Technische Hochschule Ingolstadt

Module Handbook
Autonomous Vehicle Engineering

Faculty of Electrical Engineering and Computer Science

As per: 2021-09-22

Content

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 reducing environmental pollution. 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 and 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 learning. 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 processes. 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 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:

- Sense: Sensor technology, sensor systems and sensor data fusion for recognising and recording the environment.
- 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.
- 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 inter-disciplinary 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
- 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

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 to act responsibly in their professional activities. They have acquired an understanding of the multidisciplinary context of the degree programme.

- Engineering methodology

  Graduates are able to identify, formulate and solve technical problems of autonomous mobility systems using established scientific methods. They are able to analyse processes and methods of their discipline in a scientifically sound manner. They are able to select suitable analysis, modelling, simulation and optimisation methods and apply them with a high level of handling competence.

- Engineering-oriented development and design

  Graduates have the ability to develop designs for mechatronic systems consisting of hardware and software for autonomous mobility systems according to specified requirements. They have a practice-oriented understanding of their specific design methods and the ability to apply them.

- Investigate and evaluate

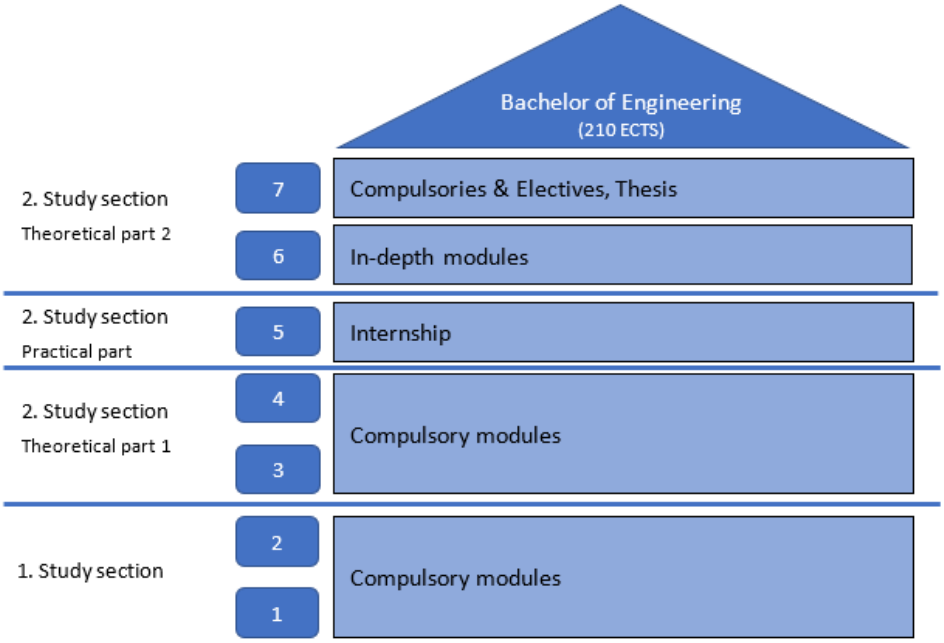
  Graduates are able to conduct literature research as well as use other sources of information for their work. They are able to independently plan and conduct tests and experiments and interpret the results.

Graduates are able to transfer new results of engineering and natural sciences into industrial development, considering safety, ecological and economic requirements. They are able to plan and control development processes. They have an understanding of applicable techniques and methods and their limitations. They are able to abstract the acquired knowledge and to deepen it on their own responsibility. They have the ability to present the results of their work in a comprehensible way both orally and in writing, and to cooperate with experts from other disciplines. They are aware of the non-technical implications of engineering work. Graduates acquire extensive knowledge in the field of development methodology of software and hardware of complex systems, which particularly have up-to-date relevance and practical relevance not limited to the field of autonomous mobility systems.

In order for graduates to be able to adapt to the changes in the modern job market, they acquire key qualifications through the degree programme such as time management, learning and working techniques, the ability to abstract, the willingness to cooperate, the ability to work in a team and the ability to communicate. They are enabled to communicate about the contents and problems of their discipline with experts and laypersons in English and German. They are able to work both individually and as members of international teams.

2.4 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).

2.5 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.)

2.6 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.

2.7 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.

2.8 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
- in the framework examination regulations (RaPO)

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 is currently being established to support the further development of the degree programme.

2.11 Dual Study Programme

In collaboration with our cooperation partners, it is possible to study with in-depth practical experience. Dual students work in the cooperation company during the lecture-free period and can thus supplement their theoretical knowledge acquired during their studies with professional practice. The quality standards of hochschule dual, the umbrella brand for dual studies in Bavaria, ensure that theory and practice are optimally interlinked.

Further information on the dual study programme and the current corporate partners of the programme can be found at https://www.thi.de/studium/studienange-bote/duales-studium.

In the dual study model, university and practical phases (especially in the semester breaks, during the practical semester and for the final thesis) regularly alternate in the study programme. The lecture times in the dual study model correspond to the normal study and lecture times at Technische Hochschule Ingolstadt.

Through the systematic combination of the learning locations university and company, the students gain professional practical experience with selected practical partners as an integral part of their studies.

The curriculum of the dual degree programme model differs from the regular degree programme concept in the following points:

- Practical semester in the cooperation company

  In both dual study models, the practical semester is carried out in the cooperation company.
- Dual modules

  Separate elective subjects are regularly offered for dual students. These events are held at the university or a dual partner. Separate projects are also offered as well as separate practical seminars for dual students. Projects and practical seminars can be credited for competences acquired outside the university in the company as a place of learning. If possible, individual events are held by lecturers from the cooperating companies.
- Final thesis in the cooperation company

  In both dual study models, the final paper is written at a cooperating company, usually on a practice-relevant topic related to the focus of study.

Organisationally, both dual study programme models are characterised by the following components:

- Introductory track

  A special event for dual students is offered as part of the compulsory introductory week at the beginning of the programme.
- Mentoring

  The central contact persons for dual students in the faculty are the respective programme directors. They organise an annual mentoring meeting with the dual students of the respective degree programme.

- Quality Management

  Separate questionnaires are included in the evaluations and surveys at the THI on the quality assurance of the dual study programme.

- Forum Dual

  Organised by the Career Service and Student Counselling (CSS), the "Forum dual" takes place once a year. The "Forum dual" promotes the professional-organisational exchange between the dual cooperation partners and the faculty and serves to ensure the quality of the dual study programmes. All cooperation partners in the dual study programme as well as representatives and dual students of the faculty are invited to the meeting.

2.12 Advisor

For all technical and functional questions and problems with regards to contents of the Autonomous Vehicle Engineering study programme please contact:

Prof. Dr. Martin Ebert, building B, room 205, Tel. 0841 / 93 48 –3804

Please adhere to the published consultation hours.

