COBURG UNIVERSITY
of applied sciences and arts

Module manual

Autonomous driving

Faculty of mechanical and automotive engineering

as of 01.07.2024

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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 submisssion
(T) ..... Team Submission

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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

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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	**Sensors for 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 Safeguarding** 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 Test & 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 / other Foreign Language**				4	5					
	Master thesis								30		**30**
	SWS total	22			24						**46**
	Total ECTS		30			30			30		**90**

Table of contents of the offered modules

Contents

Module 1: Human-Centered Design & Development Processes			
Module responsible	Prof. Dr. Alisa Lindner		
Lecturers	Prof. Dr. Alisa Lindner; Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Ralf Reißing		
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	**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> Project manual (40%), *15-20 pages* • *(T)* business idea; milestone plan; Cooperation • exercises/homework *(T)* Start-up pitch presentation (20%), *30 min per team* *(I/T)* Additional submissions (40%), *selectable by the lecturers* • exercises/homework • Oral exam, *20 min* • Written submission *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").*
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

A) Introduction to V2X
- V2X use cases
- basics of communication

B) Introduction to systems engineering I
- V-model
- Use Case diagrams
- Requirements specification (user stories)

C) Programming basics
- Introduction to Python with Jupyter
- Introduction to ROS2
- Introduction to Linux

D) Introduction to agile project execution
- Agile methods: Kanban / Scrum
- Team structure, team development and roles
- Artifacts and Processes

E) Introduction to human-centered design
- Introduction to human-centered design process
- User research and testing
- Ideation methods and prototyping
- Introduction to Value Proposition Design and Business Modelling

F) Supervised project work
- 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

The students…

- 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

- 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). *The design thinking toolbox: A guide to mastering the most popular and valuable innovation methods*. John Wiley & Sons. Norman, D. (2013) The Design of Everyday Things. New York: Basic Books.
- Osterwalder A, Pigneur Y, Bernarda G, Smith A, Papadakos T, & Smith A (2014). Value proposition design: How to create products and services customers want. ProQuest EbookCentral.
- Pfingsten, Maik: Erfolgreich Lastenhefte schreiben. Norderstedt: BoD – Books on Demand, 2016. – ISBN: 9783739249117

Programming Basics:

- Mastrodomenico, R. (2022) The Python Book. 1st edn. Wiley. Available at: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119573364.
- Schäfer, C. (2021) Quickstart Python: An Introduction to Programming for STEM Students. Wiesbaden: Springer Fachmedien Wiesbaden (essentials). Available at: https://link.springer.com/10.1007/978-3-658-33552-6.

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Module 2: System Architecture & Safety Concept			
Module responsible	Prof Dr. Lucila Patiño Studencki		
Lecturers	Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Alisa Lindner; Prof. Dr. George 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	**1**	**Every semester**	**4 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> System architecture documentation (20%): • *(T)* architecture diagrams • *(T)* Component/interface description Specifications (20%): • (T) System Description • system requirements • test cases Security analysis (20%): • case study *(T)* Start-up pitch presentation (20%), *30 min per team* *(I)* Additional charges *(20%)* • exercises/homework • Written submission *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").*

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

- **Introduction to systems engineering II**
  - Requirement Engineering (System Specification)
  - Block diagram, signal flow and system architecture in UML

- **Introduction to Deep Learning**
  - Overview of Artificial Intelligence
  - Applications
  - Mathematical and conceptual foundations

- **V2X Technologies**
  - Technology developments
  - Requirements for V2X Communication
  - V2X communication standards: 5G NR / DSRC / ITS G5
  - Layer model

- **Human factors**
  - 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**
  - 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**
  - 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

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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.

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Module 3: Sensors for Environmental Perception and Data Fusion			
Module responsible	Prof. Dr. Georg Arbeiter		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Alisa Lindner		
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	**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> Prototype (50%) • *(T)* Carrying out calibration • *(T)* Grid Map ROS • *(T)* Customer journey • *(T)* V2X Messages • *(T)* Kalman filter estimation • *(T)* Main project *(T)* Prototype demonstration (20%), *30 min per team* *(I/T)* Additional submissions (30%), *selectable by the lecturers* • Conference contribution, *20 min presentation/ poster* • Oral exam, *20 min* • Written submission • exercises/homework *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").*
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

A) Sensor technologies
- Coordinate transformations
- Functionality and applications of (3D) cameras, ultrasonic, radar and lidar sensors
- Sensor calibration

B) Deep Learning
- Improved learning methods
- Convolutional networks
- Pytorch
- Project structure for deep learning

C) Vehicle communication
- Architecture of connected vehicles
- Layers: Facilities, Network and Transport and Access
- In-Vehicle Networks

D) Sensor data fusion
- Applications of sensor data fusion
- Algorithms for state estimation: Kalman filter, particle filter
- Bayesian inference on decision fusion (occupancy maps)

E) User experience
- 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

F) Driving Dynamics II
- 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.

