company and other institutions of professional practice. The practical phase is supplemented by a key qualification subject (4 CP).

## 2.7 Internship

During their studies, all students have to complete an internship in a company which is scheduled for the 5th semester. The practical semester is carried out in companies from industry, small and medium-sized enterprises and public administration.

## 2.8 Examination Concept of the Degree Programme

In modules in which the competence goal consists of the acquisition of knowledge, the understanding of interrelationships of intra- and interdisciplinary facts and processes or the application of methods to the issues dealt with, the written examination (written exam) is the predominant form of examination. The modules include in particular the mathematical-scientific as well as the computer science modules. If the learning objective is the acquisition of skills and the use of contextual knowledge in complex and difficult situations, but also in new and unfamiliar situations, the achievement of the objective is checked by questioning or practical examinations or by checking the functionality of the artefacts/systems created by the student. The written final paper together with the presentation of the procedure and the results verify the extent to which the qualification goals of the areas of methodological and social competence have been achieved.

The following forms of examination are used:

- Written examinations in which knowledge is to be explained, methods are to be applied in known situations and both are to be transferred to answer new questions of limited scope.
- Seminar papers, in which a scientific task is worked on in writing and presented orally and is assessed with regard to content and specified formal criteria.
- Project work, in which students analyse complex problems in small groups and work out joint solutions (especially in the project).
- practical examinations in which the ability to demonstrate practice-specific techniques is demonstrated (especially in the practical courses accompanying the course)
- oral examinations in which the processing of questions is to be explained

## 2.9 Advancement Requirements

To ensure that the knowledge required for understanding the individual study sections is available, there are several prerequisites for advancement. If these prerequisites are not met, there is usually a delay in the progress of studies, which should be used to fill the respective gaps. In order to keep the total duration of the degree programme within reasonable limits, some additional deadlines must be kept. The following list provides an overview of these requirements and deadlines:

- Only those who have achieved at least 42 credit points from modules of the first study section are entitled to enter the second study section.
- Students are only entitled to enter the practical study semester if they have achieved at least the grade "sufficient" in all examinations and relevant course-related certificates of the first study section and have earned at least 20 ECTS credits from the compulsory modules of the second study section.

The binding regulations can be found in

- the Study and Examination Regulations (SPO) of the programme
- in the General Examination Regulations (APO) of Technische Hochschule Ingolstadt

## 2.10 Concept and Advisory Board

The development of the degree programme was initiated by the strategic initiative of the Presidential Board of Technische Hochschule Ingolstadt. The development of the study programme was carried out by the "Mobility programme" working group at the Faculty of Electrical Engineering and Information Technology. An advisory board with experts from automotive industry as well as professors and students from other universities of applied sciences was established to support the further development of the degree programme.

## 2.11 Advisor and Programme Coordinator

The academic advisor is available to answer any technical questions or problems related to your studies. The program director is available to answer questions about the organizational aspects of the program. The academic advisor and program director for the Autonomous Vehicle Engineering program is:

**Prof. Dr. Martin Ebert, building A, room 201185, phone: 0841 / 93 48 –3804**

Please adhere to the published consultation hours.

## 2.12 Internship Officer

For all technical and functional questions and problems with regards to contents of the internships please contact:

**Prof. Dr. Jörg Hunsinger, building A, room 123, phone: 0841 / 93 48 – 2920**

Please adhere to the published consultation hours.

### 3 Curricular Structure

The programme Autonomous Vehicle Engineering starts in the winter semester only. Courses of the 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> term are offered every winter term. Courses of the 2<sup>nd</sup>, 4<sup>th</sup>, and 6<sup>th</sup> term are offered every summer term. Courses of the 7<sup>th</sup> term (Electives, Bachelor thesis) are offered every winter term and every summer term.

#### 3.1 First Study Section

The first phase of studies comprehends two semesters containing mostly theoretical foundations and starts every winter term.

Module	No.	Subjects	Allocation to semesters			
			1. Sem.	2. Sem.	SWS	CP
Mathematics 1	1.1	Mathematics 1	5 (schrP)		7	8
	1.1	Exercise Course Mathematics 1	2			
Foundation of Computer Science	2.1	Foundation of Computer Science	4 (schrP)		6	7
	2.2	Practical Course Foundations of Computer Science	2 (LN)			
Programming 1	3.1	Programming 1	4 (schrP)		6	7
	3.2	Practical Course Programming 1	2			
Foundations of Engineering Sciences	4.1	Foundations of Engineering Sciences	5 (schrP)		7	8
	4.2	Exercise Course Foundations of Engineering Sciences	2			
Mathematics 2	5.1	Mathematics2		4 (schrP)	5	6
	5.2	Exercise Course Mathematics 2		1		
Statistics	6.1	Statistics		3 (schrP)	4	5
	6.2	Exercise Course Statistics		1		
Algorithms and Data Structures	7	Algorithms and Data Structures		4 (schrP)	4	5
Programming 2	8.1	Programming 2		4 (schrP)	6	7
	8.2	Practical Course Programming 2		2 (LN)		
Electronics, Signals and Measurement	9.1	Electronics, Signals and Measurement		4 (schrP)	6	7
	9.2	Practical Course Electronics, Signals and Measurement		2 (LN)		
<b>Sum</b>					<b>51</b>	<b>60</b>

## 3.2 Second Study Section

### Semester 3 – 5

Module	No.	Subjects	Allocation to semesters				
			3. Sem.	4. Sem.	5. Sem.	SWS	CP
Model-based Software Engineering	10.1	Model-based Software Engineering	4 (schrP)			6	6
	10.2	Practical Course Model-based Software Engineering	2 (LN)				
Vehicle Dynamics	11	Vehicle Dynamics	4 (schrP)			4	5
Modelling and Simulation	12.1	Modelling and Simulation	4 (schrP)			6	7
	12.2	Practical Course Modelling and Simulation	2 (LN)				
Digital Signal Processing	13.1	Digital Signal Processing	4 (schrP)			6	7
	13.2	Practical Course Digital Signal Processing	2 (LN)				
General Elective (Allgem.wissen. Wahlpflichtmodul)	14	General Elective	4 (LN)			4	5
Software Development Processes	15	Software Development Processes		4 (mdlP)		4	5
Foundations of Machine Learning	16.1	Foundations of Machine Learning		4 (schrP)		6	7
	16.2	Practical Course Foundations of Machine Learning		2 (LN)			
Vehicle Electronics and Vehicle Communication Networks	17.1	Vehicle Electronics and Vehicle Communication Networks		4 (schrP)		6	7
	17.2	Practical Course Vehicle Electronics and Vehicle Communication Networks		2 (LN)			
Control Engineering	18.1	Control Engineering		4 (schrP)		6	8
	18.2	Practical Course Control Engineering		2			
Scientific Seminar	19	Scientific Seminar		2 (SA)		2	3
Internship	27	Internship			(PrB)		24
	28	Internship Seminar			1 (LN)	1	2
	29	Business Management			2 (schrP)	2	4
<b>Sum</b>						<b>50</b>	<b>90</b>

## Semester 6 - 7

Module	No.	Subjects	Allocation to semesters			
			6. Sem.	7. Sem.	SWS	CP
Vehicle-to-X-Communication	20	Vehicle-to-X-Communication	4 (schrP)		4	5
Team Project	21	Team Project	4 (Prj)		4	8
Sensor Data Processing and Sensor Data Fusion	22.1	Sensor Data Processing and Sensor Data Fusion	4 (schrP)		6	7
	22.2	Practical Course Sensor Data Processing and Sensor Data Fusion	2 (LN)			
Planning and Decision-Making Algorithms	23	Planning and Decision-Making Algorithms	4 (schrP)		4	5
Vehicle Actuators	24	Vehicle Actuators	4 (schrP)		4	5
Science Elective (Fachwissenschaftliches Wahlpflichtmodul)	25	Science Elective (Fachwissenschaftliches Wahlpflichtmodul)		12 (LN)	12	15
Bachelor Thesis	26.1	Seminar Bachelor Thesis		2 (SA)	2	15
	26.2	Bachelor Thesis		(BA)		
<b>Sum</b>					<b>36</b>	<b>60</b>

### Forms of examination

- schrP            written exam
- mdIP            oral exam
- SA                seminar paper and presentation
- Prj                project work (report and presentation)
- LN                course-specific examination

For subjects with accompanying practical courses, passing their proof of performance is a prerequisite for admission to the examination.

## 4 Description of Modules

### 4.1 Compulsory Modules

<b>Mathematics 1</b>			
<b>Module abbreviation</b>	AVE_Math1	<b>Reg.-Nr.</b>	1
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	1
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Ebert, Bernd Martin (AVE_Math1) Hunsinger, Jörg (AVE_ExMath_1)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	8 ECTS / 7 SWS		
<b>Workload</b>	Contact hours	82 h	
	Self-study	118 h	
	Total	200 h	
<b>Subjects of the module</b>	1.1: Mathematics 1 1.2: Exercise Course Mathematics 1		
<b>Lecture types</b>	SU/Ü - seminar lecture/exercise		
<b>Examinations</b>			
1.1: schrP90 - written exam, 90 minutes 1.2: O - without proof of performance			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Exponentiation, roots, fractions, exponential function, logarithm Basic differentiation and integration Transforming and solving of equations and inequations Basic vector analysis: vector addition, vector products, matrices			
<b>Objectives</b>			
After successfully completing this module the students shall be able to			
<ul style="list-style-type: none"> <li>• understand and apply methods of mathematical proofs e.g. truth tables or proof by contradiction.</li> <li>• explain the basic terms, specifications and examples of univariate real and complex analysis, e.g. Power series, elementary functions, limit value, sequence, series, derivative, integral, and linear algebra, e.g. vector, matrix, linear map, linear system of equations.</li> <li>• give an overview of essential rules and methods of univariate real Analysis, e.g. differentiation, integration, and linear algebra, e.g. of matrix calculation, determinant, eigenvalue calculation, for the solution of linear systems of equations, to be specified.</li> </ul>			

- explain the different representations of complex numbers and understand the implications of the fundamental theorem of algebra, reliably calculate with and geometrically illustrate complex numbers and elementary complex functions.
- determine convergence / divergence of complex sequences and series (including power series) of numbers.
- analyze the behavior of univariate real functions through the use of differential calculus.
- correctly use important integration methods for real univariate functions and analyze univariate real functions geometrically with integral calculus, determine the power series representation of a given function and calculate its radius of convergence.
- reliably calculate, analyze and interpret solution spaces of linear systems of equations, understand the isomorphism between the vector spaces of matrices and linear maps.
- apply matrix calculus and matrix parameters in linear contexts and correctly perform matrix, rank and determinant calculations, determine eigenvalues and eigenvectors of matrices.
- apply learned methods to solve tangible technical problems.

**Content**

- Fundamentals: propositional logic, set theory, relation, function, inverse function, sequences, series, limits, convergence criteria
- Complex numbers: cartesian and polar/exponential coordinates, exponentiation, complex conjugate, fundamental theorem of algebra, polynomials, application: harmonic oscillation, AC current
- Linear algebra: Vector spaces, bases of vector spaces with infinite dimensions, vector calculus, systems of linear equations, determinants, matrix algebra, eigenvalues and eigenvectors
- Differential calculus with one variable: continuity, differential quotient, derivative, derivative of the inverse, derivation rules, basic functions, hyperbolic functions, position vector, tangent vector
- Power series, elementary functions: exponential function, trigonometric functions. Taylor series
- Integral calculus with one variable: definite and indefinite integral, primitive function, fundamental theorem of calculus, basic primitives, integration rules, product integration, integration by substitution, partial fraction method, integration of rational functions, improper integral

**Literature**

- CROFT, Anthony and Robert DAVISON, 2019. *Mathematics for engineers*. Harlow, England: Pearson. ISBN 978-1-292-25364-0
- JAMES, Glyn, Phil P. G. DYKE and John SEARL, 2018. *Advanced modern engineering mathematics*. Harlow, England: Pearson. ISBN 978-1-292-17434-1

**Additional remarks**

None

<b>Foundations of Computer Science</b>			
<b>Module abbreviation</b>	AVE_CompSci	<b>Reg.-Nr.</b>	2
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	1
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Membarth, Richard		
<b>Lecturer(s)</b>	Membarth, Richard (AVE_CompSci) Membarth, Richard (AVE_PractCompSci)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	2.1: Foundations of Computer Science 2.2: Practical Course Foundations of Computer Science		
<b>Lecture types</b>	SU/Ü - seminar lecture/exercise; Pr - practical course;		
<b>Examinations</b>			
2.1: schrP90 - written exam, 90 minutes 2.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
<p>Prerequisite for participation in the written examination is a successfully completed practical course.</p> <p>Successful completion of the practical course is a prerequisite for admission to the written examination. To successfully pass the practical course, the following points must be met:</p> <ul style="list-style-type: none"> <li>• attendance of the compulsory exercise dates</li> <li>• at least 50% of the exercises have to be submitted and evaluated as correct</li> <li>• the solutions of at least 2 exercises or related tasks has to be presented during the practical course</li> </ul>			
<b>Prerequisites according examination regulation</b>			
Prerequisite for participation in the written examination is a successfully completed practical course.			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After successful participation in the module course, students are able to</p> <ul style="list-style-type: none"> <li>• represent information of different kinds for processing by digital computers.</li> <li>• identify the elements of an instruction set architecture and assess their implications on programming and computer architecture designs.</li> <li>• explain the interaction of hardware and software.</li> <li>• formulate basic elements of procedural programming in a machine language.</li> <li>• evaluate the effect of programming alternatives on the execution speed.</li> <li>• explain concepts for performance enhancement in modern processors and the problems associated with them.</li> </ul>			

After successful participation in the practical course, students are able to

- convert numbers between different representations and perform arithmetic in these systems.
- analyze the influence of different instruction set architectures on evaluation criteria like code size and implementation effort.
- realize small programs in assembly language.
- resolve pipeline hazards in pipelines to improve performance.