2.13 Internship Officer

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

Prof. Dr. Thomas Schiele, building A, room 116, Tel. 0841 / 93 48 – 2870

Please adhere to the published consultation hours.

2.14 Programme Coordinator

For questions concerning the organizational execution of the study programme please contact:

Prof. Dr. Martin Ebert, building B, room 205, Tel. 0 841 / 9348-3804

Please adhere to the published consultation hours.

3 Curricular Structure

The programme Autonomous Vehicle Engineering starts in the winter semester only. Courses of the 1st, 3rd and 5th term are offered every winter term. Courses of the 2nd, 4th, and 6th term are offered every summer term. Courses of the 7th 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		7	8
	1.1	Exercise Course Mathematics 1	2			
Foundation of Computer Science	2.1	Foundation of Computer Science	4		6	7
	2.2	Practical Course Foundations of Computer Science	2			
Programming 1	3.1	Programming 1	4		6	7
	3.2	Practical Course Programming 1	2			
Foundations of Engineering Sciences	4.1	Foundations of Engineering Sciences	5		7	8
	4.2	Exercise Course Foundations of Engineering Sciences	2			
Mathematics 2	5.1	Mathematics2		4	5	6
	5.2	Exercise Course Mathematics 2		1		
Statistics	6.1	Statistics		3	4	5
	6.2	Exercise Course Statistics		1		
Algorithms and Data Structures	7	Algorithms and Data Structures		4	4	5
Programming 2	8.1	Programming 2		4	6	7
	8.2	Practical Course Programming 2		2		
Electronics, Signals and Measurement	9.1	Electronics, Signals and Measurement		4	6	7
	9.2	Practical Course Electronics, Signals and Measurement		2		
Sum					51	60

P written exam
LN course-related performance record (with/without success) must have been passed.

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			6	6
	10.2	Practical Course Model-based Software Engineering	2				
Vehicle Dynamics	11	Vehicle Dynamics	4			4	5
Modelling and Simulation	12.1	Modelling and Simulation	4			6	7
	12.2	Practical Course Modelling and Simulation	2				
Digital Signal Processing	13.1	Digital Signal Processing	4			6	7
	13.2	Practical Course Digital Signal Processing	2				
General Elective (Allgem.wissen. Wahlpflichtmodul)	14	General Elective	4			4	5
Software Development Processes	15	Software Development Processes		4		4	5
Foundations of Machine Learning	16.1	Foundations of Machine Learning		4		6	7
	16.2	Practical Course Foundations of Machine Learning		2			
Vehicle Electronics and Vehicle Communication Networks	17.1	Vehicle Electronics and Vehicle Communication Networks		4		6	7
	17.2	Practical Course Vehicle Electronics and Vehicle Communication Networks		2			
Control Engineering	18.1	Control Engineering		4		6	7
	18.2	Practical Course Control Engineering		2			
Scientific Seminar	19	Scientific Seminar		2		2	3
Internship	27	Internship					24
	28	Internship Seminar			1	1	2
	29	Business Management			2	2	4
Sum							90

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		4	5
Team Project	21	Team Project	4		4	8
Sensor Data Processing and Sensor Data Fusion	22.1	Sensor Data Processing and Sensor Data Fusion	4		6	7
	22.2	Practical Course Sensor Data Processing and Sensor Data Fusion	2			
Planning and Decision-Making Algorithms	23	Planning and Decision-Making Algorithms	4		4	5
Vehicle Actuators	24	Vehicle Actuators	4		4	5
Science Elective (Fachwissenschaftliches Wahlpflichtmodul)	25	Science Elective (Fachwissenschaftliches Wahlpflichtmodul)		12	12	15
Bachelor Thesis	26.1	Seminar Bachelor Thesis		2	2	15
	26.2	Bachelor Thesis				
Sum					36	60

P written exam
mdlP oral exam
SA seminar paper
PRJ project work
LN proof of performance
BA Bachelor thesis

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

Mathematics 1			
Module abbreviation:	AVE_Math1	**Reg.no.:**	1
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	1

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	8 ECTS / 7 SWS		
Workload:	Contact hours:		82 h
	Self-study:		118 h
	Total:		200 h
Subjects of the module:	1.1: Mathematics 1 1.2: Exercise Course Mathematics 1		
Lecture types:	SU - seminar teaching; Ü - exercise;		

Examinations:

1.1: schrP90 - written exam, 90 minutes
1.2: O - without proof of performance

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

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

Objectives:

After successfully completing this module the students shall be able to:

- know the major mathematical techniques and their interrelations to solve engineering problems
- understand the underlying principles
- apply the 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, 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:

- RILEY, Kenneth F., Michael P. HOBSON and Stephen J. BENCE, 2009. *Mathematical methods for physics and engineering*. 3. edition. Cambridge [u.a.]: Cambridge Univ. Press. ISBN 978-0-521-86153-3, 0-521-86153-5
- CROFT, Anthony and Robert DAVISON, 2019. *Mathematics for engineers*. F. edition. Harlow, England: Pearson. ISBN 978-1-292-25364-0
- JAMES, Glyn, Phil P. G. DYKE and John SEARL, 2018. *Advanced modern engineering mathematics*. F. edition. Harlow, England: Pearson. ISBN 978-1-292-17434-1

Additional remarks:

None

Foundations of Computer Science

Module abbreviation:	AVE_CompSci	**Reg.no.:**	2
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	1

Responsible for module:	Membarth, Richard		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours:		70 h
	Self-study:		105 h
	Total:		175 h
Subjects of the module:	2.1: Foundations of Computer Science 2.2: Practical Course Foundations of Computer Science		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

2.1: schrP90 - written exam, 90 minutes
2.2: LN - participation without/with success

Additional Explanation:

The practical part is considered to have been completed if the completions of four practical exercises have been submitted and evaluated as correct.

