

Module manual

Autonomous driving

Faculty of mechanical and automotive engineering

as of 26.06.2025

List of abbreviations

ECTS	European Credit Transfer System
HQR	Higher Education Qualifications Framework
SoSe	summer semester
SPO	study and examination regulations
SWS	semester hours per week
WiSe	winter semester
PF	portfolio review
(I)	Individual submission
(T)	Team Submission

Brief description of the course

With the introduction of the Master's degree in "Autonomous Driving" and a correlated technology center, the Coburg University of Applied Sciences takes the technological leap in the automotive industry from medium-level vehicles powered by internal combustion engines to fully autonomous vehicles into account. This global development requires, in particular, specific knowledge of new technologies such as environmental sensors, digital networking and communication, information technology data interpretation using artificial intelligence methods, mobility and user experience design, and the opportunities and risks of new business models offered by autonomous mobility.

The region around Coburg University is characterized by automotive suppliers and companies that are already driving innovation in the development of autonomous driving functions and associated sensor technologies. In order to ensure a competitive positioning of these companies in global competition, specifically trained specialists are required in the above-mentioned fields of technology. The course will have a strong application focus, so that contact between students and companies in the region is established early on and maintained throughout the course through project work, internships and theses. Further research projects by companies and the associated technology center ensure a technological and scientific connection beyond the course of study. This close interlocking of teaching and application will get the students inspired for the opportunities in the region and its companies already during their studies. Companies are also brought closer to the university through this concept and research projects can be initiated more easily from within an established network.

The primarily technical degree course is based on the requirements listed above, but it also takes into account the profile-building claim of the Coburg University of Applied Sciences as an interdisciplinary source of inspiration for shaping the future of the region. Innovative, in particular demography-specific mobility concepts in rural areas, the coupling of autonomous mobility and healthcare (e.g. mobility in elderly care), new business models (e.g. the role of the insurance industry and logistics applications), legal and ethical aspects of autonomous driving as well as social implications of mobility are considered across all study programs.

Examples of application fields are:

- Autonomous vehicle guidance using artificial intelligence methods and supporting systems (digital maps and GPS position, route determination, Car2X, point-of-interest)
- Human-centered product development and innovation management
- Development and conception of services related to autonomous driving (infotainment, robotaxis, shuttle services)
- Integration of autonomous vehicle guidance in multimodal, comprehensive mobility concepts
- Development of sensor for environment perception (radar, lidar, ultrasound, camera-based systems), detection algorithms, sensor data fusion using artificial intelligence methods and derived trajectory planning
- Design of human-machine interaction
- Development of functional safety concepts in autonomous vehicle guidance, also taking into account of cyber security requirements
- Development of test environments and test automations for the qualification of the aforementioned application fields

Explanations and Notes

ECTS points and workload

ECTS points (European Credit Transfer System) describe the average workload in hours required for the successful completion of a module. Workload is measured in full hours of 60 minutes. One ECTS point corresponds to a workload of 25 hours. A module with 8 ECTS points corresponds to a total workload of 200 hours. These are divided into attendance times with the lecturers and working hours for the preparation and follow-up of an event, group work and for exam preparation.

Module and modularization

A module is a self-contained learning unit that consists of one or more courses. Each module ends with an exam. The modularization of degree programs is intended to make it easier to count skills acquired from outside the university onto the chosen degree program.

Module Descriptions

Module descriptions are intended to give students orientation on the goals, content, sources used and the type of examination. The skills to be acquired are divided into professional competence, methodological competence and other competences. Expertise is the term used to describe knowledge and skills that were acquired upon successful completion of the module. These serve to independently identify and solve problems and tasks in an economic environment. Methodological competence refers to the ability to know methods for solving economic tasks, to know their strengths, weaknesses and application requirements and to be able to apply them. Other competencies are the ability and willingness to solve business tasks cooperatively with others. It means recognizing and respecting the expectations and values of others. They also include the willingness to act independently and responsibly, to reflect on one's own situation and the willingness to learn new knowledge and techniques.

Module structure of the course - tabular overview

HS Coburg – Master's degree in Autonomous Driving

(from summer semester 2024, as of 19/01/2024)