### Content

- information coding, representation, and arithmetic in computer systems
- basic concepts of computer architectures, universal computers, and program execution
- instruction set architectures: instruction set, addressing modes, interrupts
- basics of machine-oriented programming: memory layout, control structures, subprograms
- concepts of modern computer systems: pipelining, superscalarity, SIMD, memory hierarchy, cache memory
- information coding
- number representation and arithmetic
- the instruction cycle
- computer architecture styles
- RISC-V ISA: assembler, programming, and simulator
- pipelined processor designs

### Literature

- PATTERSON, David A. and John L. HENNESSY, 2020. *Computer Organization and Design: The Hardware Software Interface*. Cambridge, MA, USA: Morgan Kaufmann. ISBN 978-0-12-820331-6
- LEDIN, Jim, 2020. *Modern Computer Architecture and Organization: Learn x86, ARM, and RISC-V Architectures and the Design of Smartphones, PCs, and Cloud Servers*. Birmingham, UK: Packt Publishing. ISBN 978-1-83-898439-7
- HENNESSY, John L. and David A. PATTERSON, 2017. *Computer Architecture: A Quantitative Approach*. Cambridge, MA, USA: Morgan Kaufmann. ISBN 978-0-12-811905-1

### Additional remarks

None

<b>Programming 1</b>			
<b>Module abbreviation</b>	AVE_Progr_1	<b>Reg.-Nr.</b>	3
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	1
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schall, Martin		
<b>Lecturer(s)</b>	Schall, Martin (AVE_Progr_1) Karpenahalli Ramakrishna, Chidvilas; Schall, Martin (AVE_PractProg_1)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	3.1: Programming 1 3.2: Practical Course Programming 1		
<b>Lecture types</b>	3.1: SU/Ü - lecture with integrated exercises 3.2: Pr - laboratory		
<b>Examinations</b>			
3.1: schrP90 - written exam, 90 minutes 3.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
<p>Prerequisite for participation in the written examination is a successfully completed practical course.</p> <p>Within the practical course, several tests must be acquired. If the assignment is successfully completed, the lecturer will award a test certificate in each case. A total of at least four tasks (out of five) must be completed, which deal with essential topics of the lecture. The completed solutions have to be presented individually within a fixed time frame, whereby questions about the solution concept and the programme created have also to be answered. Only if all four tests are acquired in time, the admission is granted.</p>			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After completion of the module the students will be able to</p> <ul style="list-style-type: none"> <li>• understand the programming basics (operations, control structures, data types, etc.).</li> <li>• readily use the Python programming language.</li> <li>• apply various data types and control structure.</li> <li>• understand class inheritance and polymorphism.</li> <li>• understand the object-oriented program design and development.</li> <li>• understand and begin to implement code.</li> </ul>			

### Content

- Introduction: foundations of algorithms and information processing
- Information representation: data Types, variables and basic data structures
- Control structures: conditional execution, loops, lists and list processing
- Procedural abstraction: functions modules and packages
- Objects and classes
- Working with files
- Fundamental algorithms

### Literature

- LAMBERT, Kenneth A. and Martin OSBORNE, 2019. *Fundamentals of Python: first programs*. Boston, MA: Cengage. ISBN 1-337-56009-X, 978-1-337-56009-2
- ZHANG, Yue, 2015. *An Introduction to python and computer programming* [online]. Singapore [u.a.]: Springer PDF e-Book. ISBN 978-981-287-609-6, 978-981-287-608-9. Available via: <https://doi.org/10.1007/978-981-287-609-6>.
- DOWNEY, Allen B., 2015. *Think Python, 2nd Edition*.

### Additional remarks

None

## Foundations of Engineering Sciences

<b>Module abbreviation</b>	AVE_EngSci	<b>Reg.-Nr.</b>	4
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	1
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester

<b>Responsible for module</b>	Arnold, Armin		
<b>Lecturer(s)</b>	Arnold, Armin (AVE_EngSci) Arnold, Armin (AVE_ExEngSci)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	8 ECTS / 7 SWS		
<b>Workload</b>	Contact hours	82 h	
	Self-study	118 h	
	Total	200 h	
<b>Subjects of the module</b>	4.1: Foundations of Engineering Sciences 4.2: Exercise Course Foundations of Engineering Sciences		
<b>Lecture types</b>	4.1: SU - lecture 4.2: Ü - exercise course		

### Examinations

- 4.1: schrP90 - written exam, 90 minutes  
4.2: O - without proof of performance

### Additional explanations regarding examinations

Prerequisite for participation in the written examination is a successfully completed practical course.

### Prerequisites according examination regulation

None

### Recommended prerequisites

Basic knowledge of: Newtonian dynamics, optics, thermodynamics, electro-magnetism

### Objectives

After successful participation the students should be able to:

- solve basic physical problems, validate calculations, estimate relevant input tolerances/errors and their impact on the results.
- determine the center of gravity of multibody-problems, apply the sentences of conservation of momentum and energy.
- calculate the inertia of rotating bodies.
- solve problems with help of the Ideal Gas Law.
- calculate damped and undamped oscillations.
- analyse and calculate wave problems.
- apply the fundamental equations of optics.
- do calculations regarding simple electrical problems.

**Content**

- Physical properties
- Mechanics
- Resonances and waves,
- Deflection and interference
- Ideal Gas Law
- Basic electrodynamics and electrics

**Literature**

- BOLTON, William, 2020. *Engineering science*. London ; New York: Routledge, Taylor & Francis Group. ISBN 978-0-367-55445-3, 978-0-367-55443-9

**Additional remarks**

None

<b>Mathematics 2</b>			
<b>Module abbreviation</b>	AVE_Math2	<b>Reg.-Nr.</b>	5
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	2
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Ebert, Bernd Martin (AVE_Math2) Hunsinger, Jörg (AVE_ExMath2)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	6 ECTS / 5 SWS		
<b>Workload</b>	Contact hours	59 h	
	Self-study	91 h	
	Total	150 h	
<b>Subjects of the module</b>	5.1: Mathematics 2 5.2: Exercise Course Mathematics 2		
<b>Lecture types</b>	5.1: SU - lecture 5.2: Ü - exercise course		
<b>Examinations</b>			
5.1: schrP90 - written exam, 90 minutes 5.2: O - without proof of performance			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Basic calculus: exponentiation, roots, fractions, exponential function, logarithm; Basic differentiation and integration; Transforming and solving of equations and inequations; Basic vector analysis: vector addition, vector products, matrices Mathematics I			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>• reliably calculate partial and total derivatives of multivariate real functions and correctly perform important integration methods for multivariate real functions.</li> <li>• analyze the behaviour of multivariate real functions (e.g. extreme values) by using differential calculus.</li> <li>• geometrically analyze multivariate functions with multiple integration.</li> <li>• understand important multivariate integral theorems such as: divergence theorem and Stokes' theorem and apply them in the derivation of the Maxwell equations.</li> <li>• correctly apply important solution methods on simple ordinary differential equations.</li> <li>• understand how ordinary differential equations can be solved numerically.</li> </ul>			

- calculate the Laplace transform and the inverse Laplace transform of given functions and use the Laplace transform to solve ordinary differential equations.

#### Content

- Differential calculus with more than one variable: scalar functions with two and more variables, potential function, partial derivative, gradient, total differential, implicit derivation, directional derivative
- Integral calculus with more than one variable: two- and three-dimensional area integral, polar coordinates, path integral over vector and scalar field, scalar potential and gradient field, path independent integral, spherical coordinates, surface integral over vector and scalar field, flux, divergence theorem with application, vortex field, curl, Stokes' theorem, Nabla operator, Maxwell equations
- Differential equations: ordinary DE, separation of variables, inhomogeneous ODE of n-th order, harmonic vibration, numerical methods to solve ODE (Euler, Runge-Kutta)
- Laplace transform

#### Literature

- BIRD, John O., 2014. *Understanding engineering mathematics: [SI units USED]*. London ; New York: Routledge. ISBN 978-0-415-66284-0, 0-415-66284-2
- JAMES, Glyn, Phil P. G. DYKE and John SEARL, 2020. *Modern engineering mathematics*. Harlow, England: Pearson. ISBN 978-1-292-25349-7
- CROFT, Anthony and Robert DAVISON, 2019. *Mathematics for engineers*. Harlow, England: Pearson. ISBN 978-1-292-25364-0

#### Additional remarks

None

<b>Statistics</b>			
<b>Module abbreviation</b>	AVE_Stat	<b>Reg.-Nr.</b>	6
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	2
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schmidtner, Stefanie		
<b>Lecturer(s)</b>	Schmidtner, Stefanie (AVE_Stat) Schmidtner, Stefanie (AVE_ExStat)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours		47 h
	Self-study		78 h
	Total		125 h
<b>Subjects of the module</b>	6.1: Statistics 6.2: Exercise Course Statistics		
<b>Lecture types</b>	6.1: SU - lecture 6.2: Ü - exercise course		
<b>Examinations</b>			
6.1: schrP90 - written exam, 90 minutes 6.2: O - without proof of performance			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Mathematics I			
<b>Objectives</b>			
<p>After finishing this course including exercises students are able to</p> <ul style="list-style-type: none"> <li>• choose and calculate appropriate metrics for describing a data set.</li> <li>• understand different kinds of data and scaling.</li> <li>• understand and interpret visualizations of distributions.</li> <li>• explain and analyze bivariate connections.</li> <li>• understand fundamentals of probability and apply them to a given data set.</li> <li>• explain and apply the concept of conditional probability and Bayes' theorem.</li> <li>• name the most important distributions and know appropriate applications.</li> <li>• understand and use linear regression for analyzing a given dataset.</li> </ul>			
<b>Content</b>			
<p>Descriptive statistics</p> <ul style="list-style-type: none"> <li>• Visualization of distributions</li> </ul>			

- Scaling
- Metrics for descriptive analyses of a data set
- Metrics and models for bivariate connections

Probability theory and inductive statistics

- Probability space
- Conditional probability and Bayes
- Random variables
- Discrete and continuous distributions
- Selected hypothesis tests
- Linear regression
- Joint random variables
- Markov chains

**Literature**

- CARLTON, Matthew A., DEVORE, Jay L., 2017. *Probability with applications in engineering, science, and technology* [online]. Cham: Springer PDF e-Book. ISBN 978-3-319-52401-6. Available via: <https://doi.org/10.1007/978-3-319-52401-6>.
- HASTIE, Trevor, Robert TIBSHIRANI and Jerome FRIEDMAN, 2017. *The elements of statistical learning: data mining, inference, and prediction*. Second edition, corrected at 12. edition. New York, NY [u.a.]: Springer. ISBN 978-0-387-84857-0
- RICE, John A., 2007. *Mathematical statistics and data analysis*. Belmont, Calif.: Brooks/Cole, Cengage Learning. ISBN 0-495-11868-0, 978-0-495-11868-8

**Additional remarks**

None

## Algorithms and Data Structures

<b>Module abbreviation</b>	AVE_AlgoDS	<b>Reg.-Nr.</b>	7
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	2
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Membarth, Richard		
<b>Lecturer(s)</b>	Membarth, Richard		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Algorithms and Data Structures		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Programming in Python or C/C++ Computer Architecture Foundations of Computer Science			
<b>Objectives</b>			
<p>After successfully completing the module, students shall be able to</p> <ul style="list-style-type: none"> <li>analyze given algorithms and determine their runtime and memory consumption.</li> <li>name the most important data structures and describe their advantages and disadvantages.</li> <li>identify suitable data structures and algorithms for concrete problem.</li> <li>recognize implementation aspects of algorithms and data structures and describe their effects.</li> <li>realize algorithmic variants using recursive and iterative implementations.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>Classification and complexity of algorithms</li> <li>Basic data structures: array, list, stack, queue</li> <li>Graphs and their applications: traversal, transitive closure, shortest path, flow network, spanning tree, matching</li> <li>Tree data structures: binary tree, heap, binary search tree, AVL tree, B-tree</li> <li>Hash tables and their applications</li> <li>Sorting algorithms: selection sort, insertion sort, gnome sort, heapsort, quicksort, merge sort, radix sort</li> </ul>			

- Compilers: structure, tree representation, graph representation, code optimization, code generation

**Literature**

- CORMEN, Thomas H. and others, 2022. *Introduction to Algorithms*. Cambridge, MA, USA: MIT Press. ISBN 978-0-262-04630-5
- AHO, Alfred V. and others, 2007. *Compilers: Principles, Techniques, & Tools*. Boston [u.a.]: Pearson Addison-Wesley. ISBN 978-0-321-48681-3, 0-321-49169-6, 978-0-321-49169-5
- SEDGEWICK, Robert and Kevin WAYNE, 2011. *Algorithms*. ISBN 978-0-321-57351-3