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After successful participation in the module courses, students are able to

- present information of different kinds for processing by digital computers
- identify the elements of an instruction set architecture and assess their implications for programming, based on the representation of information in a manner appropriate to data processing and the principles of instruction-based execution of processing rules
- explain the interaction of hardware and software
- formulate basic elements of procedural programming in a machine language
- evaluate the effect of programming alternatives on the execution speed
- explain concepts for performance enhancement in modern processors and the problems associated with them

After successful participation in the module courses, students are able to

- analyse the influence of elements of different instruction set architectures onto evaluation criteria like code size and implementation effort
- evaluate the effect of different forms resolving pipeline hazards onto the performance
- evaluate the relationship between data structures and their memory representation and different cache implementations

Content:

- Representation of information in computer systems
- Basic concepts of computer architecture, basic structure of universal computers, basic principles of program execution
- Instruction set architecture: instruction set, addressing modes, interrupts
- Basics of machine-oriented programming: memory planning, control structures, subprograms
- Concepts of modern computer systems: pipelining, superscalarity, memory hierarchy, cache memory, SIMD-processors
- exercises related to information representation
- representing data structures and control structures at machine level
- simulation of of different forms resolving pipeline hazards
- simulation of cache memories

Literature:

- HENNESSY, John L. and David A. PATTERSON, 2019. *Computer Architecture: A Quantitative Approach*. S. edition. Cambridge, MA: Morgan Kaufmann Publishers. ISBN 978-0-12-811905-1
- LEDIN, Jim, 2020. *Modern Computer Architecture and Organization: Learn x86, ARM, and RISC-V architectures and the design of smartphones, PCs, and cloud servers*. 1. edition. Birmingham: Packt Publishing Limited. ISBN 978-1-83898-710-7
- PATTERSON, David A. and John L. HENNESSY, 2021. *Computer Organization and Design: The Hardware Software Interface*. R. edition. Cambridge, MA: Morgan Kaufmann. ISBN 978-0-12-820331-6

Additional remarks:

None

Programming 1

Module abbreviation:	AVE_Progr_1	**Reg.no.:**	3
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	1

Responsible for module:	Belzner, Lenz		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	3.1: Programming 1 3.2: Practical Course Programming 1		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

3.1: schrP90 - written exam, 90 minutes
3.2: LN - participation without/with success

Additional Explanation:

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.

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

The module is designed to teach students to program in Python in a practical manner using industry standard methods, tools and technologies. It not only teaches students the Python programming language but also improves their algorithmic thinking and problem solving capabilities so that they can write code that actually works and produces the desired functional results. Giving students enough well-thought-out coding exercises ensures this.

After completion of the module the students will be able to

- understand the programming basics (operations, control structures, data types, etc.)
- readily use the Python programming language
- apply various data types and control structure
- understand class inheritance and polymorphism
- understand the object-oriented program design and development
- understand and begin to implement code

Content:
The following topics are covered: • 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 • Advanced topics: GUI, exceptions, events and event-driven programming
Literature:
• LAMBERT, Kenneth A. and Martin OSBORNE, 2019. *Fundamentals of Python: first programs*. S. edition. Boston, MA: Cengage. ISBN 1-337-56009-X, 978-1-337-56009-2 • BEAZLEY, David M. and Brian K. JONES, 2013. *Python cookbook: [recipes for mastering Python 3]*. 3. edition. Beijing [u.a.]: O'Reilly. ISBN 978-1-449-34037-7, 1-449-34037-7 • 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.
Additional remarks:
Prerequisite for participation in the written examination is a successfully completed practical course.

Foundations of Engineering Sciences

Module abbreviation:	AVE_EngSci	**Reg.no.:**	4
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	1

Responsible for module:	Arnold, Armin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	8 ECTS / 7 SWS		
Workload:	Contact hours: 82 h Self-study: 118 h Total: 200 h		
Subjects of the module:	4.1: Foundations of Engineering Sciences 4.2: Exercise Course Foundations of Engineering Sciences		
Lecture types:	SU - seminar teaching; Ü - exercise;		

Examinations:

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

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

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
- Reonances and waves

• deflection and interference • Ideal Gas Law • basic electrodynamics and electrics
Literature:
• BOLTON, William, 2020. *Engineering Science*. 7. edition. Milton: CRC Press LLC. ISBN 978-1-00-020598-5
Additional remarks:
None

Mathematics 2

Module abbreviation:	AVE-Mathematics 2	**Reg.no.:**	5
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	1

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	6 ECTS / 5 SWS		
Workload:	Contact hours: 59 h Self-study: 91 h Total: 150 h		
Subjects of the module:	5.1: Mathematics 2 5.2: Exercise Course Mathematics 2		
Lecture types:	SU - seminar teaching; Ü - exercise;		

Examinations:

5.1: schrP90 - written exam, 90 minutes
5.2: O - without proof of performance

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

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

Objectives:

After successfully completing this module the students shall be able to:

- apply advanced competences in applying mathematical methods
- analyse complex problems and decompose them in to solvable parts
- apply knowledge in order to combine various mathematical techniques in order to solve challenging, heterogeneous tasks
- judge the convenience of possible solution approaches and compare alternative methods to solve technical problems

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, inhomogenous ODE of n-th order, harmonic vibration • Fourier series, Fourier transform, Laplace transform
Literature:
• BIRD, John O., 2014. *Understanding engineering mathematics: [SI units USED]*. F. edition. London ; New York: Routledge. ISBN 978-0-415-66284-0, 0-415-66284-2 • RILEY, Kenneth F., Michael P. HOBSON and Stephen J. BENCE, 2006. *Mathematical methods for physics and engineering*. 3. edition. Cambridge [u.a.]: Cambridge Univ. Press. ISBN 978-0-521-86153-3, 0-521-86153-5 • JAMES, Glyn, Phil P. G. DYKE and John SEARL, 2020. *Modern engineering mathematics*. S. edition. Harlow, England: Pearson. ISBN 978-1-292-25349-7
Additional remarks:
None

Statistics

Module abbreviation:	AVE-Statistics	**Reg.no.:**	6
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	2

Responsible for module:	Schmidtner, Stefanie		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	6.1: Statistics 6.2: Exercise Course Statistics		
Lecture types:	SU - seminar teaching; Ü - exercise;		

Examinations:

6.1: schrP90 - written exam, 90 minutes
6.2: O - without proof of performance

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After finishing this course including excercises students are able to:

- Choose and calculate appropriate metrics for describing a data set
- Understand different kinds of data and scaling
- Understand and interpret vizualizations of distributions
- Explain and analyze bivariate connections
- Understand fundamentals of probability and apply them to a given data set
- Explain and apply the concept of conditional probability and Bayes‘ theorem
- Name the most important distributions and know appropriate applications
- Understand and use linear regression for analyzing a given dataset

Content:

Descriptive statistics

- Vizualization of distributions
- 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
- 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*. T. edition. Belmont, Calif.: Brooks/Cole, Cengage Learning. ISBN 0-495-11868-0, 978-0-495-11868-8

Additional remarks:

None

Algorithms and Data Structures

Module abbreviation:	AVE-Algorithms and Data Structures	**Reg.no.:**	7
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	2

Responsible for module:	Membarth, Richard		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Algorithms and Data Structures		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After successfully completing the module, students shall be able to

- analyze given algorithms and determine their runtime and memory consumption
- name the most important data structures and describe their advantages and disadvantages
- identify suitable data structures and algorithms for concrete problems
- recognize implementation aspects of algorithms and data structures and describe their effects

Content:

- algorithm classification and complexity
- basic data structures
- trees, hashing, graphs

Literature:

- SEDGEWICK, Robert and Kevin WAYNE, 2011. *Algorithms*. 4. edition. Upper Saddle River, NJ [u.a.]: Addison-Wesley. ISBN 978-0-321-57351-3, 0-321-57351-X
- CORMEN, Thomas H., 2009. *Introduction to algorithms*. T. edition. Cambridge, Mass.: MIT Press. ISBN 978-0-262-27083-0

Additional remarks:

None

Programming 2

Module abbreviation:	AVE-Programming 2	**Reg.no.:**	8
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	2

Responsible for module:	Glavina, Bernhard		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	8.1: Programming 2 8.2: Practical Course Programming 2		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

8.1: schrP90 - written exam, 90 minutes
8.2: LN - participation without/with success

Additional Explanation:

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.