No.	Module description	1st semester			2 semesters			3rd semester			In total
		SWS	ECTS	P	SWS	ECTS	P	SWS	ECTS	P	
1	Human-Centered Design & Development Processes: A) Introduction to V2X B) Introduction to systems engineering I C) Programming basics D) Introduction to agile project execution E) Introduction to human-centered design F) Supervised project work	6	8	PF							
2	System Architecture & Safety Concept: A) Introduction to systems engineering II B) Introduction to Deep Learning C) V2X Technologies D) Human factors E) Traffic simulation F) Driving Dynamics I G) Supervised project work	6	8	PF							
3	Environmental Perception & Data Fusion A) Sensors technologies B) Deep Learning C) Vehicular communication D) Sensor data fusion E) User experience F) Driving Dynamics II G) Supervised project work	10	14	PF							
4	Vehicle Connectivity & Localization A) V2X in Practice B) Validation methods I C) Introduction localization and mapping D) Advanced AI E) Vehicle control F) Empirical research methods G) Supervised project work				8	9	PF				
5	Navigation and Virtual Testing A) Route and trajectory planning B) Localization and mapping C) Validation methods II D) Statistics and User Testing E) Supervised project work				6	8	PF				
6	System Testing & Product Launch A) Market / product launch and digital business models B) Validation methods III C) Scientific colloquium D) Supervised project work				6	8	PF				
7	German				4	5					
	Master thesis								30		30
	SWS total	22			24						46
	Total ECTS		30			30			30		90

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Module 1: Human-Centered Design & Development Processes

Module responsible	Prof. Dr. Georg Arbeiter		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Ralf Reißing; Priya Srinivasan		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	1	Every semester	4 weeks of lecture time 1 week of exam period

Work and exam performance

Entry requirements	<p>Formally: None</p> <p>Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management</p>
Type of exam performance	<p>Portfolio review consisting of individual and team submissions</p> <p><u>Partial examination forms:</u></p> <p>Project manual (40%), <i>15-20 pages</i></p> <ul style="list-style-type: none"> • (T) business idea; milestone plan; Cooperation • exercises/homework <p>(T) Start-up pitch presentation (20%), <i>30 min per team</i></p> <p>(I/T) Additional submissions (40%), <i>selectable by the lecturers</i></p> <ul style="list-style-type: none"> • exercises/homework • Oral exam, <i>20 min</i> • Written submission <p><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("exam period week").</i></p>
work performance	A total of 200h, of which 84,4h attendance time (6SWS) and 115,6h self-study/exam preparation
ECTS and weighting	Total 8ECTS

Scheduled courses		
Type of course	Name of the course	SWS
SU	Introduction to V2X	1 x 4/15
SU	Introduction to systems engineering I	2 x 4/15
SU	Programming Basics	3 x 4/15
SU	Introduction to agile project execution	2 x 4/15
SU	Introduction to human-centered design	4 x 4/15
P	Supervised project work	10 x 4/15
Content, methods, goals and results		
content of the module		
<p>A) Introduction to V2X</p> <ul style="list-style-type: none"> • V2X use cases • basics of communication <p>B) Introduction to systems engineering I</p> <ul style="list-style-type: none"> • V-model • Use Case diagrams • Requirements specification (user stories) <p>C) Programming basics</p> <ul style="list-style-type: none"> • Introduction to Python with Jupyter • Introduction to ROS2 • Introduction to Linux <p>D) Introduction to agile project execution</p> <ul style="list-style-type: none"> • Agile methods: Kanban / Scrum • Team structure, team development and roles • Artifacts and Processes <p>E) Introduction to human-centered design</p> <ul style="list-style-type: none"> • Introduction to human-centered design process • User research and testing • Ideation methods and prototyping • Introduction to Value Proposition Design and Business Modelling <p>F) Supervised project work</p> <ul style="list-style-type: none"> • Introduction to autonomous driving • Team building • Scientific work • Project manual: team structure and processes; state of the art; Question Zero; Stakeholder Map; Persona; product idea; use cases; milestone plan • Basic specifications: requirements, traceability, tests • Weekly meeting • Preparation of start-up pitch 		

Teaching and learning methods
Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Supervised project work to apply the knowledge gained in the project.
Learning outcomes
<p>The students...</p> <ul style="list-style-type: none"> • know how to create a project manual • know the basics of a specification • master the basics of programming in the Python language • get familiar with ROS2 and Linux • are aware of the importance of human needs for the development of innovations • can set up the human-centered development process • are able to formulate a human-centered project vision • understand team dynamics and how they can contribute to team success • can assess and fulfill their role in the team • master the basics of project planning • are aware of the current state of the art and the challenges of autonomous driving • can identify the main parts of a communication system • have an understanding of important application areas of V2X • are able to carry out independent literature research
Literature
<ul style="list-style-type: none"> • Dan Rawsthorne, Doug Shimp. 2018. Scrum Handbook: Single-Team Scrum. CreateSpace Independent Publishing Platform • IDEO (2015) The field guide to human-centered design. IDEO. https://www.designkit.org/resources/1 • Ken Schwaber. 2004. Agile Project Management With scrum. Microsoft Press, USA. • Lewrick, M., Link, P., & Leifer, L. (2020). <i>The design thinking toolbox: A guide to mastering the most popular and valuable innovation methods</i>. John Wiley & Sons. Norman, D. (2013) <i>The Design of Everyday Things</i>. New York: Basic Books. • Osterwalder A, Pigneur Y, Bernarda G, Smith A, Papadacos T, & Smith A (2014). <i>Value proposition design: How to create products and services customers want</i>. ProQuest EbookCentral. • Pflingsten, Maik: <i>Erfolgreich Lastenhefte schreiben</i>. Norderstedt: BoD – Books on Demand, 2016. – ISBN: 9783739249117 <p>Programming Basics:</p> <ul style="list-style-type: none"> • Mastrodomenico, R. (2022) <i>The Python Book</i>. 1st edn. Wiley. Available at: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119573364. • Schäfer, C. (2021) <i>Quickstart Python: An Introduction to Programming for STEM Students</i>. Wiesbaden: Springer Fachmedien Wiesbaden (essentials). Available at: https://link.springer.com/10.1007/978-3-658-33552-6.