**Additional remarks**

None

<b>Programming 2</b>			
<b>Module abbreviation</b>	AVE_Prog2	<b>Reg.-Nr.</b>	8
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	2
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Glavina, Bernhard		
<b>Lecturer(s)</b>	Glavina, Bernhard (AVE_Prog2) Glavina, Bernhard (AVE_PractProg2)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	8.1: Programming 2 8.2: Practical Course Programming 2		
<b>Lecture types</b>	8.1: SU/Ü - lecture with integrated exercises 8.2: Pr - laboratory		
<b>Examinations</b>			
8.1: schrP90 - written exam, 90 minutes 8.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
<p>Prerequisite for participation in the written examination is a successfully completed practical course.</p> <p>Within the practical course, several tests must be acquired. If the assignment is successfully completed, the lecturer will award a test certificate in each case. A total of at least four tasks (out of five) must be completed, which deal with essential topics of the lecture. The completed solutions have to be presented individually within a fixed time frame, whereby questions about the solution concept and the programme created have also to be answered. Only if all four tests are acquired in time, the admission is granted.</p> <p>Within the practical course, several tests must be acquired. If the assignment is successfully completed, the lecturer will award a test certificate in each case. A total of at least four tasks (out of five) must be completed, which deal with essential topics of the lecture. The completed solutions have to be presented individually within a fixed time frame, whereby questions about the solution concept and the program developed have also to be answered. Only if all four tests are acquired in time, the admission is granted.</p>			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Programming I			
<b>Objectives</b>			
<p>After attending the module, students will be able to</p> <ul style="list-style-type: none"> <li>state and explain the essential features of an object-oriented programming language.</li> </ul>			

- use the basic programming constructs of C++ in practical programs.
- explain the most important functions of a modern development environment and use them to create programs.
- explain the problem of proving the correctness of a program and describe and apply a systematic test methodology to reduce bugs.
- successfully demonstrate the practical application of the lessons learned in a medium-sized programming task (=practical course).

#### Content

- Introduction: object orientation and C++
- Development environment and runtime environment
- Memory management, references
- Classes, inheritance, polymorphism
- Dynamic polymorphism in C++
- Generic modules based on templates
- Static polymorphism based on templates
- Metaprogramming, function objects and  $\lambda$ -expressions
- STL library, iostreams library
- Potentials and effects of optimising translators in C++

#### Literature

- ECKEL, Bruce, 1995. *Thinking in C++*. Englewood Cliffs, NJ: Prentice Hall. ISBN 0-13-917709-4
- DMITROVIĆ, Slobodan, 2020. *Modern C++ for Absolute Beginners* [online]. *A Friendly Introduction to C++ Programming Language and C++11 to C++20 Standards*. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-6047-0. Available via: <https://doi.org/10.1007/978-1-4842-6047->.
- STROUSTRUP, Bjarne, 2013. *The C++ Programming Language*. Upper Saddle River, NJ ; Munich [u.a.]: Addison-Wesley. ISBN 9780321563842

#### Additional remarks

None

## Electronics, Signals and Measurement

<b>Module abbreviation</b>	AVE_ESM	<b>Reg.-Nr.</b>	9
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	2
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schmid, Maximilian		
<b>Lecturer(s)</b>	Elger, Gordon; Schmid, Maximilian (AVE_ESM) Elger, Gordon; Schmid, Maximilian; Streck, Egor (AVE_PractESM)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	9.1: Electronics, Signals and Measurement 9.2: Practical Course Electronics, Signals and Measurement		
<b>Lecture types</b>	9.1: SU/Ü - lecture with integrated exercises 9.2: Pr - laboratory		
<b>Examinations</b>			
9.1: schrP90 - written exam, 90 minutes 9.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. Successful completion of the practical course is a prerequisite for admission to the written examination. The practical course is considered to have been successfully passed if the required simulation programs have been independently created for all topics, these function without errors and the programs have been handed in on time.			
<b>Prerequisites according examination regulation</b>			
Prerequisite for participation in the written examination is a successfully completed practical course.			
<b>Recommended prerequisites</b>			
Mathematics I + II Foundations of Engineering Sciences			
<b>Objectives</b>			
After successfully completing the module, students shall be able to			
<ul style="list-style-type: none"> <li>• measure DC, AC and transient voltage and current signals using multimeter and oscilloscope and evaluate correctness and accuracy of the measurements and determine sources of errors.</li> <li>• understand and apply concept of characteristic curve of linear and non linear electronic elements (resistors, inductors, capacitors, diodes, transistors).</li> <li>• apply Kirchhoff's circuit laws on circuits with linear and non linear elements.</li> <li>• understand time and frequency domain to describe time dependent signals.</li> </ul>			

- derive and solve differential equation of RLC circuits and analytically calculate transient response of first and second order RLC circuits.
- understand and apply the concept of complex impedance for AC signals and analytically calculate steady state solution of AC signals using the forced frequency approach.
- understand and apply the concept of transfer function and filter for electronic circuits.
- basically, understand the semiconductor background of diode, transistors and operational amplifiers.
- understand and analyze the basic (transistor) circuits with operational amplifiers and calculate frequency dependent gain.

#### Content

- Introduction to signals
- Fourier Transform and Fourier Series
- Sampling, and aliasing
- Kirchhoff's laws, resistor networks, resistive circuit analysis
- Circuit analysis using the node and mesh methods
- Equivalent circuits, power transfer
- Dependent sources, op-amplifiers, current sources
- Capacitors and inductors
- Sinusoidal steady state response of RL- and RC-circuits
- Filters, bandwidth, Q-factor
- Transient response
- Diodes, signal conditioning, voltage regulation
- Transistors, biasing and amplification

#### Literature

- IZADIAN, Afshin, 2019. *Fundamentals of Modern Electric Circuit Analysis and Filter Synthesis*. Cham, Switzerland: Springer. ISBN 978-3-030-02484-0
- DUNN, Patrick F., 2014. *Measurement and data analysis for engineering and science*. Boca Raton, Fla. [u.a.] : CRC Press. ISBN 978-1-4665-9496-8

#### Additional remarks

None

<b>Model-based Software Engineering</b>			
<b>Module abbreviation</b>	AVE_MBSE	<b>Reg.-Nr.</b>	10
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	3
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Ebert, Bernd Martin (AVE_MBSE) Ebert, Bernd Martin (AVE_PractMBSE)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	6 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	80 h	
	Total	150 h	
<b>Subjects of the module</b>	10.1: Model-based Software Engineering 10.2: Practical Course Model-based Software Engineering		
<b>Lecture types</b>	10.1: SU/Ü - lecture with integrated exercises 10.2: Pr - laboratory		
<b>Examinations</b>			
10.1: schrP90 - written exam, 90 minutes 10.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. To successfully complete the practical course, participants have to complete 3 (three) out of 5 (five) assignments and to present their independently acquired solutions to the weekly exercise sheets at least two (2) times.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section. Prerequisite for participation in the written examination is a successfully completed practical course.			
<b>Recommended prerequisites</b>			
Basic knowledge of object orientation Basic knowledge of programming in C++, Python or Java Basic knowledge of algorithms and data structures			
<b>Objectives</b>			
After successfully completing this module the students shall be able to <ul style="list-style-type: none"> <li>understand what a meta-model is and explain the benefits and pitfalls of model-based-software development.</li> <li>understand and apply the concept of object-oriented software development.</li> <li>are able to apply and assess different modeling techniques using UML.</li> <li>understand the relationship between model and implemented code.</li> </ul>			

- model structural characteristics of software by using class diagrams, object diagrams, and package diagrams.
- model behavioral characteristics of software by using use case diagrams, state machine diagrams, sequence diagrams and activity diagrams.
- know the basic architectural principles.
- have an overview of most common SW design patterns and how they are use.

#### Content

- MBSE principles and use cases
- Object oriented programming
- UML
- MDA Model Driven Architecture
- OCL Object constraint language
- Software Aritecture Patterns
- Software Design Patterns
- Model-to-model transformations
- Model-to-text transformations: code generation
- Model quality
- SysML

#### Literature

- SEIDL, Martina and Neil PITMAN, 2015. *UML @ Classroom: an introduction to object-oriented modeling*. Cham [u.a.]: Springer. ISBN 978-3-319-12741-5, 978-3-319-12742-2
- FRIEDENTHAL, Sanford, Alan MOORE and Rick STEINER, 2015. *A practical guide to SysML: the systems modeling language*. Waltham, MA: Elsevier/Morgan Kaufmann. ISBN 978-0-12-800800-3, 0-12-800800-8
- BRAMBILLA, Marco, Jordi CABOT and Manuel WIMMER, 2017. *Model-driven software engineering in practice*. [San Rafael, Calif.]: Morgan & Claypool Publishers. ISBN 978-1-62705-988-6

#### Additional remarks

None

## Vehicle Dynamics

<b>Module abbreviation</b>	AVE_VehDyn	<b>Reg.-Nr.</b>	11
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	3
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Arnold, Armin		
<b>Lecturer(s)</b>	Arnold, Armin		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Vehicle Dynamics		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Foundations of Engineering Sciences			
<b>Objectives</b>			
<p>After successfully completing the module the students shall be able to</p> <ul style="list-style-type: none"> <li>• explain and judge all tire properties that are important for vehicle dynamics.</li> <li>• calculate according to some simplified vehicle models.</li> <li>• analyse how drivetrain, brakes and other chassis components work together, e.g. like control arms, spring rates, position of center of gravity, differentials including limited slip differentials, torque-vectoring-differentials.</li> <li>• explain ABS-control.</li> <li>• explain vehicle stability control systems.</li> <li>• deduct the additional possibilities given by four-wheel-steering, torque-vectoring and active suspensions.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Tire and tire properties under different conditions (camber, normal force, combinations of longitudinal and/or lateral slip, Kamm's circle and its application)</li> <li>• Vehicle models (Single track model, dual track model)</li> <li>• Influencing driving behaviour by suspension (roll- and instant-centre), spring stiffness, position of centre of gravity, and distribution of driving- and braking-torques</li> <li>• ABS</li> <li>• Vehicle stability control</li> </ul>			

- Torque vectoring

#### Literature

- REIMPELL, Jörn, 2001. *The automotive chassis: engineering principles: chassis and vehicle overall, wheel suspensions and types of drive, axle kinematics and elastokinematics, steering - springing - tyres, construction and calculations advice*. Oxford [u.a.]: Butterworth-Heinemann. ISBN 0-7506-5054-0, 978-0-7506-5054-0
- MILLIKEN, William, 1995. *Race car vehicle dynamics*. ISBN 1-56091-526-9, 978-1-56091-526-3
- GENTA, Giancarlo, MORELLO, Lorenzo, 2020. *The Automotive Chassis: Volume 1: Components Design* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-030-35635-4. Available via: <https://doi.org/10.1007/978-3-030-35635-4>.
- HANEY, Paul, 2012. *The racing & high-performance tire: using the tires to tune for grip and balance*. Dallas, Tex. [u.a.]: InfoTire [u.a.]. ISBN 0-9646414-2-9, 978-0-7680-12415

#### Additional remarks

None

<b>Modelling and Simulation</b>			
<b>Module abbreviation</b>	AVE_ModSim	<b>Reg.-Nr.</b>	12
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	3
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schiele, Thomas		
<b>Lecturer(s)</b>	Schiele, Thomas (AVE_ModSim) Schiele, Thomas (AVE_PractModSim)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	12.1: Modelling and Simulation 12.2: Practical Course Modelling and Simulation		
<b>Lecture types</b>	12.1: SU/Ü - lecture with integrated exercises 12.2: Pr - laboratory		
<b>Examinations</b>			
12.1: schrP90 - written exam, 90 minutes 12.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
<p>As part of the practical course several audits (focussing on derivation, implementation and validation of real experimental setups as simulation models in MATLAB/Simulink) must be obtained. Upon successful completion of the predefined tasks, the lecturer will award one certificate for each audit. A total of five out of six audits must be completed successfully by each group. The final solutions have to be presented by the practical course groups within a fixed time frame (one audit every 7-14 days), whereby questions about the solution concept and the programs and models created must also be answered. Only if at least five of the six audits are completed on time the practical course will be graded as successfully completed.</p> <p>Participating in the practical course means that five of six audits have been taken in person and on time.</p>			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Mathematics 1 + 2 Electronics, Signals and Measurement Foundations of Engineering Sciences			
<b>Objectives</b>			
<p>After a successful participation of this course students are able</p> <ul style="list-style-type: none"> <li>• to investigate real technical systems, to structure them into appropriate subsystems and derive suitable differential equations or systems of differential equations.</li> </ul>			

- to implement and simulate simple physical or experimental modeling approaches (script and block-diagram-based implementation methods).
- to analyze physical model approaches (stability, stiffness, ...), simplify them if needed or useful (linearization, ...), parametrize the models and do plausibility checks of simulation results.
- to choose a suitable solver based on the results of model/differential equation analysis and define the necessary parameters of the respective solver algorithm (step size, tolerances, ...).
- to make use of different mathematical or experimental approaches to determine or optimize system parameters
- to validate implemented models based on data sets generated from real system measurements.