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Module 4: Vehicle Connectivity & Localization			
Module responsible	Prof. Dr. Lucila Patiño Studencki		
Lecturers	Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Georg Arbeiter; Prof. Dr. Alisa Lindner; 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> *(T)* Main project (55%) • Processing of a use case (conception, implementation, test strategy) • Demonstration, *30 min per team* *(T)* Traffic engineering and simulation (15%) • Simulation of a traffic scenario • Presentation of results *(I/T)* Additional submissions (30%), *selectable by the lecturers* • Written submission • Oral exam, *20 min* • Exercises/homework *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").*
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

A) V2X in practice
- V2X technologies (ETSI-G5 / C-V2X)
- V2X messages and applications
- Measurement in V2X-Networks

B) Validation methods I
- Basics of quality assurance and testing
- Methods for testing mechatronic systems, especially test case determination, test execution, test evaluation
- Software Unit Verification

C) Introduction to localization and mapping
- Map views
- Odometry

D) Advanced AI
- Data sets and annotation
- Sequential Networks (RNNs)
- Unsupervised Learning

E) Vehicle control
- Basic control strategies
- Implementation of controllers for longitudinal and lateral dynamics

F) Empirical research methods
- Research questions and hypotheses
- Design of experiments
- Basics of Null Hypothesis Significance Testing
- Descriptive statistics and data visualization

G) Supervised project work
- 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
- know how dynamic object tracking technologies work
- 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-Platfoms
- 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.

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Module 5: Navigation and Virtual Safeguarding			
Module responsible	Prof. Dr. Georg Arbeiter		
Lecturers	Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Alisa Lindner; Prof. Dr. Ralf Reißing,		
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> *(T)* Main project (40%) • Hardware and software prototype • Know Report, *about 10-15 pages* • Demonstration prototype, *30 min per team* • Setup of test environment and test automation *(T)* Side project (20%) • Know Report, *5-10 pages* • Presentation/demonstration, *20 min per team* *(I/T)* Additional submissions (40%), *selectable by the lecturers* • Exercises/homework • Oral exam, *20 min* • Written submission *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").*
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

A) Route and trajectory planning
- Path planning algorithms (Geometric Path)
- Trajectory planning (methods and kinematics)

B) Localization and mapping
- Measuring and estimation methods for localization
- Approaches to SLAM (Simultaneous Localization and Mapping): EKF-based, PF-based and graph-based

C) Validation methods II
- Software Integration Tests

D) Statistics and User Testing
- 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

E) Supervised project work
- Side project
- Weekly meeting
- Safeguarding of driving functions
- Implementation of planning, navigation and control

Teaching and learning methods

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.

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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, Boscariol 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)

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Module 6: System Test & Product Launch			
Module responsible	Prof. Dr. Alisa Lindner		
Lecturers	Prof. Dr. Alisa Lindner; Prof. Dr. Georg Arbeiter; Prof. Dr. Lucila Patiño Studencki; Prof. Dr. Ralf Reißing; Prof. Dr.-Ing. 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	**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> Main project (35%) • *(T)* Scientific report use case (technical documentation, test report) • *(T)* Demonstration Use Case • Oral exam, *10 min* Scientific colloquium (25%) • Scientific poster • Presentation, *20 minutes* • Oral exam, *10 min* *(I/T)* Additional submissions (40%), *selectable by the lecturers* • Written Submissions • Oral exam, *10 min* *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").*
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

A) Market / product launch and digital business models

- 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

B) Validation methods III

- System test and user test (verification and validation)

C) Scientific colloquium

- Scientific research on a topic
- Carrying out practical experiments on this topic
- Presentation and defense of the results

D) Supervised project work

- 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

The students…

- 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.

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Module 7: German / other Foreign Language

Module responsible	Dr. Regina Graßmann		
Lecturers	Ms. Isilay Schmidt, Ms. Laura Silke Klotzek		
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 1st 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

This intensive language course is committed to an activity-orientated approach, it teaches elementary language skills in German as a foreign language - taking into account the multilingual language profile - and cultural and regional aspects.

Teaching and learning methods
Class room Teaching, Live Online-Learning Sessions (Learning platform Moodle, Zoom)
Learning outcomes
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.
literature
Learning Material A1: • Starten Wir! A1 ISBN 978-3-19-016000-6 (Kursbuch)/ ISBN 978-3-19-026000-3 (Arbeitsbuch); • Starten wir! A1 – Interaktive digitale Ausgabe (Kursbuch: ISBN 978-3-19-166000-0, Arbeitsbuch: 978-3-19-176000-7); • Glossar Deutsch-Englisch ISBN 978-3-19-286000-3; • Sprachkurs Plus Deutsch A1/A2, Englische Ausgabe ISBN 978-3-19-199475-4, Hueber Verlag Learning Material A2: • Starten Wir! A2 ISBN 978-3-19-046000-7 (Kursbuch)/ ISBN 978-3-19-096000-2 (Arbeitsbuch), Hueber Verlag • Starten wir! A2 – Interaktive digitale Ausgabe (Kursbuch: ISBN 978-3-19-186000-4; Arbeitsbuch: ISBN 978-3-19-196000-1) • Glossar Deutsch-Englisch ISBN 978-3-19-286000-3 • Sprachkurs Plus Deutsch A1/A2, Englische Ausgabe ISBN 978-3-19-199475-4

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 / other Foreign Language	x			