Module 2: System Architecture & Safety Concept

Module responsible	Prof Dr. Lucila Patiño Studencki		
Lecturers	Prof. Dr. Lucila Patiño Studencki; Prof. Dr. George Arbeiter; Prof. Dr. Ralf Reißing; Prof. Dr. Mathias Wilde; Priya Srinivasan		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
compulsory module	1	Every semester	4 weeks of lecture time 1 week of exam period

Work and exam performance

Entry requirements	<p>Formally: None</p> <p>Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management</p>
Type of exam performance	<p>Portfolio review consisting of individual and team submissions;</p> <p><u>Partial examination forms:</u></p> <p>System architecture documentation (20%):</p> <ul style="list-style-type: none"> • (T) architecture diagrams • (T) Component/interface description <p>Specifications (20%):</p> <ul style="list-style-type: none"> • (T) System Description • system requirements • test cases <p>Security analysis (20%):</p> <ul style="list-style-type: none"> • case study <p>(T) Start-up pitch presentation (20%), 30 min per team</p> <p>(I) Additional charges (20%)</p> <ul style="list-style-type: none"> • exercises/homeworks • Written submission • Presentations <p><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("exam period week").</i></p>

Work performance	A total of 200h, of which 84,4h attendance time (6SWS) and 115,6h self-study/exam preparation	
ECTS and weighting	Total 8ECTS	
Planned courses		
Type of course	Name of the course	SWS
SU	Introduction to systems engineering II	1 x 4/15
SU	Introduction to Deep Learning	2 x 4/15
SU	V2X Technologies	2 x 4/15
SU	Human Factors	2 x 4/15
SU	Traffic simulation	3 x 4/15
SU	Driving Dynamics I	2 x 4/15
P	Supervised project work	10 x 4/15
Content, methods, goals and results		
Content of the module		
<ul style="list-style-type: none"> • Introduction to systems engineering II <ul style="list-style-type: none"> • Requirement Engineering (System Specification) • Block diagram, signal flow and system architecture in UML • Introduction to Deep Learning <ul style="list-style-type: none"> • Overview of Artificial Intelligence • Applications • Mathematical and conceptual foundations • V2X Technologies <ul style="list-style-type: none"> • Technology developments • Requirements for V2X Communication • V2X communication standards: 5G NR / DSRC / ITS G5 • Layer model • Human factors <ul style="list-style-type: none"> • Micro, meso, and macro level of Human Factors • Introduction to theories of human-vehicle interaction in assisted, automated, and autonomous driving • Human performance • Traffic and simulation <ul style="list-style-type: none"> • Fundamentals of traffic simulation and modelling • Introduction to the “Simulation of Urban Mobility” (SUMO) tool • Parameter analysis of traffic simulation • Data sources and data collection • Driving Dynamics I <ul style="list-style-type: none"> • Interaction of driver, vehicle and environment • Steering systems 		

- **Supervised project work**
 - Creation of a requirements specification
 - Definition of test cases
 - Creation of the system architecture
 - Creation of a security analysis for a use case
 - Realization of a user study
 - Introduction to GIT
 - Integration of ROS2 into the project

Teaching and learning methods

Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Supervised project work to apply the knowledge gained in the project.

Learning outcomes

The students...