After successful participation of the practical course students are able to:

- apply different methods (discussed in the lecture) to derive differential equations of electrical, mechanical and electro-mechanical systems
- use standard implementation methods in Matlab/Simulink
- determination and optimization of model parameters based on methods discussed during the lecture
- validate the implemented models using measurement data generated during lab experiments

### Content

- Methodological approaches to derive ordinary differential equations from simple electrical and mechanical systems
- Different methods to implement linear and non-linear differential equations in Matlab/Simulink (transfer functions, state space representation, ...)
- Laplace-Transformation and its fields of application (implementation and analysis of LTI-systems)
- Differentiation between physical and experimental modeling approaches
- Methods to linearize non-linear problems
- Different methods to parameterize simulation models or optimize model parameters
- Analysis of differential-equation-based model approaches focusing on stability and (time based) dynamic behavior
- Validation of simulation models based on real measurement data
- Problem-based selection of suitable solver algorithms (fixed-step or variable-step solvers)

Practical Course:

- Introduction into implementation of dynamic systems in Matlab/Simulink
- Implementation and parameter identification of a non-linear mechanical system (comparison between mathematical and physical pendulum model)
- Modeling, implementation, validation and parameter optimization of a linear electrical system (oscillating circuit)
- Modeling, implementation, validation and parameter optimization of a switched electrical system (DC-DC converter, buck converter)
- Implementation and validation of electromechanical systems (simple vehicle, DC-motor to lift a mass, crane trolley system)

### Literature

- ESFANDIARI, Ramin S. and Bei LU, 2018. *Modeling and analysis of dynamic systems*. Boca Raton ; London ; New York: CRC Press. ISBN 978-1-1387-2642-0
- CLOSE, Charles M., Dean K. FREDERICK and Jonathan C. NEWELL, 2002. *Modeling and analysis of dynamic systems*. New York: Wiley. ISBN 0-471-39442-4
- ISERMANN, Rolf, MÜNCHHOF, Marco, 2011. *Identification of Dynamic Systems: An Introduction with Applications* [online]. Berlin, Heidelberg: Springer Berlin Heidelberg PDF e-Book. ISBN 978-3-540-78879-9. Available via: <https://doi.org/10.1007/978-3-540-78879-9>.
- CHATURVEDI, Devendra K., 2010. *Modeling and simulation of systems using MATLAB and Simulink*. Boca Raton, Fla. [u.a.]: CRC Press. ISBN 978-1-439-80672-2, 1-439-80672-1
- HOSSAIN, Eklas, 2022. *MATLAB and Simulink Crash Course for Engineers* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-030-89762-8. Available via: <https://doi.org/10.1007/978-3-030-89762-8>.

<b>Additional remarks</b>
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None
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<b>Digital Signal Processing</b>			
<b>Module abbreviation</b>	AVE_DiSigProc	<b>Reg.-Nr.</b>	13
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	3
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Mecking, Michael		
<b>Lecturer(s)</b>	Mecking, Michael (AVE_DiSigProc) Mecking, Michael (AVE_PractDiSigProc)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	13.1: Digital Signal Processing 13.2: Practical Course Digital Signal Processing		
<b>Lecture types</b>	13.1: SU/Ü - lecture with integrated exercises 13.2: Pr - laboratory		
<b>Examinations</b>			
13.1: schrP90 - written exam, 90 minutes 13.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. The practical course is considered to be passed successfully if the required simulation programs have been created independently for all topics, yield the desired results and have been handed in on time.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section. Prerequisite for participation in the written examination is a successfully completed practical course.			
<b>Recommended prerequisites</b>			
thorough understanding of complex calculus and mathematical analysis			
<b>Objectives</b>			
<p>Upon completion of the module, students will be able to</p> <ul style="list-style-type: none"> <li>• Represent and manipulate signals in the time and frequency domain.</li> <li>• Describe and analyse the properties of discrete-time linear systems in the time and frequency domain using discrete-time transforms.</li> <li>• Design linear discrete-time filters with prescribed properties.</li> <li>• Evaluate different realisations of discrete-time systems based on canonical structures.</li> <li>• Understand the impact of finite word-length effects in the realisation of discrete-time systems.</li> <li>• Determine the limitations and impact of sampling and quantisation on the conversion of analogue to digital signals.</li> <li>• Apply (fast) Fourier-Transforms to analyse and realise discrete-time signal processing systems.</li> </ul>			

- Use MATLAB to analyse and synthesise discrete-time signals and systems.

#### Content

- Discrete-time signals and systems: description in the time-domain, impulse response, convolution, linearity, time-invariance, causality, stability
- Frequency-domain representation: frequency response, discrete-time Fourier-Transform and its properties
- Analysis of LTI-systems: the z-Transform and its properties, system transfer function, allpass and minimum phase systems, linear-phase systems
- Sampling and reconstruction of band-limited signals, analogue-to-digital conversion, quantisation
- Design of digital filters with prescribed properties using windowing techniques, optimisation, the bilinear transform as well as band-transforms
- Realisation of discrete-time filters: filter structures and signal flow graphs, transposition methods, canonical as well as cascade and parallel architectures
- Digital multi-rate systems, decimation and interpolation, oversampling analogue-to-digital conversion
- The Discrete Fourier-Transform and fast algorithms (FFT) using decimation in time and frequency, applications of the DFT

#### Literature

- OPPENHEIM, Alan V. and Ronald W. SCHAFER, 2014. *Discrete-time signal processing*. Harlow: Pearson. ISBN 978-1-292-03815-5
- ANTONIOU, A., 2017. *Digital Filters - Analysis, Design and Signal Processing Applications*. ISBN 0071846034
- VAIDYANATHAN, P. P., 2024. *Signals, systems, and signal processing*. Cambridge: Cambridge University Press. ISBN 978-1-00-941229-2

#### Additional remarks

None

## Software Development Processes

<b>Module abbreviation</b>	AVE_SWDevProc	<b>Reg.-Nr.</b>	15
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	4
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Bublitz, Lucas; Schewik, Timo		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Software Development Processes		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
mdIP - oral exam - 15 - 30 min.			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Programming in C++ or Python Model based software engineering			
<b>Objectives</b>			
After successfully completing this module the students shall be able to			
<ul style="list-style-type: none"> <li>• know the major building blocks of the complete software development life cycle.</li> <li>• understand the difference between classical and agile development methods.</li> <li>• asses and apply the best suitable development methodology for a software development project.</li> <li>• collect and manage requirements.</li> <li>• apply methods of software testing.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Overall software engineering process: system analysis, requirements engineering, software design / architecture, software test: verification and validation, software maintenance and operation</li> <li>• Process models: waterfall, spiral model, v-Model (XT)</li> <li>• Agile methods: extreme programming, Kanban, Scrum</li> <li>• Software project management</li> </ul>			

<b>Literature</b>
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- HALL THAYER, Richard and Merlin DORFMAN, 2012. *SOFTWARE ENGINEERING ESSENTIALS, Volume I: The Development Process*. Carmichael, California: Software Management Training Press. ISBN 978-0985270704
- DAJSUREN, Yanja, DEN BRAND, Mark van, 2019. *Automotive systems and software engineering: state of the art and future trends* [online]. Cham: Springer PDF e-Book. ISBN 978-3-030-12157-0. Available via: <https://doi.org/10.1007/978-3-030-12157-0>.
- WANG, Yingxu and Graham KING, 2000. *Software engineering processes: principles and applications*. Boca Raton [u.a.]: CRC Press. ISBN 0-8493-2366-5

<b>Additional remarks</b>
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None
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<b>Foundations of Machine Learning</b>			
<b>Module abbreviation</b>	AVE_ML	<b>Reg.-Nr.</b>	16
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	4
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Botsch, Michael		
<b>Lecturer(s)</b>	Botsch, Michael (AVE_ML) Fertig, Alexander; Kalyana Sundaram, Abinav (AVE_PractML)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	16.1: Foundations of Machine Learning 16.2: Practical Course Foundations of Machine Learning		
<b>Lecture types</b>	16.1: SU/Ü - lecture with integrated exercises 16.2: Pr - laboratory		
<b>Examinations</b>			
16.1: schrP90 - written exam, 90 minutes 16.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. Successful completion of the practical course is a prerequisite for admission to the written examination. The practical course is considered to be passed successfully if the required machine learning problems have been created independently for all topics, yield the desired results and have been handed in on time.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section.			
<b>Recommended prerequisites</b>			
Programming 1 and 2 Math 1 and 2 (Linear Algebra and Calculus) Statistics 1			
<b>Objectives</b>			
After a successful participation of this course students are able to <ul style="list-style-type: none"> <li>• understand statistical machine learning.</li> <li>• identify ML potential and limitations in application domains.</li> <li>• choose appropriate ML methods, models, and algorithms for a given problem.</li> <li>• analyze properties of ML models and algorithms.</li> <li>• apply ML algorithms in detail to particular datasets.</li> <li>• implement preprocessing, models, training and evaluation in Python.</li> </ul>			

## Content

- Generalization and validation
- Classification
- Linear models
- Decision trees
- Ensembles
- Neural networks
- Convolutions and image processing
- Recurrency and sequence processing
- Attention and transformers
- Unsupervised learning and generative models

## Literature

- MURPHY, Kevin P., 2022. *Probabilistic machine Learning: an introduction*. Cambridge, Massachusetts: The MIT Press. ISBN 978-0-262-04682-4
- VAN DER PLAS, Jake. *Python Data Science Handbook* [online]. [Accessed on: ]. Available via: <https://jakevdp.github.io/PythonDataScienceHandbook/>
- GÉRON, Aurélien, 2023. *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: concepts, tools, and techniques to build intelligent systems*. Beijing ; Boston ; Farnham ; Sebastopol ; Tokyo: O'Reilly. ISBN 978-1-0981-2597-4

## Additional remarks

None

<b>Vehicle Electronics and Vehicle Communication Networks</b>			
<b>Module abbreviation</b>	AVE_VECS	<b>Reg.-Nr.</b>	17
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	4
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Brandmeier, Thomas		
<b>Lecturer(s)</b>	Bauernfeind, Jonas; Lugner, Robert; Sequeira, Gerald; Zdetski, Dennis (AVE_VECS) Huber, Robert; Vazquez Munoz, Alvaro; Zdetski, Dennis (AVE-PractVECS)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours		70 h
	Self-study		105 h
	Total		175 h
<b>Subjects of the module</b>	17.1: Vehicle Electronics and Vehicle Communication Networks 17.2: Practical Course Vehicle Electronics and Vehicle Communication Networks		
<b>Lecture types</b>	17.1: SU/Ü - lecture with integrated exercises 17.2: Pr - laboratory		
<b>Examinations</b>			
17.1: schrP90 - written exam, 90 minutes 17.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. Practical course: To earn the proof of participation all given exercises have to be completed and documented.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Electronics, Signals, and Measurement Digital Signal Processing			
<b>Objectives</b>			
After successfully completing this module the students shall be able to <ul style="list-style-type: none"> <li>• have an overview of vehicle electronics, especially in the automotive sector.</li> <li>• understand the latest developments in automotive technology.</li> <li>• use electrotechnical fundamentals to describe the development and manufacturing of vehicle components such as sensors, actuators and bus systems.</li> <li>• know the basics of software architecture for vehicle electronic systems / control units.</li> </ul>			

### Content

- Introduction to automotive electric standards
- Electronic components of vehicle systems (sensors, control units, actors)
- Vehicle communication systems (LIN, CAN, TTP, Flexray, Ethernet,...),
- Driver assistance systems and slip control systems (ABS, ESP),
- Selected drive-by-wire applications and vehicle dynamics control systems

### Literature

- ROBERT BOSCH GMBH (ED.), 2014. *Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive* [online]. PDF e-Book. ISBN 978-3-658-01784-2. Available via: <https://doi.org/10.1007/978-3-658-01784-2>.
- RIBBENS, William B., 2013. *Understanding automotive electronics: an engineering perspective* [online]. Amsterdam [u.a.]: Elsevier, Butterworth-Heinemann PDF e-Book. ISBN 978-0-08-097097-4, 978-0-08-097097-4. Available via: <http://www.sciencedirect.com/science/book/9780080970974>.
- WANG, Yunpeng and others, 2017. *Connected vehicle systems: communications, data, and control*. Boca Raton: CRC Press, Taylor & Francis Group. ISBN 978-1-138-03587-4
- MÖLLER, Dietmar, HAAS, Roland E., 2019. *Guide to automotive connectivity and cybersecurity: trends, technologies, innovations and applications* [online]. Cham: Springer PDF e-Book. ISBN 978-3-319-73512-2. Available via: <https://doi.org/10.1007/978-3-319-73512-2>.