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After attending the module, students will be able to

- state and explain the essential features of an object-oriented programming language.
- 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 λ-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
- STROUSTRUP, Bjarne, 2015. *Die C++-Programmiersprache* [online]. *[Vom Erfinder von C++]* . München: Hanser PDF e-Book. ISBN 978-3-446-43981-8. Available via: https://www.hanser-elibrary.com/doi/book/10.3139/9783446439818.
- 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*. 4. edition. Upper Saddle River, NJ ; Munich [u.a.]: Addison-Wesley. ISBN 9780321563842

Additional remarks:

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

Electronics, Signals and Measurement

Module abbreviation:	AVE-Electronics, Signals and Measurement	**Reg.no.:**	9
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	2

Responsible for module:	Elger, Gordon		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	9.1: Electronics, Signals and Measurement 9.2: Practical Course Electronics, Signals and Measurement		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

9.1: schrP90 - written exam, 90 minutes
9.2: LN - participation without/with success

Additional Explanation:

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 programmes have been independently created for all topics, these function without errors and the programmes have been handed in on time.

Prerequisites according examination regulation:

Foundations of Engineering Sciences, Mathematics1

Recommended prerequisites:

Mathematics2

Objectives:

The course is designed to provide a practical - hands on - introduction to electronics with a focus on measurement and signals. The prerequisites are basic math courses including differential and integral calculus as well as electricity and magnetism. No prior experience with electronics is necessary. The aim of the course is to provide students with the theoretical and practical knowledge necessary to work in a modern science or engineering setting. The students will get the ability for basic electronic circuit design. The students are empowered to perform electric measurement and judge the correctness and accuracy of the measurement. The students are capable to analytically calculate and experimentally measure continuous current and time dependent voltage and current signals in electronic circuits. The student understand the time and frequency behavior of signals and the concept of time-frequency dualism.

Content:

The content of the course is the following:

- 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, Linear Circuits Analysis
- Equivalent Circuits, Power Transfer
- Dependent Sources, Op Amps, Current Sources
- Capacitors and Inductors
- Sinusoidal Steady State Response of RL and RC Circuits
- Sinusoidal Steady State Response: Impedance
- Filters, Bandwidth, Q Factor
- Transient Response
- Diodes, Signal Conditioning, Voltage Regulation
- Transistors, Biasing and Amplification
- Introduction to the Op Amp

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*. 3. edition. Boca Raton, Fla. [u.a.] : CRC Press. ISBN 978-1-4665-9496-8

Additional remarks:

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

Model-based Software Engineering

Module abbreviation:	AVE-Model-based Software Engineering	**Reg.no.:**	10
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	3

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	6 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 80 h Total: 150 h		
Subjects of the module:	10.1: Model-based Software Engineering 10.2: Practical Course Model-based Software Engineering		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

10.1: schrP90 - written exam, 90 minutes
10.2: LN - participation without/with success

Additional Explanation:

Practical course: To earn the proof of participation all given exercises have to be completed and documented.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- explain the benefits and pitfalls of model-based-software development
- understand what a meta-model is
- are able to apply and assess different modeling techniques
- understand the relationship between model and implemented code
- know the basic architectural principles

To successfully complete the practical course the following conditions have to be fulfilled:

- at least 50% of the exercises have to be submitted and evaluated as correct
- the solutions of at least 2 exercises (from different work sheets) has to be presented during the practical course

Content:

- MBSE principles
- MBSE use cases

- Object oriented programming
- UML
  - class diagrams
  - package diagrams
  - composite structures
  - component diagrams
  - deployment diagrams
  - use case diagrams
  - statechart diagrams
  - activity diagrams
  - interaction diagrams
- MDA Model Driven Architecture
- OCL Object constraint language
- Model-to-model transformations
- Model-to-text transformations: code generation
- Model quality
- SysML

Literature:

- PILONE, Dan and Neil PITMAN, 2006. *UML 2.0 in a Nutshell*. 1. edition. Beijing, Köln [u.a.]: O'Reilly. ISBN 3-89721-342-7
- 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*. T. edition. 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*. S. edition. [San Rafael, Calif.]: Morgan & Claypool Publishers. ISBN 978-1-62705-988-6

Additional remarks:

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

Vehicle Dynamics

Module abbreviation:	AVE-VehDyn	**Reg.no.:**	11
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	3

Responsible for module:	Arnold, Armin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Vehicle Dynamics		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing the module the students shall be able to

- explain and judge all tire properties that are important for vehicle dynamics
- calculate according to some simplified vehicle models
- 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
- explain ABS-control
- explain vehicle stability control systems
- deduct the additional possibilities given by four-wheel-steering, torque-vectoring and active suspensions

Content:

- Tire and tire properties under different conditions (camber, normal force, combinations of longitudinal and/or lateral slip, Kamm's circle and its application)
- Vehicle models (Single track model, dual track model)
- Influencing driving behaviour by
  - Suspension: Roll- und instant center, (elasto)-kinematics
  - Spring stiffnesses
  - Position of center of gravity
  - Distribution of driving- and braking torques

- ABS
- Vehicle stability control
- Torque vectoring

Literature:

- REIMPELL, Jörnsen, 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*. 2. edition. Oxford [u.a.]: Butterworth-Heinemann. ISBN 0-7506-5054-0, 978-0-7506-5054-0
- MILLIKEN, William, . *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

Modelling and Simulation

Module abbreviation:	AVE-Modelling and Simulation	**Reg.no.:**	12
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	3

Responsible for module:	Schiele, Thomas		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	12.1: Modelling and Simulation 12.2: Practical Course Modelling and Simulation		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

12.1: schrP90 - written exam, 90 minutes
12.2: LN - participation without/with success

Additional Explanation:

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 programmes have been independently created for all topics, these function without errors and the programmes have been handed in on time.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After a successful participation of this course students are able:

- to investigate real technical systems, to structure them into appropriate subsystems and derive suitable differential equations or systems of differential equations
- to implement and simulate simple physical or experimental modeling approaches (script and block-diagram-based implementation methods). Hint: during this lecture Matlab/Simulink is used for model implementation and simulation
- 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 describe fundamental differences of common numerical solving approaches for ordinary differential equations (fixed step and variable step solving algorithms)
- 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 validate implemented models based on data sets generated from real system measurements

Content:

- theoretical fundamentals of dynamic systems and their mathematical representation through differential equations
- 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, …)
- 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
- Simple methods to parameterize simulation models
- 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)

Literature:

- KAHLERT, Jörg, 2004. *Simulation technischer Systeme: Eine beispielorientierte Einführung* [online]. Wiesbaden: Vieweg+Teubner Verlag PDF e-Book. ISBN 978-3-322-80247-7, 978-3-322-80248-4. Available via: https://doi.org/10.1007/978-3-322-80247-7.
- NOLLAU, Reiner, 2009. *Modellierung und Simulation technischer Systeme: eine praxisnahe Einführung* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 978-3-540-89120-8, 978-3-540-89121-5. Available via: https://doi.org/10.1007/978-3-540-89121-5.
- GLÖCKLER, Michael, 2018. *Simulation mechatronischer Systeme: Grundlagen und Beispiele für MATLAB und Simulink* [online]. Wiesbaden: Springer Fachmedien Wiesbaden PDF e-Book. ISBN 978-3-658-20703-8. Available via: https://doi.org/10.1007/978-3-658-20703-8.
- ANGERMANN, Anne, Martin RAU and Michael BEUSCHEL, 2017. *MATLAB - Simulink - Stateflow : Grundlagen, Tollboxen, Beispiele*. 9. edition. Oldenbourg: DeGruyter. ISBN 978-3-11-048489-2 ; 978-3-11-048495-3

Additional remarks:

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

Digital Signal Processing

Module abbreviation:	AVE-Digital Signal Processing	**Reg.no.:**	13
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	3
Responsible for module:	Mecking, Michael		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	13.1: Digital Signal Processing 13.2: Practical Course Digital Signal Processing		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

13.1: schrP90 - written exam, 90 minutes
13.2: LN - participation without/with success

Additional Explanation:

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 programmes have been independently created for all topics, these function without errors and the programmes have been handed in on time.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

The module is designed to provide the students with a thorough introduction to the principles of digital signal processing. After the successful completion of the module the students will be able to:

- describe and analyse signals in the time and frequency domain,
- describe the properties of discrete-time linear systems and implement systems using different canonical structures,
- design linear discrete-time filters with prescribed properties,
- understand the impact of finite word-length effects in the realisation of discrete-time systems,
- describe the impact of digital filters on stochastic signals,
- use statistical signal processing for estimation purposes

Content:

- Review of the Fourier-Transform for continuous signals
- Sampling and reconstruction of band-limited signals, analog-to-digital conversion, quantisation
- The Z-Transform and its properties

- Discrete-time systems: linearity, time-invariance, causality, stability, impulse response and convolution, frequency-domain representation, system transfer function, canonical filter structures and signal flow graphs, allpass and minimum phase systems
- Design of digital filters with prescribed properties using windowing techniques and the bilinear transform, band transformations
- The Discrete Fourier Transform, fast algorithms using decimation in time and frequency, applications of the DFT
- Digital multi-rate systems, decimation and interpolation, oversampling analog to digital conversion
- Statistical signal processing, autocorrelation function and power spectral density, orthogonality principle, linear estimation and Wiener filters

Literature:

- OPPENHEIM, Alan V. and Ronald W. SCHAFER, 2014. *Discrete-time signal processing*. T. edition. Harlow: Pearson. ISBN 978-1-292-03815-5
- INGLE, Vinay K. and John G. PROAKIS, 2017. *Digital signal processing using MATLAB: a problem solving companion*. f. edition. [S.l.]: Cengage Learning. ISBN 978-1-305-63753-5
- ANTONIOU, A., 2017. *Digital Filters - Analysis, Design and Signal Processing Applications*. ISBN 0071846034
- KAMMEYER,, K. and K. KROSCHEL, 2018. *Digitale Signalverarbeitung: Filterung und Spektralanalyse mit MATLAB-Übungen*. ISBN 978-3-658-20134-0

Additional remarks:

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

Software Development Processes

Module abbreviation:	AVE-Software Development Processes	**Reg.no.:**	15
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	4

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Software Development Processes		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

mdlP - oral exam, 15 minutes

Additional Explanation:
None

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- know the major building blocks of the complete software development life cycle
- understand the difference between classical and agile development methods
- asses and apply the best suitable development methodolgy for a software development project

Content:

- Overall Software Engineering process
  - System analysis
  - Requirements Engineering
  - Software design / architecture
  - Software Test - Verification and validation
  - Software maintenance and operation
- Process models
  - Waterfall
  - Spiral model
  - V-Model (XT)
- Agile methods

○ Extreme Programming ○ Kanban ○ Scrum • Software project management
Literature:
• HALL THAYER, Richard and Merlin DORFMAN, 2012. *SOFTWARE ENGINEERING ESSENTIALS, Volume I: The Development Process*. 4. edition. Carmichael, California: Software Management Training Press. ISBN 978-0985270704
Additional remarks:
None

Foundations of Machine Learning

Module abbreviation:	AVE-Foundations of Machine Learning	**Reg.no.:**	16
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	4

Responsible for module:	Belzner, Lenz		
Language of instruction:	German	**Language of exam:**	German
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	16.1: Foundations of Machine Learning 16.2: Practical Course Foundations of Machine Learning		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

16.1: schrP90 - written exam, 90 minutes
16.2: LN - participation without/with success

Additional Explanation:

Practical course: To earn the proof of participation all given exercises have to be completed and documented.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

Programming 1 and 2
Math 1 and 2 (Algebra and Calculus)
Statistics 1

Objectives:

After a successful participation of this course students are able:

- Understand statistical machine learning
- Identify ML potential and limitations in application domains
- Choose appropriate ML methods, models, and algorithms for a given problem
- Implement preprocessing, models, training and evaluation in python

Content:

- preliminaries
  - probability and distributions
  - gradient free and gradient based optimization
- machine learning principles
  - parametric and non-parametric models
  - fitting models and distributions

- generalization, overfitting, underfitting
- training, validation, and testing
- bias & variance
- bagging & boosting
- ensembles
- feature engineering
- generative vs. discriminative models
- model selection