- can define system components and interfaces
- are able to analyze safety-critical situations
- master the mathematical basics for deep learning
- can apply algorithms for deep learning
- can create a specification
- know the different vehicle communication standards
- can determine requirements for the communication system
- are able to conduct user studies and derive user requirements
- know theories of human-machine interaction
- can critically examine the interaction between man and machine
- know the basics and criteria of viable and sustainable business models of networked mobility
- are able to carry out traffic simulations, determine key figures from them and evaluate the results
- recognize the benefits of traffic simulations for traffic optimization and analysis of autonomous driving scenarios
- know the basics of vehicle dynamics, with a focus on lateral dynamics

Literature

- Barceló J (2010) Models, Traffic Models, Simulation, and Traffic Simulation. International Series in Operations Research & Management Science, vol 145. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-6142-6_1
- Gassmann, Oliver/Böhm, Jonas/Palmié, Maximilian (2018): Smart City: Innovationen für die vernetzte Stadt - Geschäftsmodelle und Management. München: Hanser.
- Proff, Heike/Fojcik, Thomas M. (Hg.) (2016): Nationale und internationale Trends in der Mobilität: technische und betriebswirtschaftliche Aspekte. Wiesbaden: Springer Gabler. (= Research).
- ETSI Intelligent Transportation Systems Standards www.etsi.org
- Fisher, D. L., Horrey, W. J., Lee, J. D., & Regan, M. A. (Eds.). (2020). Handbook of human factors for automated, connected, and intelligent vehicles. CRC Press.
- Lidwell, W., Holden, K., & Butler, J. (2010). Universal principles of design, revised and updated: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design. ProQuest Ebook Central.
- Trick, Ulrich, 2021, 5G: An Introduction to the 5th Generation Mobile Networks. De Gruyter Oldenburg Sommer, Dressler, 2015, Vehicular Networking, Cambridge University Press
- Wickens, C. D., Hollands, J. G., Banbury, S., & Parasuraman, R. (2016). Engineering Psychology and Human Performance. Oxon, USA: Routledge.

Introduction to Deep Learning:

- Bhattacharyya, S. et al. (eds) (2020) Deep Learning: Research and Applications. De Gruyter. Available at: <https://www.degruyter.com/document/doi/10.1515/9783110670905/html>.
- Weidman, S. (2019) Deep learning from scratch: Building with Python from first principles. First edition, September 2019. Sebastopol: O'Reilly Media.

Module 3: Environmental Perception and Data Fusion

Module responsible	Prof. Dr. Georg Arbeiter		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Priya Srinivasan		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	1	Every semester	7 weeks of lecture time 1 week of exam period

Work and exam performance

Entry requirements	<p>Formally: None</p> <p>Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management</p>
Type of exam performance	<p>Portfolio review consisting of individual and team submissions;</p> <p><u>Partial examination forms:</u></p> <p style="margin-left: 40px;">Prototype (50%)</p> <ul style="list-style-type: none"> • (T) Carrying out calibration • (T) Grid Map ROS • (T) Customer journey • (T) V2X Messages • (T) Kalman filter estimation • (T) Main project <p style="margin-left: 40px;">(T) Prototype demonstration (20%), 30 min per team</p> <p style="margin-left: 40px;">(I/T) Additional submissions (30%), <i>selectable by the lecturers</i></p> <ul style="list-style-type: none"> • Conference contribution, 20 min presentation/ poster • Oral exam, 20 min • Written submission • exercises/homework <p style="margin-left: 40px;"><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("buffer week").</i></p>
Work performance	A total of 350h, of which 112,9 h attendance time (10SWS) and 237,1h self-study/exam preparation
ECTS and weighting	Total 14ECTS

Planned courses		
Type of course	Name of the course	SWS
SU	Sensor technologies	2 x 7/15
SU	Deep learning	2 x 7/15
SU	Vehicle communication	2 x 7/15
SU	Sensor data fusion	2 x 7/15
SU	User Experience	2 x 7/15
SU	Driving dynamics II	2 x 7/15
P	Supervised project work	10 x 7/15
Content, methods, goals and results		
content of the module		
<p>A) Sensor technologies</p> <ul style="list-style-type: none"> • Coordinate transformations • Functionality and applications of (3D) cameras, ultrasonic, radar and lidar sensors • Sensor calibration <p>B) Deep Learning</p> <ul style="list-style-type: none"> • Improved learning methods • Convolutional networks • Pytorch • Project structure for deep learning <p>C) Vehicle communication</p> <ul style="list-style-type: none"> • Architecture of connected vehicles • Messages for V2X • Layers: Facilities and Network and Transport • In-Vehicle Networks <p>D) Sensor data fusion</p> <ul style="list-style-type: none"> • Applications of sensor data fusion • Kalman Filter for state estimation • Bayesian inference for occupancy grid maps <p>E) User experience</p> <ul style="list-style-type: none"> • Perception of autonomous systems in media and society • Usage behavior of and trust in automation • Success and adaption of innovations • Motion sickness, driving comfort, and driving style in automated driving • Universal Design <p>F) Driving Dynamics II</p> <ul style="list-style-type: none"> • Lateral dynamics • Requirements for vehicle control systems 		

G) Supervised project work

- **Commissioning and calibration of sensors**
- **Implementation of AI-based detection algorithms**
- **Basic implementation of the architecture in hardware and software**
- **Building a prototype for user testing**
- **Conducting user tests to evaluate the user experience**
- **Weekly meeting**

Teaching and learning methods

Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Independent development of a scientific topic as a conference contribution. Supervised project work to apply the knowledge gained in the project.