### Additional remarks

None

<b>Control Engineering</b>			
<b>Module abbreviation</b>	AVE_CtrlEng	<b>Reg.-Nr.</b>	18
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	4
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Kefferpütz, Klaus		
<b>Lecturer(s)</b>	Kefferpütz, Klaus (AVE_CtrlEng) Huber, Stephan (AVE_PractCtrlEng)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	8 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	130 h	
	Total	200 h	
<b>Subjects of the module</b>	18.1: Control Engineering 18.2: Practical Course Control Engineering		
<b>Lecture types</b>	18.1: SU/Ü - lecture with integrated exercises 18.2: Pr - laboratory		
<b>Examinations</b>			
18.1: schrP90 - written exam, 90 minutes 18.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course. Successful completion of the practical course requires successful participation of all 6 lab course appointments and a detailed understanding of the corresponding content. The basic requirement for this is a punctual and prepared attendance at the lab course date.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Mathematics I + II Modelling and Simulation			
<b>Objectives</b>			
After successfully completing this module the students shall be able to			
<ul style="list-style-type: none"> <li>analyze control systems and create models in the time and frequency domain.</li> <li>analyze systems with regards to dynamics, oscillatory behavior and stability.</li> <li>understand the system specifications which a closed-loop circuit must fulfill.</li> <li>evaluate and select suitable controller structures in accordance to the specifications.</li> <li>apply different methods to parameterize the controller structures and analyze the results in simulations.</li> <li>apply and implement the controller structures digitally on a microprocessor.</li> <li>solve control tasks independently, evaluate and document the results according to scientific criteria.</li> </ul>			

Successful completion of the practical course requires successful participation of all 6 lab course appointments and a detailed understanding of the corresponding content. The basic requirement for this is a punctual and prepared attendance at the lab course date.

#### Content

- Creation of models for dynamical systems
- System description and representation in the time and frequency domain
- Elementary control loop elements
- Control loops: requirements, behavior, design
- Controller synthesis: root locus / Bode diagram / full-state feedback / empirical approach
- Description and analysis of SISO systems in the state space
- Controller design for SISO systems in the state space
- Implementation of control algorithms
- Introduction to the control functions of the MATLAB / SIMULINK software package

#### Literature

- FRANKLIN, Gene , David POWELL and Abbas EMAMI-NAEINI, 2020. *Feedback control of dynamic systems* . Boston: Pearson. ISBN 978-1-292-27452-2
- SUN, Jing, 2018. *Control engineering: fundamentals* [online]. Berlin: De Gruyter PDF e-Book. ISBN 978-3-11-057327-5. Available via: <https://doi.org/10.1515/9783110573275>.
- OGATA, Katsuhiko , 2010. *Modern control engineering* . Upper Saddle River: Pearson. ISBN 978-0-13-713337-6

#### Additional remarks

In case of non-participation of a practical examination, the type of examination may change.

<b>Scientific Seminar</b>			
<b>Module abbreviation</b>	AVE_SciSem	<b>Reg.-Nr.</b>	19
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	4
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Ebert, Bernd Martin; Huber, Werner; Schiele, Thomas		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	3 ECTS / 2 SWS		
<b>Workload</b>	Contact hours	23 h	
	Self-study	52 h	
	Total	75 h	
<b>Subjects of the module</b>	Scientific Seminar		
<b>Lecture types</b>	S - seminar		
<b>Examinations</b>			
seminar paper and presentation			
<b>Additional explanations regarding examinations</b>			
<p>The seminar paper is a term paper with an oral presentation. According to the APO, the term paper is 3000 to 6000 words and approx. 10 to 20 pages. The term paper is to be written with a word processing software. The oral presentation has a length of 30 to 45 minutes and can also take place during the semester.</p> <p>By submitting the paper you have to give a declaration of authorship. Any usage of AI-Tools has to be mentioned. Every used prompt and the AI -tools' response has to be added to the appendix of the paper. Violation of these rules is equivalent to a violation of the declaration of authorship and leads to a failure in the examination.</p>			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Basic knowledge of good scientific practice			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>independently acquire specific specialist knowledge (literature work, analysis, conclusions).</li> <li>present comprehensibly using suitable media.</li> <li>follow a technical talk critically and discuss the content professionally.</li> <li>strengthen their interdisciplinary and communicative competences.</li> <li>summarize the content of their presentation in the form of a brief written elaboration.</li> </ul>			
<b>Content</b>			
The technical topic of the seminar changes from course to course. The subject is mostly embedded into an area closely related to the degree programme. Literature is provided by the respective lecturer and serves as basis for the presentation and written elaboration.			

<b>Literature</b>
Will be specified at the beginning
<b>Additional remarks</b>
None

## Vehicle-to-X-Communication

<b>Module abbreviation</b>	AVE_V2X	<b>Reg.-Nr.</b>	20
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	6
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Festag, Andreas		
<b>Lecturer(s)</b>	Festag, Andreas		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Vehicle-to-X-Communication		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Foundations of Engineering Sciences Vehicle Electronics and Vehicle Communication Networks			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>understand the layered design of communication networks.</li> <li>explain the principles and application of protocols in communication networks for reliable communication, media access, routing and transport control.</li> <li>describe the application, use cases and requirements for Vehicle-to-X communication networks.</li> <li>describe the architectures and communication technologies for Vehicle-to-X communication.</li> <li>understand the advantages and disadvantages of existing Vehicle-to-X systems.</li> <li>evaluate current and future proposals of architectures for Vehicle-to-X communication networks.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>The mobile radio channel, digital modulation schemes (e.g., PSK, QAM) and OFDM signalling</li> <li>Channel capacity, error correction and detection</li> <li>Reliable communication over error prone channels using ARQ schemes (e.g., stop-and-wait, go-back-N, selective repeat)</li> <li>Media access of wireless channels (ALOHA, CSMA with collision detection and avoidance)</li> <li>Examples of wireless communication systems, 5G-cellular and WiFi Vehicle-to-X communication systems</li> </ul>			

- IP mobility support, ad hoc networking and congestion control for Vehicle-to-X
- Vehicle-to-X data security, anonymity and standardisation
- Vehicle-to-X use cases and applications (e.g., sensor data sharing, maneuver coordination)
- Future developments and outlook

#### Literature

- KUROSE, James F. and Keith W. ROSS, 2022. *Computer networking: a top-down approach*. Harlow: Pearson. ISBN 978-1-292-40546-9, 1-292-40546-5
- TANENBAUM, Andrew S., Nick FEAMSTER and David WETHERALL, 2021. *Computer networks*. Harlow: Pearson. ISBN 978-1-292-37406-2
- SOMMER, Christoph and Falko DRESSLER, 2015. *Vehicular networking*. Cambridge: Cambridge Univ. Press. ISBN 978-1-107-04671-9
- CAMPOLO, Claudia, 2015. *Vehicular ad hoc networks: standards, solutions, and research* [online]. Cham [u.a.]: Springer PDF e-Book. ISBN 978-3-319-15497-8, 978-3-319-15496-1. Available via: <https://doi.org/10.1007/978-3-319-15497-8>.

#### Additional remarks

None

<b>Team Project</b>			
<b>Module abbreviation</b>	AVE_PROJ	<b>Reg.-Nr.</b>	21
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	6
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Geisler, Markus; Giesler, Björn; Roth, Carla; Sequeira, Gerald; Ulreich, Fabian; Yan, Zhiran		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	8 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	153 h	
	Total	200 h	
<b>Subjects of the module</b>	Team Project		
<b>Lecture types</b>	Proj - project		
<b>Examinations</b>			
Project report and oral presentation 15 min.			
<b>Additional explanations regarding examinations</b>			
The project work is a group work in which several students work on a common task in a team. Each student has to contribute individually to the joint task, submit a project report and present the results orally. According to the APO, the scope of the project report is 1500 words to 7500 words or approx. 5 to 25 pages, the scope of the oral presentation is 15 to 45 minutes according to the APO. The project report is to be written with a word processing programme.			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Scientific Seminar Software Development Processes Basic problem solving skills			
<b>Objectives</b>			
After successfully completing this module the students shall be able to			
<ul style="list-style-type: none"> <li>organize themselves in a team, discuss the project in varying but always appropriate detail, report progress in oral and/or written form.</li> <li>apply the competencies acquired during their studies in order to analyze a complex technical task and work on it successfully in a team over a semester.</li> <li>deal with technical and non-technical problems. that may occur during the implementation of a project lasting several weeks.</li> <li>critically question the goals of the project and consider them in the sense of an overall success of the project.</li> <li>present project results convincingly in front of an audience.</li> </ul>			

- write a focused report containing: analysis, solution concept and implementation.

**Content**

Working on a project in the field of electrical engineering and information technology in a team. Topics are compiled every semester, according to the tasks from the laboratories and research facilities as well as the offers from companies.

**Literature**

Will be specified at the beginning

**Additional remarks**

None

## Sensor Data Processing and Sensor Data Fusion

<b>Module abbreviation</b>	AVE_SDPF	<b>Reg.-Nr.</b>	22
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	6
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Kefferpütz, Klaus		
<b>Lecturer(s)</b>	Kefferpütz, Klaus (AVE_SDPF) Zieher, Simon (AVE_PractSDPF)		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	7 ECTS / 6 SWS		
<b>Workload</b>	Contact hours	70 h	
	Self-study	105 h	
	Total	175 h	
<b>Subjects of the module</b>	22.1: Sensor Data Processing and Sensor Data Fusion 22.2: Practical Course Sensor Data Processing and Sensor Data Fusion		
<b>Lecture types</b>	22.1: SU/Ü - lecture with integrated exercises 22.2: Pr - laboratory		
<b>Examinations</b>			
22.1: schrP90 - written exam, 90 minutes 22.2: LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
Prerequisite for participation in the written examination is a successfully completed practical course.			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Mathematics I + II Digital Signal Processing Programming I + II Electronics, Signals, and Measurements Control Engineering			
<b>Objectives</b>			
After successfully completing this module the students shall be able to			
<ul style="list-style-type: none"> <li>understand the fundamental principles in estimation and detection theory.</li> <li>implement algorithms for parameter estimation in linear and nonlinear models and for detection and estimation of the position of a target in a sensor network.</li> <li>apply the Kalman filter to linear state space models with a multitude of sensors.</li> <li>apply nonlinear filters (extended Kalman filter, unscented Kalman filter, particle filter) to nonlinear or non-Gaussian state space models.</li> <li>implement basic algorithms for simultaneous localization and mapping (SLAM).</li> <li>describe and model the most common sensors used in sensor fusion applications.</li> </ul>			

- implement the most common motion models in target tracking and navigation applications.
- understand the interplay of the above in a few concrete real applications.

#### Content

- Estimation theory for linear and nonlinear models
- Cramér-Rao lower bound (CRLB). Models for sensor network applications
- Detection and Filter theory
- Modeling and motion models
- Kalman filter. Kalman filter approximations for nonlinear models (EKF, UKF)
- The point-mass filter and the particle filter
- The particle filter theory
- The marginalized particle filter
- Simultaneous localization and mapping (SLAM)
- Sensors and sensor-near signal processing. Filter and model validation

#### Literature

- GUSTAFSSON, Fredrik, 2018. *Statistical sensor fusion*. Lund: Studentlitteratur. ISBN 978-91-44-12724-8, 91-44-12724-3
- MITCHELL, Harvey B., 2007. *Multi-sensor data fusion: an introduction* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 978-1-61583-489-1, 978-3-540-71463-7. Available via: <https://doi.org/10.1007/978-3-540-71559-7>.
- GIBBS, Bruce. P., © 2011. *Advanced kalman filtering, least-squares and modeling: a practical handbook* [online]. Hoboken, N.J.: Wiley PDF e-Book. ISBN 978-0-470-89003-5, 0-470-89003-7. Available via: <https://onlinelibrary.wiley.com/doi/book/10.1002/9780470890042>.