- supervised learning
  - classification
  - regression
- unsupervised learning
  - density estimation & anomaly detection
  - dimensionality reduction & embeddings
  - clustering
  - generative models
- advanced topics
  - deep learning
  - spatial and temporal modeling
  - ML ops and architectures
  - interpretability
  - bayesian vs. frequentist approaches
  - reinforcement learning

Literature:

- MURPHY, Kevin Patrick. *Probabilistic Machine Learning: An Introduction* [online]. [Accessed on:]. Available via: https://probml.github.io/pml-book/book1.html
- VAN DER PLAS, Jake. *Python Data Science Handbook* [online]. [Accessed on:]. Available via: https://jakevdp.github.io/PythonDataScienceHandbook/

Additional remarks:

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

Vehicle Electronics and Vehicle Communication Networks

Module abbreviation:	AVE-Vehicle Electronics and Vehicle Co	**Reg.no.:**	17
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	4

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	17.1: Vehicle Electronics and Vehicle Communication Networks 17.2: Practical Course Vehicle Electronics and Vehicle Communication Networks		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

17.1: schrP90 - written exam, 90 minutes
17.2: LN - participation without/with success

Additional Explanation:

Practical course: To earn the proof of participation all given exercises have to be completed and documented.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- have an overview of vehicle electronics, especially in the automotive sector
- understand the latest developments in automotive technology
- use electrotechnical fundamentals to describe the development and manufacturing of vehicle components such as sensors, actuators and bus systems
- know the basics of software architecture for vehicle electronic systems / control units.

Content:

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

- Safety requirements according to ISO26262 and their influence on the development of vehicle systems

Literature:

- -, , 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.
- MARSCHOLIK, Christoph and Peter SUBKE, 2008. *Road vehicles - diagnostic communication: technology and applications*. [. edition. Heidelberg [u.a.]: Hüthig. ISBN 978-3-7785-4048-0
- 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:

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

Control Engineering

Module abbreviation:	AVE-Control Engineering	**Reg.no.:**	18
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	3

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	8 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 130 h Total: 200 h		
Subjects of the module:	18.1: Control Engineering 18.2: Practical Course Control Engineering		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

18.1: schrP90 - written exam, 90 minutes
18.2: LN - participation without/with success

Additional Explanation:

Practical course: To earn the proof of participation all given exercises have to be completed and documented.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- Analyze control systems and create models in the time and frequency domain
- Analyze systems with regards to dynamics, vibration behavior and stability
- Select and parameterize suitable controller structures
- Verify the results in simulations
- Solve control tasks independently, evaluate and document the results according to scientific criteria.

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 / 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:
• 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.
Additional remarks:
Prerequisite for participation in the written examination is a successfully completed practical course.

Scientific Seminar

Module abbreviation:	AVE-Scientific Seminar	**Reg.no.:**	19
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	4

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	3 ECTS / 2 SWS		
Workload:	Contact hours: 23 h Self-study: 52 h Total: 75 h		
Subjects of the module:	Scientific Seminar		
Lecture types:	S - Seminar		

Examinations:

seminar paper and presentation

Additional Explanation:

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.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- independently acquire specific specialist knowledge (literature work, analysis, conclusions)
- present comprehensibly using suitable media
- follow a technical talk critically and discuss the content professionally
- strengthen their interdisciplinary and communicative competences
- summarize the content of their presentation in the form of a brief written elaboration

Content:

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.

Literature:

Will be specified at the beginning

Additional remarks:

None

Vehicle-to-X-Communication

Module abbreviation:	AVE-Vehicle-to-X-Communication	**Reg.no.:**	20
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	6

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Vehicle-to-X-Communication		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- describe the requirements, use cases, architectures and communication technologies for Vehicle2X communication
- apply concepts of information dissemination for Vehicle2X services
- understand transmission and media access procedures, communication protocols of the network, transport and facilities layer as well as data security and system management
- evaluate the advantages and disadvantages of existing Vehicle2X systems and estimate future developments

Content:

- Vehicle2X use cases and system architecture
- Vehicle2X frequency spectrum
- WLAN-V2X
  - System overview
  - Physical transmission and media access procedures
  - Congestion control
- Cellular V2X
  - overview of cellular networks
  - Sidelink for Vehicle2X communication

- Architecture, channel structure, synchronization, resource management, scheduling and overload control
- Comparison of WLAN-V2X and Cellular-V2X
- IP mobility support and ad hoc networking for Vehicle2X
- Vehicle2X data security and anonymity
- Vehicle2X standardization
- Communication support for vehicle automation
- Future developments and outlook

Literature:

- SOMMER, Christoph and Falko DRESSLER, 2015. *Vehicular networking*. 1. edition. 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.
- DAHLMAN, Erik, PARKVALL, Stefan, SKÖLD, Johan, 2016. *4G, LTE-advanced pro and the road to 5G* [online]. London: Academic Press PDF e-Book. ISBN 978-0-12-804611-1. Available via: http://www.sciencedirect.com/science/book/9780128045756.

Additional remarks:

None

Team Project

Module abbreviation:	AVE-Team Project	**Reg.no.:**	21
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	6

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	8 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 153 h Total: 200 h		
Subjects of the module:	Team Project		
Lecture types:	Prj - project		

Examinations:

PJ - Project report and presentation

Additional Explanation:

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, if necessary, 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.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- 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.
- present project results convincingly in front of an audience
- 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

Module abbreviation:	AVE-Sensor Data Processing and Sensor	**Reg.no.:**	22
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	6

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	7 ECTS / 6 SWS		
Workload:	Contact hours: 70 h Self-study: 105 h Total: 175 h		
Subjects of the module:	22.1: Sensor Data Processing and Sensor Data Fusion 22.2: Practical Course Sensor Data Processing and Sensor Data Fusion		
Lecture types:	SU/Ü - seminar class/exercise; Pr - practical course;		

Examinations:

22.1: schrP90 - written exam, 90 minutes
22.2: LN - participation without/with success

Additional Explanation:

Practical course: To earn the proof of participation all given exercises have to be completed and documented.