Learning outcomes

The students...

- can understand and apply improved learning methods for neural networks
- can implement convolutional networks
- can set up projects for deep learning
- understand how different sensor technologies work and can use them
- are able to perform a sensor calibration
- understand how a V2X communication system is structured
- are able to interpret V2X messages
- can identify the main functions of the layers in the V2X framework
- know the most important algorithms for sensor data fusion and the underlying theory.
- can apply state estimation algorithms and analyze their results
- can use decision fusion techniques to create an occupancy map for their work
- have advanced knowledge of the constructs user experience and user acceptance
- transfer general success criteria for innovations to their own project
- deepen their skills in scientific work
- are able to present their own research results in a scientific format
- have advanced knowledge of vehicle dynamics

Literature

- Sommer, Dressler, 2015, Vehicular Networking, Cambridge University Press
- ETSI Intelligent Transportation Systems Standards www.etsi.org
- Grewal, Mohinder S., and Angus P. Andrews. Kalman filtering: Theory and Practice with MATLAB. John Wiley & Sons, 2014.
- Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human factors*, 46(1), 50-80.
- Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human factors*, 39(2), 230-253.
- Riener, A., Jeon, M., & Alvarez, I. (2021). User Experience Design in the Era of Automated Driving. Springer Studies in Computational Intelligence.
- Sebastian Thrun, Wolfram Burgard, Fox, Dieter. " Probabilistic robotics." 2005
- Sommer, Dressler, 2015, Vehicular Networking, Cambridge University Press
- Werner, Martin. (2017). Nachrichtentechnik. Springer, 10.1007/978-3-8348-2581-0.
- Zimmermann, Schmidgall, 2014, Bussysteme in der Fahrzeugtechnik.

Sensor technologies:

- Maître, H. (2017) From photon to pixel: The digital camera handbook. Revised and updated 2nd edition. London; Hoboken, NJ: ISTE Ltd; John Wiley & Sons, Inc (Wiley Online Library). Available at: <https://doi.org/10.1002/9781119402442>.
- Szeliski, R. (2022) Computer Vision: Algorithms and Applications. Cham: Springer International Publishing (Texts in Computer Science). Available at: <https://doi.org/10.1007/978-3-030-34372-9>.
- McManamon, P. (2019) LiDAR Technologies and Systems. Available at: <https://doi.org/10.1117/3.2518254>.

Introduction to Deep Learning:

- Bhattacharyya, S. et al. (eds) (2020) Deep Learning: Research and Applications. De Gruyter. Available at: <https://www.degruyter.com/document/doi/10.1515/9783110670905/html>.
- Weidman, S. (2019) Deep learning from scratch: Building with Python from first principles. First edition, September 2019. Sebastopol: O'Reilly Media.

Module 4: Vehicle Connectivity & Localization			
Module responsible	Prof. Dr. Lucila Patiño Studencki		
Lecturers	Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Georg Arbeiter; Prof. Dr. Ralf Reißing; Prof. Dr. Mathias Wilde		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	2	Every semester	5 weeks of lecture time 1 week of exam period
Work and exam performance			
Entry requirements	Formally: None Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management		
Type of exam performance	Portfolio review consisting of individual and team submissions; <u>Partial examination forms:</u> <ul style="list-style-type: none"> • (I/T) Main project (25%) Prototype Implementation • Start-up pitch presentation <i>20 min per team</i> • Prototype Demonstration, <i>10 min per team</i> • (I/T) Additional submissions (30%), <i>selectable by the lecturers</i> <ul style="list-style-type: none"> • Exercises/homework • Written submissions • Practices <p><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("buffer week").</i></p>		
Work performance	A total of 250h, of which 90 h attendance time (10SWS) and 160 h self-study/exam preparation		
ECTS and weighting	Total 10ECTS		

Planned courses		
Type of course	Name of the course	SWS
SU	V2X in Practice	2 x 5/15
SU	Validation Methods I	2x5/15
SU	Introduction to localization and mapping	1 x 5/15
SU	Advanced AI	2 x 5/15
SU	Vehicle Control	2 x 5/15
SU	Empirical research methods	2 x 5/15
P	Project work	13 x 5/15
Content, methods, goals and results		
Content of the module		
<p>A) V2X in practice</p> <ul style="list-style-type: none"> • Access Layer • Measurements in V2X-Networks • Key Performance Indicators of V2X-Technologies <p>B) Validation methods I</p> <ul style="list-style-type: none"> • Basics of quality assurance and testing • Methods for testing mechatronic systems, especially test case determination, test execution, test evaluation • Software Unit Verification <p>C) Introduction to localization and mapping</p> <ul style="list-style-type: none"> • Map representations • Odometry <p>D) Advanced AI</p> <ul style="list-style-type: none"> • Data sets and annotation • Sequential Networks (RNNs) • Unsupervised Learning <p>E) Vehicle control</p> <ul style="list-style-type: none"> • Basic control strategies • Implementation of controllers for longitudinal and lateral dynamics <p>F) Empirical research methods</p> <ul style="list-style-type: none"> • Research questions and hypotheses • Design of experiments • Basics of Null Hypothesis Significance Testing • Descriptive statistics and data visualization <p>G) Supervised project work</p> <ul style="list-style-type: none"> • Realization of the human-machine interface • Implementation of object recognition • Commissioning of an autonomous system 		