#### Additional remarks

None

## Planning and Decision-Making Algorithms

<b>Module abbreviation</b>	AVE_PDMA	<b>Reg.-Nr.</b>	23
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	6
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Hagerer, Andreas		
<b>Lecturer(s)</b>	Hagerer, Andreas		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Planning and Decision-Making Algorithms		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Foundations of Machine Learning Algorithms and Data Structures			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>understand the basic principles of planning and decision making.</li> <li>understand the hierarchical structure of autonomous vehicle decision-making (strategic, tactical, and reactive planning)</li> <li>implement and evaluate key planning algorithms such as A*, Dijkstra's, RRT, RRT*, and potential fields</li> <li>apply probabilistic decision-making techniques to handle uncertainty</li> <li>design and simulate behavior prediction and trajectory planning modules</li> <li>use simulation environments to test and validate planning systems</li> </ul>			
<b>Content</b>			
<ol style="list-style-type: none"> <li>Introduction to Planning and Decision-Making <ul style="list-style-type: none"> <li>What is planning? What is decision-making?</li> <li>Everyday examples (e.g., navigation apps, robot vacuums, game AI)</li> </ul> </li> <li>Foundations of Planning Algorithms <ul style="list-style-type: none"> <li>graph-based search: A*, Dijkstra's, D* Lite</li> <li>grid-based and road-network planning</li> </ul> </li> </ol>			

- heuristic design and optimality vs. speed trade-offs
- 3. Classical Decision Algorithm
  - problem formulation
  - languages of planning problems
  - heuristics for state-space search
- 4. Route Planning Algorithms
  - static routing
  - exploiting hierarchy
- 5. Behavior Planning
  - Finite State Machines
  - Behaviour Trees
  - Sequential Decision Processes
- 6. Motion Planning
  - combinatorial path planning
  - sampling-based path planning

#### Literature

- LAVALLE, Steven Michael, 2006. *Planning algorithms* [online]. Cambridge: Cambridge University Press PDF e-Book. ISBN 978-0-511-54687-7. Available via: <https://doi.org/10.1017/CBO9780511546877>.
- EDELKAMP, Stefan and Stefan SCHRÖDL, © 2012. *Heuristic search: theory and applications*. Amsterdam: Elsevier/Morgan Kaufmann. ISBN 978-0-12-372512-7, 0-12-372512-7
- SUTTON, Richard S. and Andrew BARTO, 2020. *Reinforcement learning: an introduction*. Cambridge, Massachusetts ; London, England: The MIT Press.
- LAPAN, Maxim, January 2020. *Deep reinforcement learning hands-on: apply modern RL methods to practical problems of chatbots, robotics, discrete optimization, web automation, and more*. Birmingham ; Mumbai: Packt. ISBN 978-1-83882-004-6

#### Additional remarks

None

## Vehicle Actuators

<b>Module abbreviation</b>	AVE_VehAct	<b>Reg.-Nr.</b>	24
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	6
<b>Module frequency</b>	only summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Birkner, Christian		
<b>Lecturer(s)</b>	Birkner, Christian; Tolksdorf, Leon		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Vehicle Actuators		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
Eligibility to enter the second study section			
<b>Recommended prerequisites</b>			
Foundations of Engineering Sciences Vehicle Dynamics Modelling and Simulation			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>question and classify the functionality and operating principles of specific mechatronic systems.</li> <li>develop independent interpretations for mechatronic systems and evaluate them in a targeted manner.</li> <li>gain a well-founded understanding of important sensors for AD-related mechatronics and describe them in technical detail.</li> <li>conceive and design mechatronic components of automated vehicle systems and assign these systems to the assemblies and functional units of a vehicle and describe their requirements.</li> <li>know the basics of electrical systems, vehicle bodies, drive machines, braking systems, steering systems.</li> <li>explain the powertrain in the vehicle and demonstrate the interaction in the overall network and compare powertrains in terms of design and functionality and their control strategies.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>Modeling and description of mechatronic systems and identification of the essential components</li> <li>Mathematical and functional modes of action of important sensors in automated driving and their properties (resolution, linearity, transfer functions, system identification)</li> </ul>			

- Essential actuators of mechatronic systems (electrical, piezoelectric drives)
- Function chain description of mechanical variables via electrical detection and circuitry
- Basics of data interpretation of mechatronic system states
- Mechatronic components of automated driving functions with steering, chassis and motor

#### Literature

- JOUANEH, Musa, 2013. *Fundamentals of mechatronics*. Stamford, Conn.: Cengage Learning. ISBN 978-1-111-56902-0
- SCHRAMM, Dieter, HILLER, Manfred, BARDINI, Roberto, 2018. *Vehicle Dynamics: Modeling and Simulation* [online]. Berlin, Heidelberg: Springer Berlin Heidelberg PDF e-Book. ISBN 978-3-662-54483-9. Available via: <https://doi.org/10.1007/978-3-662-54483-9>.
- BOLTON, William, 2019. *Mechatronics: electronic control systems in mechanical and electrical engineering*. Harlow, England: Pearson. ISBN 978-1-292-25100-4

#### Additional remarks

None

<b>Internship</b>			
<b>Module abbreviation</b>	AVE_Internship	<b>Reg.-Nr.</b>	27
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	5
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>			
<b>Lecturer(s)</b>	NN,		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	24 ECTS / 0 SWS		
<b>Workload</b>	Contact hours	0 h	
	Self-study	600 h	
	Total	600 h	
<b>Subjects of the module</b>	Internship		
<b>Lecture types</b>	Pr - laboratory		
<b>Examinations</b>			
Internship report			
<b>Additional explanations regarding examinations</b>			
The internship report should inform about the activities carried out during the internship. The length is 8 to 25 pages (without cover sheets and indexes). More details are specified in the curriculum. The report is to be written with a word processing programme.			
<b>Prerequisites according examination regulation</b>			
Prerequisites to start of industry internship are 1) having completed all exams of the first study section 2) having earned at least 20 ECTS out of the second study section			
<b>Recommended prerequisites</b>			
German level B1 or higher.			
<b>Objectives</b>			
After successfully completing this module the students shall be able <ul style="list-style-type: none"> <li>to apply scientific methods acquired during their studies to concrete problems.</li> <li>are aware of the future professional requirements.</li> <li>know the basic elements of everyday business life.</li> <li>are able to successfully solve tasks or subtasks on their own responsibility, which are aligned with the study progress.</li> <li>can contribute to the overall success as a member of a project team.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>Working in work and content-related operational tasks using the engineering methods learned</li> <li>Getting to know operational processes and working methods</li> </ul>			

<b>Literature</b>
Will be specified at the beginning
<b>Additional remarks</b>
None

<b>Internship Seminar</b>			
<b>Module abbreviation</b>	AVE_InternshipSem	<b>Reg.-Nr.</b>	28
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	5
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Ebert, Bernd Martin		
<b>Lecturer(s)</b>	Fuchs, Hildegard; Glavina, Bernhard; Hunsinger, Jörg; Karg, Sonja		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	2 ECTS / 1 SWS		
<b>Workload</b>	Contact hours		12 h
	Self-study		38 h
	Total		50 h
<b>Subjects of the module</b>	Internship Seminar		
<b>Lecture types</b>	S - Seminar		
<b>Examinations</b>			
LN - participation without/with success			
<b>Additional explanations regarding examinations</b>			
An oral presentation of a length of 30 to 45 minutes.			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Scientific Seminar Basic presentation skills			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>• reflect on their own project experiences in relation to those of fellow students.</li> <li>• objectively assess their presentation performance through the feedback of the other participants.</li> <li>• combine their practical experience with theoretical knowledge.</li> <li>• expand the variety of possible solutions to typical technical and methodological problems.</li> <li>• strengthen their social skills.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Introduction</li> <li>• Presentation of the topics in short presentations</li> <li>• Discussion of the contents and statements of the presentation</li> <li>• Discussion of the presentation by the speaker</li> </ul>			
<b>Literature</b>			
Will be specified at the beginning			

<b>Additional remarks</b>
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None
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<b>Business Management</b>			
<b>Module abbreviation</b>	AVE_BMgmt	<b>Reg.-Nr.</b>	29
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	5, 6
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Sobotta, Tassilo		
<b>Lecturer(s)</b>	Sobotta, Tassilo		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	4 ECTS / 2 SWS		
<b>Workload</b>	Contact hours	23 h	
	Self-study	77 h	
	Total	100 h	
<b>Subjects of the module</b>	Business Management		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
schrP90 - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>• understand and analyze business management interrelationships.</li> <li>• understand the basics of business administration.</li> <li>• put business management interrelationships together to form a well-founded overall picture of the role of business administration within the economic sciences.</li> <li>• develop professional competencies on the basis of business administration knowledge.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• The environment of business</li> <li>• Business ownership and entrepreneurship</li> <li>• Management and organization</li> <li>• Human Resources</li> </ul>			
<b>Literature</b>			
<ul style="list-style-type: none"> <li>• PRIDE, William M., Robert J. HUGHES and Jack R. KAPOOR, 2022. <i>Foundations of business</i>. Boston, MA: Cengage Learning. ISBN 978-0-357-71794-3, 0-357-71794-5</li> <li>• LOVINS, Amory and Ken WEBSTER, 2013. <i>A new dynamic: effective business in a circular economy</i>. Cowes (Isle of Wight): Ellen MacArthur Foundation Publ.. ISBN 978-0-9927784-1-5, 0-9927784-1-7</li> </ul>			

<b>Additional remarks</b>
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None
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<b>Seminar Bachelor Thesis</b>			
<b>Module abbreviation</b>	AVE-BTS	<b>Reg.-Nr.</b>	26
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	7
<b>Module frequency</b>	winter and summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>			
<b>Lecturer(s)</b>	All lecturers		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	3 ECTS / 2 SWS		
<b>Workload</b>	Contact hours		23 h
	Self-study		52 h
	Total		75 h
<b>Subjects of the module</b>	Seminar Bachelor Thesis		
<b>Lecture types</b>	S - seminar		
<b>Examinations</b>			
Colloquium			
<b>Additional explanations regarding examinations</b>			
<p>The proof of achievement is provided in the form of a colloquium.</p> <p>In the course of the seminar on the Bachelor thesis, students must participate in regular meetings with the supervising professor/lecturer (first examiner).</p>			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
Basics in good scientific practice All mandatory courses successfully completed			
<b>Objectives</b>			
<p>After attending the module the students should</p> <ul style="list-style-type: none"> <li>• know both formal and content-related requirements of a Bachelor's thesis and are familiar with the assessment criteria of which the grade will be derived.</li> <li>• be familiar with the basic scientific working methods that are to be applied in the preparation of a thesis.</li> <li>• be able to follow good scientific practice and apply scientific working methods.</li> <li>• be able to carry out their Bachelor's thesis in a structured manner (time and resource planning, outline).</li> <li>• be able to obtain the necessary information for the thesis from scientific sources.</li> <li>• be able to present and discuss interim results of their final thesis.</li> </ul>			
<b>Content</b>			
<p>The seminar on the Bachelor's thesis is held by the supervising professors/lecturers (first examiner) to accompany the Bachelor's thesis. In the seminar, the progress of the thesis in terms of content as well as the structure of the thesis is presented by the student and discussed together with the supervisor.</p>			

In terms of content, the graduates are essentially familiarised with the technique of scientific work as well as good scientific practice. By means of case studies (e.g. completed theses), students learn to better understand the challenges of writing a thesis (content structure/red thread, approach, type and scope of execution, etc.).

Under guidance, a systematic methodology for solving the problems typical of the degree programme is practised using the example of the given assignment. This includes the detailed problem analysis, the identification of a suitable theoretical or experimental solution strategy, the solution of the problem in the given time period and the documentation of the results.

<b>Literature</b>
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Will be specified at the beginning
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<b>Additional remarks</b>
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None
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<b>Bachelor Thesis</b>			
<b>Module abbreviation</b>	AVE-BT	<b>Reg.-Nr.</b>	26
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Compulsory Subject	7
<b>Module frequency</b>	winter and summer term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>			
<b>Lecturer(s)</b>	All lecturers		
<b>Language of instruction</b>	English	<b>Language of exams</b>	German/English
<b>Credit points / SWS</b>	12 ECTS / 0 SWS		
<b>Workload</b>	Contact hours	0 h	
	Self-study	300 h	
	Total	300 h	
<b>Subjects of the module</b>	Bachelor Thesis		
<b>Lecture types</b>	BA - Bachelor Thesis		
<b>Examinations</b>			
Bachelor-Thesis			
<b>Additional explanations regarding examinations</b>			
<p>Students usually look for a topic for their thesis on their own. Topics are either offered internally by professors or academic staff of the university in notices (also online), or result from the cooperation of the student with an external company. In the case of an external topic, the student must inspire a lecturer at the university with his or her topic so that the lecturer takes on the role of the first examiner. For this purpose, it is advisable to outline the topic and the planned approach in a short paper. This exposé serves to convince the lecturer desired as the first examiner.</p>			
<b>Prerequisites according examination regulation</b>			
The Bachelor thesis can be issued at the beginning of the sixth semester at the earliest; a prerequisite is the successful completion of the internship.			
<b>Recommended prerequisites</b>			
Basics in good scientific practice All mandatory courses successfully completed			
<b>Objectives</b>			
<p>After participating in the module course, the participants are able</p> <ul style="list-style-type: none"> <li>to work on a problem taken from the subject area in a qualified and independent manner according to scientific methods within a set deadline and a given budget.</li> <li>to work out a systematic and creative solution for a technical problem in the subject area.</li> <li>to determine and evaluate the limits of the proposed solution to the problem.</li> <li>to formulate a scientific problem in writing.</li> <li>to describe, document and present a problem, its classification in an overall context as well as a presentation and discussion of the problem-solving path and the results.</li> <li>to apply scientific working methods.</li> </ul>			

### Content

The Bachelor's thesis is a graduation thesis specific to the degree programme in engineering. The topic can be worked on in practice, e.g. in a company, or in research at the THI.

- Scientific analysis of a problem specific to the course of study
- Literature and patent research
- Development of a solution concept taking into account scientific, technical and operational aspects
- Evaluation of alternative solution concepts and selection of the best solution concept (technical, economic evaluation)
- Implementation of the selected solution concept of a problem specific to the course of study
- Critical analysis of the results obtained
- Project Management (especially time and budget management)
- Comprehensible and formally correct presentation and documentation of the results in the Bachelor's thesis
- Comprehensible and correct presentation of the results in the Bachelor thesis in the final presentation
- Scientific practice and scientific working methods

### Literature

Will be specified at the beginning

### Additional remarks

The thesis can be written in English or German language.

## 4.2 Science Elective

To illustrate the breadth of topics covered, some elective modules of the category 'Scientific Elective' currently offered are described below.