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- Understand the fundamental principles in estimation and detection theory.
- Implement algorithms for parameter estimation in linear and nonlinear models.
- Implement algorithms for detection and estimation of the position of a target in a sensor network.
- Apply the Kalman filter to linear state space models with a multitude of sensors.
- Apply nonlinear filters (extended Kalman filter, unscented Kalman filter, particle filter) to nonlinear or non-Gaussian state space models.
- Implement basic algorithms for simultaneous localization and mapping (SLAM).
- Describe and model the most common sensors used in sensor fusion applications.
- 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:

1. Estimation theory for linear and nonlinear models.

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

Literature:

- GUSTAFSSON, Fredrik, 2018. *Statistical sensor fusion*. T. edition. Lund: Studentlitteratur. ISBN 978-91-44-12724-8, 91-44-12724-3

Additional remarks:

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

Planning and Decision-Making Algorithms

Module abbreviation:	AVE-Planning and Decision-Making Algorithms	**Reg.no.:**	23
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	6

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Planning and Decision-Making Algorithms		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:
None

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- understand the basic principles of robotic planning and decision making
- assess and choose the optimal algorith for a given problem
- implemenmt basic planning and decision making algorithms

Content:

- Single-Stage Decision Making
  - optimal decisions
  - statistical decision theory
  - Bayesian classification and parameter estimation
  - utility theory
  - criticisms of Bayesian analysis
  - multiobjective optimality
- Planning: Sequential Decision Making
  - search algorithms
  - decision trees
  - Markov decision processes

- value functions
- reinforcement learning
- dynamic programming approaches

- Integrating Planning, Sensing, and Acting
  - conditional plans
  - reactive planning/feedback
  - connections to control theory
  - a Bayesian framework
  - information spaces
- Game Theory: Multiple Decision Makers
  - single and multi-stage games
  - equilibrium concepts
  - pure and mixed strategies
  - noncooperative, cooperative, and bargaining models
  - communication issues
- Logic-Based Concepts
  - temporal logic
  - partial order planning, refinement
  - abstraction, coercion
  - hierarchial 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

Additional remarks:

None

Vehicle Actuators

Module abbreviation:	AVE-Vehicle Actuators	**Reg.no.:**	24
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Compulsory Subject	6

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Vehicle Actuators		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

Eligibility to enter the second study section

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- question and classify the functionality and operating principles of specific mechatronic
- develop independent interpretations for mechatronic systems and evaluate them in a targeted manner
- gain a well-founded understanding of important sensors for AD-related mechatronics and describe them in technical detail
- conceive and design mechatronic components of automated vehicle systems

Content:

- Modeling and description of mechatronic systems and identification of the essential components
- Mathematical and functional modes of action of important sensors in automated driving and their properties (resolution, linearity, transfer functions, system identification)
- 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*. S. edition. Stamford, Conn.: Cengage Learning. ISBN 978-1-111-56902-0

Additional remarks:
None

Internship

Module abbreviation:	AVE-Internship	**Reg.no.:**	27
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)		5

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	24 ECTS / 0 SWS		
Workload:	Contact hours:		0 h
	Self-study:		600 h
	Total:		600 h
Subjects of the module:	Internship		
Lecture types:	Pr - laboratory		

Examinations:

Internship report

Additional Explanation:

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.

Prerequisites according examination regulation:

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

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- know the basic elements of everyday business life.
- be familiar with the future professional requirements
- apply their theoretical knowledge gained in previous semesters in an engineering-related position

Content:

- Working in work and content-related operational tasks using the engineering methods learned
- Getting to know operational processes and working methods

Literature:

Will be specified at the beginning

Additional remarks:

None

Internship Seminar

Module abbreviation:	AVE-Internship Seminar	**Reg.no.:**	28
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)		5

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	2 ECTS / 1 SWS		
Workload:	Contact hours: 12 h Self-study: 38 h Total: 50 h		
Subjects of the module:	Internship Seminar		
Lecture types:	S - Seminar		

Examinations:

LN - participation without/with success

Additional Explanation:

An oral presentation of a length of 30 to 45 minutes.

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- reflect on their own project experiences in relation to those of fellow students
- objectively assess their presentation performance through the feedback of the other participants
- combine their practical experience with theoretical knowledge
- expand the variety of possible solutions to typical technical and methodological problems strengthen their social skills

Content:

- Introduction
- Presentation of the topics in short presentations
- discussion of the contents and statements of the presentation
- discussion of the presentation by the speaker

Literature:

Will be specified at the beginning

Additional remarks:

None

Business Management

Module abbreviation:	AVE-Business Management	**Reg.no.:**	29
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)		5

Responsible for module:			
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	4 ECTS / 2 SWS		
Workload:	Contact hours: 23 h Self-study: 77 h Total: 100 h		
Subjects of the module:	Business Management		
Lecture types:	SU/Ü - seminar class/exercise		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:
None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After successfully completing this module the students shall be able to:

- plan and act in an economically sensible manner as engineers in a company

Content:

- Strategic and operational goals of companies
- Processes and organizational structure
- Market, brands, marketing
- Business indicators
- Accounting, profit and loss account, EBIT, EBITDA
- Contribution margin accounting
- Amortization of investments
- Innovation management
- Controlling

Literature:

- HUTZSCHENREUTER, Thomas, 2015. *Allgemeine Betriebswirtschaftslehre: Grundlagen mit zahlreichen Praxisbeispielen* [online]. Wiesbaden: Springer Gabler PDF e-Book. ISBN 978-3-658-08564-3, 978-3-658-08563-6. Available via: https://doi.org/10.1007/978-3-658-08564-3.

Additional remarks:
None

Seminar Bachelor Thesis

Module abbreviation:	AVE-BTS	**Reg.no.:**	26.1
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)		7

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	3 ECTS / 2 SWS		
Workload:	Contact hours: 23 h Self-study: 52 h Total: 75 h		
Subjects of the module:	Seminar Bachelor Thesis		
Lecture types:	S - Seminar		

Examinations:

Presentation

Additional Explanation:

The proof of achievement is provided in the form of a colloquium.
In the course of the seminar on the Bachelor thesis, students must participate in regular meetings with the supervising professor/lecturer (first examiner).

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

After attending the module

- the students know both formal and content-related requirements that are placed on a Bachelor's thesis.
- are familiar with the assessment criteria on the basis of which the assessors derive the grade of the thesis
- are familiar with the basic scientific working methods that are to be applied in the preparation of a thesis
- students are able to follow good scientific practice and apply scientific working methods
- are the students able to carry out their Bachelor's thesis in a structured manner (time and resource planning, outline)
- are the students able to obtain the necessary information for the thesis from scientific sources
- students are able to present and discuss interim results of their final thesis

Content:

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.

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.
Literature:
Will be specified at the beginning
Additional remarks:
None

Bachelor Thesis

Module abbreviation:	AVE-BT	**Reg.no.:**	26.2
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)		7

Responsible for module:	Ebert, Bernd Martin		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	12 ECTS / 0 SWS		
Workload:	Contact hours:		0 h
	Self-study:		300 h
	Total:		300 h
Subjects of the module:	Bachelor Thesis		
Lecture types:	Prj - project		

Examinations:

Bachelor-Thesis

Additional Explanation:

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.

Prerequisites according examination regulation:

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.