- Weekly meeting

Teaching and learning methods

Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Project work to apply the knowledge gained in the project.

Learning outcomes

The students...

- know the different map representations and can use them in the project
- can use estimation algorithms to solve localization tasks
- master the basics of quality assurance and testing
- can review and evaluate documents and code
- can integrate and commission various components of an autonomous system
- are able to recognize the interaction of driver, vehicle and environment
- are familiar with the requirements for systems for vehicle control and know the approaches to implementation
- recognize the importance of algorithms and digital methods
- are able to set up an empirical research project including research questions and hypotheses
- are familiar with the concept of Null Hypothesis Significance Testing
- are able to visualize descriptive data
- can establish a communication using V2X-Platforms
- can measure main parameters of V2X-Communication systems

Literature

- Cairo, A. (2012). *The Functional Art: An introduction to information graphics and visualization*. New Riders.
- Field, A., & Hole, G. (2002). *How to design and report experiments*. Sage.
- Goodfellow, I., Bengio, Y. and Courville, A. (2016) *Deep Learning*. MIT Press. <https://www.amazon.de/Deep-Learning-Adaptive-Computation-Machine/dp/0262035618>
- Mueller, John Paul (2020): *Deep Learning kompakt für Dummies*. 1. Aufl. Weinheim: Wiley
- Sebastian Thrun, Wolfram Burgard, Fox, Dieter, "Probabilistic robotics." 2005
- Paul, Anup Kumar, and Takuro Sato. "Localization in wireless sensor networks: A survey on algorithms, measurement techniques, applications and challenges." *Journal of sensor and actuator networks* 6.4 (2017): 24.

Module 5: Navigation and Virtual Testing

Module responsible	Prof. Dr. Georg Arbeiter		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Ralf Reißing; Prof. Dr. Tilo Strutz		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	2	Every semester	5 weeks of lecture time 1 week of exam period

Work and exam performance

Entry requirements	<p>Formally: None</p> <p>Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management</p>
Type of exam performance	<p>Portfolio review consisting of individual and team submissions;</p> <p><u>Partial examination forms:</u></p> <p>(T) Main project (50%)</p> <ul style="list-style-type: none"> • Hardware and software prototype • Know Report, <i>about 10-15 pages</i> • Demonstration prototype, <i>30 min per team</i> • Setup of test environment and test automation <p>(I/T) Additional submissions (50%), <i>selectable by the lecturers</i></p> <ul style="list-style-type: none"> • Exercises/homework • Oral exam, <i>20 min</i> • Written submission <p><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("buffer week").</i></p>
Work performance	A total of 250h, of which 90 h attendance time (10SWS) and 160h self-study/exam preparation
ECTS and weighting	Total 10ECTS

Planned courses		
Type of course	Name of the course	SWS
SU	Route and trajectory planning	1 x 5/15
SU	Localization and mapping	2 x 5/15
SU	Validation Methods II	2 x 5/15
SU	Statistics and User Testing	2 x 5/15
P	Supervised Project work	11 x 5/15
Content, methods, goals and results		
Content of the module		
<p>A) Route and trajectory planning</p> <ul style="list-style-type: none"> • Path planning algorithms (Geometric Path) • Trajectory planning (methods and kinematics) <p>B) Localization and mapping</p> <ul style="list-style-type: none"> • Measuring and estimation methods for localization • Approaches for Simultaneous Localization and Mapping (SLAM): EKF-based, PF-based and graph-based <p>C) Validation methods II</p> <ul style="list-style-type: none"> • Software Integration Tests <p>D) Statistics and User Testing</p> <ul style="list-style-type: none"> • Basics of inferential statistics • Methods for testing difference and correlation hypotheses • Reporting and interpreting results • Planning reliable user studies and tests • Opportunities and risks of different test environments <p>E) Supervised project work</p> <ul style="list-style-type: none"> • Weekly meeting • Safeguarding of driving functions • Implementation of planning, navigation and control 		
Teaching and learning methods		
<p>Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Independent project work to apply the acquired knowledge in the project.</p>		

Learning outcomes

The students...