## Advanced C++ Programming

<b>Module abbreviation</b>	CAI_ACPP	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Berkenbrock, Gian		
<b>Lecturer(s)</b>	Berkenbrock, Gian		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	79 h	
	Total	126 h	
<b>Subjects of the module</b>	Advanced C++ Programming		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After successful participation, students are able to:</p> <ul style="list-style-type: none"> <li>• Understanding Object-Oriented Programming in C++</li> <li>• explain the C++ template mechanism</li> <li>• design and implement template data structures and functions for algorithmic problem solving,</li> <li>• understand and apply concept</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Object-oriented mechanism in C++</li> <li>• Class relations</li> <li>• Function and operator overloading</li> <li>• C++ template mechanism and the standard template library</li> <li>• Algorithms and templates</li> </ul>			
<b>Literature</b>			
<ul style="list-style-type: none"> <li>• WILL, Torsten T., 2025. <i>C++: The Comprehensive Guide</i>. Boston, MA: Rheinwerk Publishing. ISBN 978-1-4932-2626-9, 1-4932-2626-6</li> </ul>			

- DMITROVIĆ, Slobodan, 2023. *Modern C++ for absolute beginners: a friendly introduction to the C++ programming language and C++11 to C++23 standards* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-9274-7. Available via: <https://doi.org/10.1007/978-1-4842-9274-7>.
- KUSSWURM, Daniel, 2024. *Practical C++ STL Programming: Real-World Applications with C++20 and C++23* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 9798868807749. Available via: <https://doi.org/10.1007/979-8-8688-0774-9>.
- BANCILA, Marius, 2024. *Modern C++ programming cookbook: master modern C++ including the latest features of C++23 with 140+ practical recipes*. Birmingham ; Mumbai: Packt. ISBN 9781835084847

<b>Additional remarks</b>
None

## Advanced Webtechnologies

<b>Module abbreviation</b>	CAI_AWT	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Windisch, Hans-Michael		
<b>Lecturer(s)</b>	Windisch, Hans-Michael		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Advanced Webtechnologies		
<b>Lecture types</b>	SU - lecture		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
To successfully complete the module students need to pass a written exam.			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>By the end of the lecture, students will be able to</p> <ul style="list-style-type: none"> <li>• use HTML, CSS and JavaScript and TypeScript to develop web applications.</li> <li>• design web applications based on modern web application software architectures.</li> <li>• design and implement REST APIs with nodeJS.</li> <li>• develop medium sized web applications (client side) with Angular.</li> <li>• develop medium sized web applications (client side) with React.</li> <li>• design and implement React web applications with Next.js.</li> <li>• dockerize web apps and run them in docker containers.</li> </ul>			
<b>Content</b>			
<ol style="list-style-type: none"> <li>1. Client-Side Technology Stack: <ul style="list-style-type: none"> <li>○ HTML5, CSS3, JavaScript</li> <li>○ Overview of modern client-side development tools and libraries.</li> <li>○ Build tools and package managers</li> </ul> </li> <li>2. Software Architectures for Web Applications: <ul style="list-style-type: none"> <li>○ Server side page generation</li> <li>○ JS client and REST server</li> </ul> </li> </ol>			

- Server side components, server side rendering
- 3. TypeScript:
  - Introduction to TypeScript and its benefits over JavaScript.
  - Understanding TypeScript syntax and features: types, interfaces, and classes.
- 4. REST APIs:
  - Principles of RESTful architecture and its importance in web development.
  - Designing and implementing RESTful APIs.
- 5. Building Web Applications with Angular:
  - Overview of Angular framework and its core concepts.
  - Setting up an Angular project and understanding the Angular CLI.
  - Developing single-page applications (SPAs) with Angular components, services, and routing.
- 6. React:
  - Introduction to React and its component-based architecture.
  - Managing state and props in React applications.
  - Utilizing React hooks and context API for advanced state management.
- 7. Building Web Applications with React/Next.js:
  - Combining React with Next.js for server-side rendering (SSR) and static site generation (SSG).
  - Setting up a Next.js project and exploring its file-based routing system.
  - Implementing SSR, SSG, and dynamic routing in Next.js applications.
- 8. Containerizing Apps with Docker:
  - Introduction to Docker and its role in modern web development.
  - Creating and managing Docker containers for development and production.
  - Best practices for containerizing web applications and working with Docker Compose.

#### Literature

- WIERUCH, Robin, 2023. *The road to React: with React 18 and React Hooks : required knowledge: JavaScript*. [Erscheinungsort nicht ermittelbar]: [Verlag nicht ermittelbar]. ISBN 9781720043997

#### Additional remarks

Students should have a solid understanding of basic web development concepts including HTML, CSS and JavaScript.

<b>Computer Vision</b>			
<b>Module abbreviation</b>	AVE_CV	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	General Elective Subject	3,4,5,6,7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schall, Martin		
<b>Lecturer(s)</b>	Schall, Martin		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Computer Vision		
<b>Lecture types</b>	SU - lecture		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After successfully completing this module the students shall be able to</p> <ul style="list-style-type: none"> <li>• understand pinhole cameras and their geometry.</li> <li>• understand camera sensors and the Bayer filter.</li> <li>• understand convolutions in 1D and 2D.</li> <li>• understand basic computer vision operations.</li> <li>• understand the basics of artificial neural networks.</li> <li>• understand convolutional neural networks (CNNs).</li> <li>• understand stereo estimation and motion estimation.</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Affine transformations.</li> <li>• Camera models and the pinhole camera.</li> <li>• Camera sensors, Bayer filter and color spaces.</li> <li>• Convolutions in 1D and 2D.</li> <li>• Edge and corner detectors.</li> <li>• Stereo estimation.</li> <li>• Motion estimation.</li> </ul>			

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| <ul style="list-style-type: none"><li>• Image segmentation.</li><li>• Perceptron and multi-layer perceptron.</li><li>• Gradient descent and backpropagation.</li><li>• Convolutional neural networks (CNNs) and their applications.</li><li>• Autoencoders and their applications.</li><li>• U-Nets and their applications.</li></ul> |
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<b>Literature</b>
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Will be specified at the beginning
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<b>Additional remarks</b>
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None
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<b>Embedded Systems</b>			
<b>Module abbreviation</b>	AVE_EmbSys	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Specialised Elective Subject	7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Schiele, Thomas		
<b>Lecturer(s)</b>	Schiele, Thomas		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Embedded Systems		
<b>Lecture types</b>	SU - lecture		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
basic knowledge in programming, electronics and signals			
<b>Objectives</b>			
<p>After a successful participation of this course students are able</p> <ul style="list-style-type: none"> <li>to reflect the architecture and design of microcomputersystems.</li> <li>to explain interaction between hard- and software of embedded systems.</li> <li>to program embeded systems in C and analyze systems on software (debugging) and hardware level (electrical signals).</li> <li>to understand basic priniciples of interaction of embedded systems in vehicle networks.</li> <li>to explain the difference between standard and auto-code generation approaches.</li> <li>apply their theoretical knowledge in practical applications of embedded systems (software development and design of basic electrical circuits).</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>architecture of microcomputersystems</li> <li>design of microprocessors and microcontrollers</li> <li>architecture of ECU programs (main loop, interrupt-mode)</li> <li>peripherals of miicrocontrollers (ports, timers, serial communication, analog-digital-converters)</li> <li>standard communication protocols (SPI, I2C, UART, LIN, CAN, Ethernet)</li> <li>visualization and transmission of captured data</li> </ul>			

- basics of real-time operating systems (RTOS)
- programming of microcontrollers using standard programming languages (C, ...)
- model based software development and auto-code generation using Simulink

#### Literature

- JIMÉNEZ, Manuel, PALOMERA, Rogelio, COUVERTIER, Isidoro, 2014. *Introduction to Embedded Systems: Using Microcontrollers and the MSP430* [online]. PDF e-Book. ISBN 978-1-4614-3143-5. Available via: <https://doi.org/10.1007/978-1-4614-3143-5>.
- BAI, Ying, 2015. *Practical microcontroller engineering with ARM technology* [online]. Hoboken, New Jersey: Wiley PDF e-Book. ISBN 978-1-119-05839-7, 1-119-05839-2. Available via: <https://onlinelibrary.wiley.com/doi/book/10.1002/9781119058397>.
- WÜST, Klaus, 2011. *Mikroprozessortechnik: Grundlagen, Architekturen, Schaltungstechnik und Betrieb von Mikroprozessoren und Mikrocontrollern ; mit 44 Tabellen* [online]. Wiesbaden: Vieweg + Teubner PDF e-Book. ISBN 978-3-8348-0906-3, 978-3-8348-9881-4. Available via: <https://doi.org/10.1007/978-3-8348-9881-4>.
- FLIK, Thomas, 2005. *Mikroprozessortechnik und Rechnerstrukturen* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 3-540-22270-7, 978-3-540-22270-5. Available via: <https://doi.org/10.1007/b137981>.

#### Additional remarks

None

## Basic Principles of Driver Assistance Systems and Automated Driving

<b>Module abbreviation</b>	EMB_FAS	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	4,5,6,7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Helmer, Thomas		
<b>Lecturer(s)</b>	Helmer, Thomas		
<b>Language of instruction</b>	German	<b>Language of exams</b>	German
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	79 h	
	Total	126 h	
<b>Subjects of the module</b>	Basic Principles of Driver Assistance Systems and Automated Driving		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
To be determined			
<b>Content</b>			
To be determined			
<b>Literature</b>			
<ul style="list-style-type: none"> <li>• WINNER, Hermann, HAKULI, Stephan, LOTZ, Felix, SINGER, Christina, 2019-. <i>Handbook of Driver Assistance Systems: Basic Information, Components and Systems for Active Safety and Comfort</i> [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-319-09840-1. Available via: <a href="https://doi.org/10.1007/978-3-319-09840-1">https://doi.org/10.1007/978-3-319-09840-1</a>.</li> <li>• ESKANDARIAN, Azim, 2012. <i>Handbook of intelligent vehicles: with 81 tables</i> [online]. London [u.a.]: Springer PDF e-Book. ISBN 978-0-85729-084-7, 978-0-85729-085-4. Available via: <a href="https://doi.org/10.1007/978-0-85729-085-4">https://doi.org/10.1007/978-0-85729-085-4</a>.</li> <li>• MAURER, Markus, GERDES, J. Christian, LENZ, Barbara, WINNER, Hermann, 2016. <i>Autonomous driving: technical, legal and social aspects</i> [online]. Berlin: Springer-Verlag PDF e-Book. ISBN 978-3-662-48847-8. Available via: <a href="https://doi.org/10.1007/978-3-662-48847-8">https://doi.org/10.1007/978-3-662-48847-8</a>.</li> <li>• BUBB, Heiner, BENGLER, Klaus, GRÜNEN, Rainer E., VOLLRATH, Mark, 2021. <i>Automotive Ergonomics</i> [online]. Wiesbaden: Springer Fachmedien Wiesbaden PDF e-Book. ISBN 978-3-658-33941-8. Available via: <a href="https://doi.org/10.1007/978-3-658-33941-8">https://doi.org/10.1007/978-3-658-33941-8</a>.</li> </ul>			

<b>Additional remarks</b>
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None
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## Basic Principles of Overall Vehicle

<b>Module abbreviation</b>	EMB_GLGFZ	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	4,5
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Dengler, Stefan		
<b>Lecturer(s)</b>	Dengler, Stefan; Huber, Werner		
<b>Language of instruction</b>	German	<b>Language of exams</b>	German
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Basic Principles of Overall Vehicle		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>Nach erfolgreicher Teilnahme an den Lehrveranstaltungen verfügen die Studierenden über</p> <ul style="list-style-type: none"> <li>erweiterte Fachkenntnisse über den Entwicklungsprozess des Gesamtfahrzeugs</li> <li>vertiefte Kenntnis über die Gesamtfahrzeugeigenschaften, deren Entwicklung Absicherungs- und Testverfahren sowie die Funktionserprobung</li> <li>Kenntnis zur Gesamtfahrzeug-Architektur (geometrische, funktionale und systemtechnische Gestaltung).</li> <li>Kenntnisse zu Technologien, Komponenten, Funktionen des Fahrzeugs und deren Einfluss auf die Eigenschaften des Gfzg</li> </ul>			
<b>Content</b>			
<p>Die Lehrveranstaltung gibt einen Überblick über die unterschiedlichen Themenfelder und Bewertungskenngrößen der Gesamtfahrzeugentwicklung. Gegenüber der Fokussierung einzelner technischer Komponenten und Baugruppen, steht bei der Betrachtung des Gesamtfahrzeugs die Vernetzungs- und Integrationsarbeit sowie die Akzeptanzbewertung der Eigenschaften des Gesamtprodukts im Vordergrund.</p> <p>Kernelemente der VL sind, ein Verständnis für die Gesamtfahrzeugeigenschaften zu schaffen. Dies geschieht am Beispiel spezifischer Eigenschaften wie Akustik, Emission/Verbrauch, Passive und Aktive Sicherheit, Aerodynamik, Fahrleistung und Werkstoffen.</p>			

Ein Schwerpunkt liegt auf der Bewertung und Absicherung der gesetzlichen und individuellen unternehmensspezifischen Anforderungen der genannten Gesamtfahrzeugeigenschaften mittels Absicherungs- und Testmethoden. Ergänzt wird die VL durch Aufzeigen des Produktentwicklungsprozesses, der E/E Architektur als Grundlage aller Fahrzeugfunktionen und der zunehmenden Bedeutung der Funktionssicherheit. Im Rahmen eines Praxistags erhalten die Studierenden einen Einblick in die Beurteilung von Gesamtfahrzeugeigenschaften und eine Einführung in die Funktionserprobung.