Recommended prerequisites:

None

Objectives:

After participating in the module course, the participants are able to

- 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
- to work out a systematic and creative solution for a technical problem in the subject area
- to determine and evaluate the limits of the proposed solution to the problem
- formulate a scientific problem in writing
- 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
- follow good scientific practice and apply scientific working methods

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 • Good scientific practice and scientific working methods
Literature:
Will be specified at the beginning
Additional remarks:
None

4.2 General Elective

Ethics of Digitization

Module abbreviation:	AVE-Ethics	**Reg.no.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	General Scientific Elective Subject	3

Responsible for module:	Uhl, Matthias		
Language of instruction:	English	**Language of exam:**	English
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	Ethics of Digitization		
Lecture types:	SU - lecture		

Examinations:

schrP90 - written exam, 90 minutes

Additional Explanation:
None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

On successful completion of the course, students will be able to

- outline the most pressing questions currently discussed in the ethics of digitization
- distinguish meta-ethical, normative, and empirical arguments in ethics
- know the most important normative theories and are able apply them to the field of digitization
- apply ethical arguments to case studies from the field of artificial intelligence, e.g., self-driving cars
- discuss the role of empirical research for the ethics of human-machine interaction and machine ethics
- transcend their own normative viewpoint by critically reflecting on it.

Content:

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?

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

Module abbreviation:	SZ_GERM_INTENS_B1	**Reg.no.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Elective subject	

Responsible for module:	Lohmann, Christoph		
Language of instruction:	German	**Language of exam:**	German
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	German B1 intensive		
Lecture types:	SU/Ü - lecture with integrated exercises		

Examinations:

LN - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

Die Studierenden können über Vergangenes berichten, Sachverhalte beschreiben, über Irreales sprechen, Beschwerden formulieren und darauf reagieren, Arbeitsabläufe beschreiben, über Fehler sprechen, Vergleiche anstellen sowie eine strukturierte Diskussion führen. Dabei verstehen sie auch längere Hör- und Lesetexte und können sich mündlich und schriftlich zu verschiedenen Themen des Alltags äußern.

Content:

Themen: Veränderungen im Leben, Werbung, Statistiken und Grafiken, Fernweh und Heimat, Regeln für höfliches Benehmen, Einbürgerung, Verkehr der Zukunft, u.a.

Grammatik: Konjunktionen (als, wenn, nachdem, indem, während, bevor, sowohl ... als auch, ...), Plusquamperfekt, Konjunktiv II, Passiv, indirekte Fragen, Adjektivdeklination, Relativsätze, Infinitivsätze mit "zu", Vergleichssätze, Futur I, u.a.

Literature:

- 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*. 1. edition. München: Hueber Verlag. ISBN 978-3-19-031878-0, 3-19-031878-6

Additional remarks:

Students have completed level A2. Minimim number of students: 8

German B2 Intensive

Module abbreviation:	SZ_GERM_B2_INTENS	**Reg.no.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Elective subject	

Responsible for module:	Copelea, Michaela		
Language of instruction:	German	**Language of exam:**	German
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	German B2 Intensive		
Lecture types:	SU/Ü - lecture with integrated exercises		

Examinations:

LN - written exam, 90 minutes

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

Die Studierenden können sich spontan und fließend verständigen und sich zu einem breiten Themenspektrum klar und differenziert äußern, auch in Diskussionen. Sie können die Hauptinhalte komplexer und abstrakter Texte verstehen und klare, detaillierte Texte zu verschiedenen Themen verfassen und dabei Argumente gegeneinander abwägen.

Content:

Es werden Themen des studentischen Lebens, aus Familie und Gesellschaft in Deutschland sowie Aspekte der Geschäftskommunikation wie Präsentationen, Korrespondenz und Besprechungen behandelt. Grammatikalische Inhalte: Zweiteilige Konnektoren; Passiv, Mittelfeld im Hauptsatz, Nebensätze, Konjunktiv II, Futur II, indirekte Rede u.a.

Literature:

- PERLMANN-BALME, Michaela, Susanne SCHWALB and Magdalena MATUSSEK, 2014. *Sicher! B2 Deutsch als Fremdsprache, Kursbuch*. 1. edition. Ismaning: Hueber. ISBN 978-3-19-001207-7
- PERLMANN-BALME, MICHAELA, , SCHWALB, SUSANNE and MATUSSEK, MAGDALENA, 2014. *Sicher! B2 Deutsch als Fremdsprache Arbeitsbuch*. 1. edition. Ismaning: Hueber. ISBN 978-3-19-0011207-4

Additional remarks:

Mindestteilnehmerzahl 8 Studierende

German in the Workcontext

Module abbreviation:	SZ_GERM_WORK	**Reg.no.:**	14
Curriculum:	**Programme**	**Module type**	**Semester**
	Autonomous Vehicle Engineering (SPO WiSe 20/21)	Elective subject	

Responsible for module:	Lohmann, Sabina		
Language of instruction:	German	**Language of exam:**	German
Credit points / SWS:	5 ECTS / 4 SWS		
Workload:	Contact hours: 47 h Self-study: 78 h Total: 125 h		
Subjects of the module:	German in the Workcontext		
Lecture types:	SU/Ü - lecture with integrated exercises		

Examinations:

LN - presentation (10-15 min.) and written composition (8-10 pages)

Additional Explanation:

None

Prerequisites according examination regulation:

None

Recommended prerequisites:

None

Objectives:

Die Studenten besitzen die notwendigen sprachlichen Fähigkeiten, die sie im Arbeitsalltag mit Vorgesetzen, Kollegen und im Kundenkontakt benötigen. Sie können geschäftliche E-Mails und Briefe verfassen, sowie selbstständig telefonieren und an Besprechungen teilnehmen.

Content:

Anredeformen; erster Arbeitstag; Bewerbungsschreiben; Besprechungen, Vertretung; Vertretungsstelle; Kunden beraten, Anfrage und Angebot; Bestellung schreiben; Bankgespräch und Mahnschreiben; Konfliktsituationen; Betriebsrat; Urlaubs- und Überstundenregelungen

Literature:

- MÜLLER, Annette, Sabine SCHLÜTER and Tina JAKOBSEN, 2017. *Im Beruf Neu B1+/B2 Kursbuch*. 1. edition. München: Hueber. ISBN 978-3-19-201190-1
- HAGNER, Valeska and Sabine SCHÜLTER, 2018. *Im Beruf Neu B1+/B2 Arbeitsbuch*. 1. edition. München: Hueber. ISBN 978-3-19-211190-7
- HERING, Axel, Magdalena MATUSSEK and Michaela PERLMANN-BALME, 2018. *Sicher! Übungsgrammatik Niveau B1+/B2/C1*. 1. edition. München: Hueber. ISBN 978-3-19-301206-7

Additional remarks:

Mindestteilnehmerzahl 8 Studierende