- can implement methods for maneuver planning and navigation
- are able to understand different motion models for vehicles
- can implement a trajectory control
- can evaluate software and mechatronic systems (focus: automotive)
- can virtually secure driving functions
- are able to analyze SLAM algorithms and interpret results
- know the basics of descriptive statistics and hypothesis testing
- can critically question and interpret statistics and presentations of results
- can classify and analyze data they have collected themselves and present and discuss the derived results
- know the fundamentals of inferential statistics
- can conduct an empirical research project
- are able to report and interpret results of experiments

Literature

- Field, A. (2013). Discovering statistics using IBM SPSS statistics. Legend.
- Gasparetto A, Boscarol P, Lanzutti A, Vidoni R (2015) Path Planning and Trajectory Planning Algorithms: A General Overview. In: Carbone G, Gomez-Bravo F (eds) Motion and Operation Planning of Robotic Systems. Mechanisms and Machine Science, vol 29. Springer, Cham. https://doi.org/10.1007/978-3-319-14705-5_1
- Sebastian Thrun, Wolfram Burgard Fox, Dieter, "Probabilistic robotics." 2005
- Grisetti, Giorgio, et al. "A tutorial on graph-based SLAM." IEEE Intelligent Transportation Systems Magazine 2.4 (2010)

Module 6: System Test & Product Launch			
Module responsible	Prof. Dr. Lucila Patiño Studencki		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Ralf Reißing; Prof. Dr. Eva Brandmeier		
Language of instruction and examination	English		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	2	Every semester	5 weeks of lecture time 1 week of exam period
Work and exam performance			
Entry requirements	<p>Formally: None</p> <p>Content-wise / recommended by lecturers: Basic engineering mathematics; basic knowledge of computer science; Basics of project management</p>		
Type of exam performance	<p>Portfolio review consisting of individual and team submissions;</p> <p><u>Partial examination forms:</u></p> <p>Main project (35%)</p> <ul style="list-style-type: none"> • (T) Scientific report use case (technical documentation, test report) • (T) Demonstration Use Case • Oral exam, 10 min <p>Scientific colloquium (25%)</p> <ul style="list-style-type: none"> • Scientific poster • Presentation, 20 minutes • Oral exam, 10 min <p>(I/T) Additional submissions (40%), <i>selectable by the lecturers</i></p> <ul style="list-style-type: none"> • Written Submissions • Oral exam, 10 min <p><i>The individual submissions are due during the lecture period and are selected and announced by the lecturers at the beginning of the module. Lecture-free days are available between the modules to prepare for the final presentations ("exam period week").</i></p>		
Work performance	A total of 250h, of which 90 h attendance time (10SWS) and 160h self-study/exam preparation		
ECTS and weighting	Total 10ECTS		

Planned courses		
Type of course	Name of the course	SWS
SU	Market / product launch and digital business models	2 x 5/15
SU	Validation Methods III	2 x 5/15
SU	Scientific Colloquium	4 x 5/15
P	Supervised Project work	10 x 5/15
Content, methods, goals and results		
content of the module		
<p>A) Market / product launch and digital business models</p> <ul style="list-style-type: none"> • Consideration of data-based business models and their stakeholders • Basics of product launch and target group-driven marketing • Evaluation of various possible digital business models • Development of a product launch strategy taking aspects of user acceptance into account <p>B) Validation methods III</p> <ul style="list-style-type: none"> • System test and user test (verification and validation) <p>C) Scientific colloquium</p> <ul style="list-style-type: none"> • Scientific research on a topic • Carrying out practical experiments on this topic • Presentation and defense of the results <p>D) Supervised project work</p> <ul style="list-style-type: none"> • Implementation and validation of scenarios on the autonomous system • Documentation of the technical implementation • Final demo with presentation 		
Teaching and learning methods		
Imparting the basics in seminars with integrated exercises. Deepening and expanding knowledge through self-study. Project work to apply the knowledge gained in the project.		
Learning outcomes		
<p>The students...</p> <ul style="list-style-type: none"> • are able to evaluate technical solutions in different test environments • can carry out and evaluate user studies as summative evaluation • can validate driving functions in a field test and document test results • have improved their argumentation and discussion skills • have implemented a product prototype and demonstrated how it works 		

literature

- ITS Sensors and Architectures for Traffic Management and Connected Vehicles, Lawrence A. Klein. Publisher: Taylor & Francis Ltd; 1st Edition (20 Aug 2017)
- Field, A (2017): Discovering Statistics Using IBM SPSS Statistics, Sage Publications, 5th Edition, ISBN-10: 9781526419521
- Sauro, J., & Lewis, J.R. (2016). Quantifying the user experience: Practical statistics for user research. Morgan Kaufman.