**Literature**

Will be specified at the beginning

**Additional remarks**

None

## Model-based Systems Engineering

<b>Module abbreviation</b>	IB_MBSE	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Kugele, Stefan		
<b>Lecturer(s)</b>	Kugele, Stefan		
<b>Language of instruction</b>	German	<b>Language of exams</b>	German
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Model-based Systems Engineering		
<b>Lecture types</b>	SU - lecture		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>Die Studierenden erwerben fundierte Kenntnisse über die modellbasierte Entwicklung komplexer technischer Systeme über den gesamten Lebenszyklus hinweg. Sie verstehen den Mehrwert modellbasierter Ansätze im Vergleich zur dokumentenzentrierten Entwicklung und können MBSE in unterschiedlichen Anwendungsdomänen anwenden.</p> <p>Nach erfolgreichem Abschluss des Moduls sind die Studierenden in der Lage:</p> <ul style="list-style-type: none"> <li>• die Grundprinzipien, Prozesse und Standards modellbasierter Systementwicklung zu erklären,</li> <li>• geeignete Modellierungssprachen (z. B. SysML) zur Beschreibung funktionaler, struktureller und verhaltensbezogener Aspekte technischer Systeme einzusetzen,</li> <li>• systematisch Anforderungen, Architekturen und Verhalten in Modellen zu integrieren und zu analysieren,</li> <li>• beispielshafte Werkzeuge zur Modellierung von Systemen einzusetzen,</li> <li>• ein vollständiges Systemmodell in einem durchgängigen MBSE-Prozess zu entwickeln.</li> </ul>			
<b>Content</b>			
To be determined			
<b>Literature</b>			
<ul style="list-style-type: none"> <li>• KOSSIAKOFF, Alexander, 2020. <i>Systems engineering: principles and practice</i>. Hoboken, N.J.: Wiley. ISBN 978-1-119-51666-8</li> </ul>			

- |   |
|---|
| <ul style="list-style-type: none"><li>• WALDEN, David D. and others, 2023. <i>Systems engineering handbook: a guide for system life cycle processes and activities</i>. Hoboken, NJ: Wiley. ISBN 1119814294, 978-1-119-81429-0</li><li>• , 2023. <i>ISO/IEC/IEEE 15288/Systems engineering - system life cycle processes</i>.</li></ul> |
|---|

<b>Additional remarks</b>
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None
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## Principles of Modern Software Development

<b>Module abbreviation</b>	IB_PMSD	<b>Reg.-Nr.</b>	25
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	7
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Neumeier, Stefan		
<b>Lecturer(s)</b>	Neumeier, Stefan; Weiss, Peter		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	79 h	
	Total	126 h	
<b>Subjects of the module</b>	Principles of Modern Software Development		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>On successful completion of the course, students will be able to:</p> <ul style="list-style-type: none"> <li>• understand modern software development principles</li> <li>• identify pros and cons of programming languages for specific projects</li> <li>• understand how safety and resource efficient programming can work</li> <li>• know how to apply the Rust programming language to support the goals of modern software development with focus on resource efficiency and safety</li> <li>• understand Software Testing and the respective process</li> <li>• apply techniques for profiling and tracing</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Modern software development principles</li> <li>• Introduction of different approaches for programming languages and the corresponding pros and cons</li> <li>• Introduction and identification of safety-critical aspects in modern software</li> <li>• Programming in Rust to support safe and resource-efficient programming “by design”</li> <li>• Embedding of Rust in existing software development processes and interaction with other programming languages</li> <li>• Techniques for profiling and tracing</li> </ul>			

<b>Literature</b>
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- KLABNIK, Steve and Carol NICHOLS, 2018. *The Rust programming language*. San Francisco: No Starch Press. ISBN 978-1-59327-828-1, 1-59327-828-4
- MARTIN, Robert C. and others, 2018. *Clean architecture: a craftsman's guide to software structure and design*. Boston: Prentice Hall. ISBN 978-0-13-449416-6, 0-13-449416-4
- ANDRIST, Björn, Viktor SEHR and B. GARNEY, 2020. *C++ high performance: master the art of optimizing the functioning of your C++ code*. Birmingham ; Mumbai: Packt Publishing. ISBN 978-1-83921-258-1

<b>Additional remarks</b>
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None
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### 4.3 General Elective

To illustrate the breadth of topics covered, some elective modules of the category 'General Elective' currently offered are described below.

## Ethics of Digitization

<b>Module abbreviation</b>	AVE-Ethics	<b>Reg.-Nr.</b>	14
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	General Scientific Elective Subject	3
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Uhl, Matthias		
<b>Lecturer(s)</b>	Uhl, Matthias		
<b>Language of instruction</b>	German	<b>Language of exams</b>	German
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	Ethics of Digitization		
<b>Lecture types</b>	SU - lecture		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>After successful completion of the course, students will be able to</p> <ul style="list-style-type: none"> <li>• outline the most pressing questions currently discussed in the ethics of digitization</li> <li>• distinguish meta-ethical, normative, and empirical arguments in ethics</li> <li>• know the most important normative theories and are able apply them to the field of digitization</li> <li>• apply ethical arguments to case studies from the field of artificial intelligence, e.g., self-driving cars</li> <li>• discuss the role of empirical research for the ethics of human-machine interaction and machine ethics</li> <li>• transcend their own normative viewpoint by critically reflecting on it.</li> </ul>			
<b>Content</b>			
<p>The ethics of digitization deals with questions of machine ethics and ethics of human-machine interaction. We will tackle both fields extensively in the course. Machine ethics asks which morality artificial agents should apply. In which sense can they take ethical decisions? Who should bear the responsibility if something goes wrong? Should we ever leave ethical decisions to autonomous systems or do we always have to keep the human in the loop?</p>			

The ethics of human-machine interaction is interested in the ethical influence that the cooperation and competition with machines has on our own moral conduct. We need a profound empirical understanding about the unintentional and often subtle effects that these interactions have on us as humans. Do we still own our decisions if we merely follow the advice of a recommender system? Does the mediation of our experience through technology change the way we think about moral issues? Can we shape people's moral behavior through the design of human-machine interfaces?

#### Literature

- HAIDT, Jonathan, 2001. The Emotional Dog and Its Rational Tail: A Social Intuitionist Approach to Moral Judgment. In: *Psychological Review*. **108**(4), p.814-834.
- FRANKENA, William K., HOERSTER, Norbert, 2017. *Ethik: eine analytische Einführung* [online]. Wiesbaden: Springer VS PDF e-Book. ISBN 978-3-658-10748-2, 978-3-658-10747-5. Available via: <https://doi.org/10.1007/978-3-658-10748-2>.
- LIAO, S. Matthew, 2020. *Ethics of artificial intelligence* [online]. Oxford: Oxford University Press PDF e-Book. ISBN 978-0-19-090506-4. Available via: <https://doi.org/10.1093/oso/9780190905033.001.0001>.
- Without author. *A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems* [online]. , 2019 [Accessed on: ]. Available via: <https://ethicsinaction.ieee.org/>

#### Additional remarks

None

## German B1 Intensive AVE

<b>Module abbreviation</b>	SZ_AVE_GERM_INTENS_B1	<b>Reg.-Nr.</b>	14
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	General Scientific Elective Subject	3,4
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Klingenberg, Lothar		
<b>Lecturer(s)</b>	Klingenberg, Lothar; Nehir, Mehmet; Pohl, Esther; Seitz, Daniela		
<b>Language of instruction</b>	German	<b>Language of exams</b>	German
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours	47 h	
	Self-study	78 h	
	Total	125 h	
<b>Subjects of the module</b>	German B1 Intensive AVE		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - written exam, 90 minutes			
<b>Additional explanations regarding examinations</b>			
None			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>Nach dem Besuch des Moduls sind die Studierenden in der Lage, in schriftlicher wie mündlicher Form</p> <ul style="list-style-type: none"> <li>• über Vergangenes zu berichten</li> <li>• Sachverhalte zu beschreiben</li> <li>• über Irreales zu sprechen</li> <li>• Beschwerden zu formulieren und darauf zu reagieren</li> <li>• Arbeitsabläufe zu beschreiben und über Fehler zu sprechen</li> <li>• Vergleiche anzu stellen sowie eine strukturierte Diskussion zu führen</li> </ul>			
<b>Content</b>			
<ul style="list-style-type: none"> <li>• Veränderungen im Leben, Werbung, Fernweh und Heimat</li> <li>• Regeln für höfliches Benehmen</li> <li>• Einbürgerung</li> <li>• Verkehr der Zukunft</li> <li>• Grammatik: Konjunktionen, Plusquamperfekt, Konjunktiv II, Passiv, indirekte Fragen, Adjektivdeklination, Relativsätze, Infinitivsätze mit "zu", Vergleichssätze, Futur I</li> </ul>			

<b>Literature</b>
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- KRENN, Wilfried and Herbert PUCHTA, 2016. *Motive: Kompaktkurs DaF : Deutsch als Fremdsprache : Kursbuch, Lektion 1–30 : B1*. München: Hueber Verlag. ISBN 978-3-19-001878-9, 3-19-001878-2
- KRENN, Wilfried and Herbert PUCHTA, 2016. *Motive: Kompaktkurs DaF : Deutsch als Fremdsprache : Arbeitsbuch, Lektion 1–30 : A1, A2, B1*. München: Hueber Verlag. ISBN 978-3-19-031878-0, 3-19-031878-6

<b>Additional remarks</b>
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Students have completed level A2. Minimum number of students: 8

<b>eTHics_basic</b>			
<b>Module abbreviation</b>	IB_ETHICS_en	<b>Reg.-Nr.</b>	14
<b>Curriculum</b>	<b>Study Programme</b>	<b>Module type</b>	<b>Semester</b>
	Autonomous Vehicle Engineering	Einsetzungstext ist leer!	
<b>Module frequency</b>	only winter term	<b>Module duration</b>	1 semester
<b>Responsible for module</b>	Crompton, Laura		
<b>Lecturer(s)</b>	Crompton, Laura		
<b>Language of instruction</b>	English	<b>Language of exams</b>	English
<b>Credit points / SWS</b>	5 ECTS / 4 SWS		
<b>Workload</b>	Contact hours		47 h
	Self-study		78 h
	Total		125 h
<b>Subjects of the module</b>	eTHics_basic		
<b>Lecture types</b>	SU/Ü - lecture with integrated exercises		
<b>Examinations</b>			
LN - seminar paper (10-15 pages) and oral examination (15-30 minutes)			
<b>Additional explanations regarding examinations</b>			
Grading is three quarters based on five papers (~ 2 pages each) that will be handed in over the course of the term. Paper submissions will be complemented by obligatory in-class presentations (~ 20 minutes).			
<b>Prerequisites according examination regulation</b>			
None			
<b>Recommended prerequisites</b>			
None			
<b>Objectives</b>			
<p>On successful completion of the course, students will be able to</p> <ul style="list-style-type: none"> <li>• outline the most pressing questions currently discussed in the ethics of technology.</li> <li>• distinguish meta-ethical, normative, and empirical arguments in ethics.</li> <li>• apply normative theories from ethics to the field of technology.</li> <li>• apply ethical arguments to case studies from the field of artificial intelligence, e.g., self-driving cars.</li> <li>• discuss the role of empirical research for the ethics of human-machine interaction and machine ethics.</li> <li>• transcend their own normative viewpoint by critically reflecting on it.</li> <li>• formulate their own research questions to inquire into the ethics of technology and outline research designs to address them.</li> </ul>			
<b>Content</b>			
<p>The ethics of technology deals with moral questions that concern the usage of technologies. It raises fundamental questions about our relationship with technologies.</p> <ul style="list-style-type: none"> <li>• Should we delegate ethical tasks to machines?</li> <li>• Which normative principles should guide the design of our artefacts?</li> <li>• How does the interaction with artefacts influence our moral behavior?</li> </ul>			

- Can we change this influence by the ethically aligned design of the human-machine interface?

Certain technologies may raise more specific questions.

- What are the challenges of hybrid traffic in which manual and automatized cars will have to cooperate?
- How should medical recommender system communicate uncertainty to medical professionals?
- What effects does social media have on our society's culture?

In this module, we will discuss recent topics from the realm of the ethics of technology. In biweekly lectures, changing experts will share their views on the ethical implications of different technologies.

These lectures will be complemented by a pre-reading course in which students will individually familiarize themselves with relevant literature from the field and together subject this literature to criticism.

Students will be required to summarize their learnings from the lectures and the literature in reflection reports. To complete the module, they will also have to actively participate in the "eTHIcs conference," in which they will give a presentation on a relevant topic and participate in a peer-evaluation of the topics presented.

#### Literature

- SHAFER-LANDAU, Russ, 2019. *A Concise Introduction to Ethics*. ISBN 978-0190058173
- LIAO, S. Matthew, 2020. *Ethics of artificial intelligence*. New York, NY: Oxford University Press. ISBN 978-0-19-090503-3, 978-0-19-090504-0

#### Additional remarks

In combination with the module "eTHIcs applied: Applications of the Ethics of Technology," this module leads to the certificate "eTHIcs."