Module 7: German			
Module responsible	N.N.		
Lecturers	N.N., N. N.		
Language of instruction and examination	English / German		
Module type	Study semester	Quotation cycle	Length of time
Compulsory module	2	Every semester	Complete second semester
Work and exam performance			
Entry requirements	Formally: None Content-wise / recommended by lecturers: Attendance of pre-course in 1 st semester		
Type of exam performance	Written exam /Final test; oral exam		
Work performance	A total of 90h, of which 65h attendance time (4 SWS) and 25h self-study/exam preparation		
ECTS and weighting	Total 5 ECTS		
Planned courses			
Type of course	Name of the course	SWS	
SU	Language Course	4	
Content, methods, goals and results			
content of the module			
<p>The <i>German Basics</i> (Level A1, A2, B1) courses are designed for international students with little or no previous knowledge of German. The aim is to build up basic knowledge that will enable students to participate for the communication in every day and academic scenarios (oral/written) from the start of the program. The course content is tailored to the needs of the target group (e.g. internship):</p> <ul style="list-style-type: none"> ▪ practice-oriented learning objectives (aligned by typical language/writing activities) ▪ Basic vocabulary ▪ Written communication: text type specific structures ▪ Teaching learning strategies to enable autonomous learning ▪ Use of authentic material <p>The focus is on everyday communication in studies and work, (lexis and grammar follow this content (form follows content/function))</p>			

Teaching and learning methods
Class room Teaching, Live Online-Learning Sessions (Learning platform Moodle, MS-Teams)
Learning outcomes (A1, A2, B1 CEFR)
<p>Students acquire linguistic and cultural competences (reading, listening, writing and speaking skills) for everyday life and study in German. German is usually the second, third or additional language English. It is of central importance for multilingual learners to recognize the language as a system (language comparison). In this way, they develop a deeper understanding of linguistic structures (grammar, lexis) and the cultural context, which improves their ability to communicate independently in everyday life. Students can furthermore use language assistants, apps, online resources and similar tools to manage and expand their language learning.</p> <p>Students are enabled to communicate in everyday situations (shopping, living, mobility, studies and internships, leisure time, etc.) in a manner appropriate to the target group. The aim is to organize the individual language learning process in the foreign language in a multicultural group and using digital media in a cooperative, independent and successful manner.</p>
Learning Material and Literature
<p>Learning Material</p> <ul style="list-style-type: none"> • Kurs DaF A1. Deutsch für Studium und Beruf, Kurs- und Übungsbuch. 2023. KLETT: ISBN 978-3-12-676838-2 • Kurs DaF A1. Deutsch für Studium und Beruf Kurs- und Übungsbuch, 2023. Hybride Ausgabe allango, KLETT: ISBN 978-3-12-676841-2. • Kurs DaF A2. Deutsch für Studium und Beruf, Kurs- und Übungsbuch. 2024. KLETT: ISBN 978-3-12-676840-5. • Kurs DaF A2. Deutsch für Studium und Beruf Kurs- und Übungsbuch. 2024. Hybride Ausgabe allango, KLETT: ISBN 978-3-12-676840-5. • Kurs DaF B1. Deutsch für Studium und Beruf, Kurs- und Übungsbuch. 2025. KLETT: ISBN 978-3-12-676842-9. • Kurs DaF B1. Deutsch für Studium und Beruf Kurs- und Übungsbuch. 2024. Hybride Ausgabe allango, KLETT. <p>Literature</p> <ul style="list-style-type: none"> • Council of Europe: <u>Global scale - Table 1 (CEFR 3.3): Common Reference levels (coe.int)</u> Council of Europe: <u>Official translations of the CEFR Global Scale (coe.int)</u> [03.04.25] • <u>Gemeinsamer Europäischer Referenzrahmen für Sprachen: lernen, lehren, beurteilen.</u> Begleitband. 2020. Stuttgart: Klett, ISBN 978-3-12-676999-0. [03.04.25] • Glaboniat, M.; Müller, M.; Rusch, P.; Schmitz, Helen; Wertenschlag, L.. 2013. Profile deutsch A1-C2. 1. Aufl., Lernzielbestimmungen, Kannbeschreibungen, Kommunikative Mittel. Stuttgart: Klett, ISBN 978-3-12-606518-4.

Risk assessment

Here you will find an overview of which courses relating to pregnancy and/or breastfeeding can be attended.

Green	The course is safe.
Yellow	Participation in the course requires a review in individual cases.
Red	The student is not permitted to participate in the course.

Risk assessment of the modules				
module number	module name	Danger		Remarks
1	Human-Centered Design & Development Processes	x		
2	System Architecture & Safety Concept	x		
3	Sensors for Environmental Perception & Data Fusion	x		
4	Vehicle Connectivity & Localization	x		
5	Navigation & Virtual Safeguarding	x		
6	System Test & Product Launch	x		
7	German	x		