Technische Hochschule Ingolstadt

Module Handbook

M.Eng. AI Engineering of Autonomous Systems

Faculty of

Electrical Engineering and Information Technology

Study and examination regulation WS 23/24

As of 2026-03-01

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1 Introduction and Overview

The rise of AI and autonomous systems is about to revolutionise various industries and find application in a wide range of fields, from transportation and logistics to healthcare and agriculture. Self-driving cars are transforming the automotive industry, promising safer and more efficient transportation. Unmanned aerial vehicles (UAVs) are revolutionising delivery services, enabling quick and reliable parcel distribution. In industries like manufacturing and warehousing, autonomous robots streamline operations, enhancing productivity and reducing costs. As the demand for AI engineers and experts continues to soar, this Master‘s programme aims to nurture a new generation of professionals who can harness the power of AI to create innovative and intelligent autonomous systems.

Throughout this program, students will learn how to design, develop, and deploy intelligent systems that can learn, make decisions and operate autonomously, i.e., without human intervention. Basic building blocks of autonomous systems such as sensor networks and data fusion, data engineering, computing as well as communication technologies are explored and combined with AI engineering methods like perception and cognition, machine learning and decision making.

Legal Basis

This module handbook describes the curriculum of the Master's degree program in AI Engineering of Autonomous Systems and its courses in accordance with the General Examination Regulations of the Technical University of Ingolstadt (APO THI) dated July 17, 2023. The curriculum is described in an appendix that applies to all students who have enrolled in M.Eng. AI Engineering of Autonomous Systems at TH Ingolstadt since winter term 2023/24. In addition, the Study and Examination Regulation (SPO) specifies, in particular, the qualification requirements. Students who have enrolled in the program described here in winter term 2023/24 are studying according to the statutes dated February 13, 2023. Students enrolled in winter term 2024/25 study in accordance with the statutes dated February 13, 2023, as amended by the amendment to the statutes dated April 29, 2024.

In particular, the module handbook specifies the study objectives and content of the individual compulsory modules as well as the division of the semester hours per week per module and semester. It also contains more detailed provisions on course-related performance and attendance assessments. In the event of ambiguities, the higher-level study and examination regulations take precedence.

The list of compulsory and elective courses offered in a specific semester are documented in the study guide for the respective semester. The study guide is published in the Moodle course room dedicated to this degree program.

2 Programme Description

2.1 Contents

The programme consists of compulsory modules in the following areas:

Intelligent Sensing and Exploration

Sensors are the sensory organs of autonomous systems, key to their mobility and autonomy. Data from multiple and even different sensors are combined to quickly and accurately communicate information about the environment, physical events, activities or situations to decision-making components.

Planning and Control/Decision Making

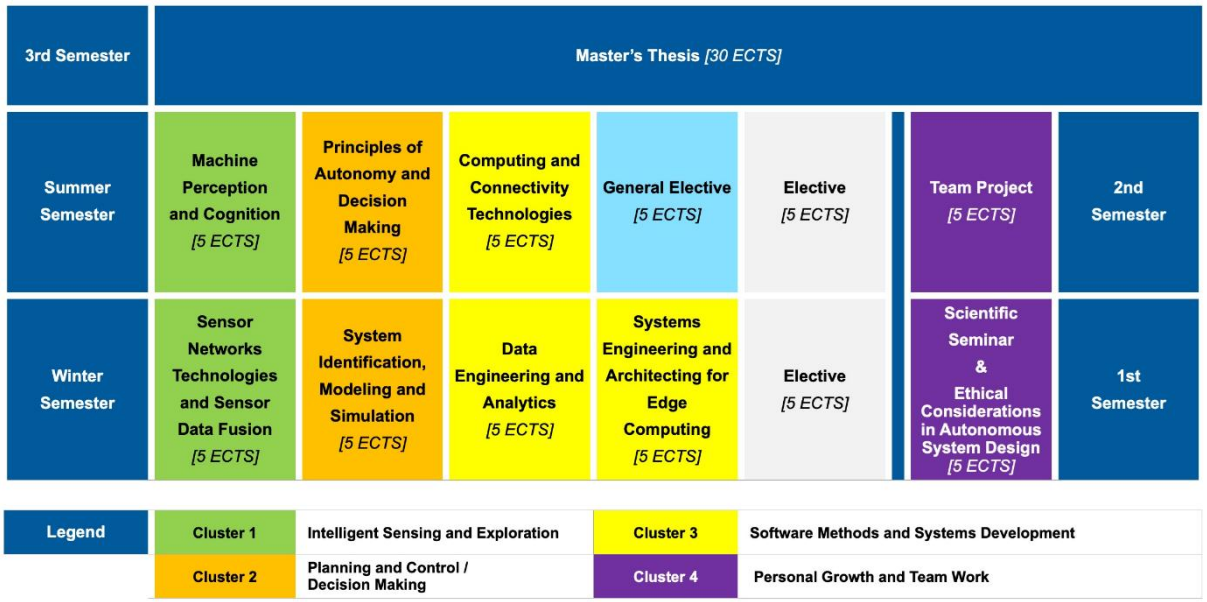
Planning with intelligence is a prerequisite for autonomous and predictive action. Systems need to be able to plan their actions in order to achieve a given goal and to respond to unexpected or new situations by changing their behaviour. Machine learning methods are used to combine sensor-data with past experience and draw conclusions that can be used to improve actions.

Software Methods and System Development

The development of autonomous systems is approached from a software engineering perspective. Various characteristics of autonomous systems, architectures, and models will be covered in order to demonstrate the technical feasibility of systems that dynamically adapt their behaviour to changes in operating conditions by means of software.

Personal Growth and Team Work

This focus area strengthens both individual academic development and collaborative competence. The scientific seminar allows students to explore a new technical topic, write a structured seminar paper, present their findings to an audience, and actively engage in discussion and questions. The team project gives students the opportunity to apply their technical knowledge in practice, deepen their understanding, and experience working together by sharing responsibility and relying on each other's contributions. In the master's thesis, students independently carry out a substantial research or development project, write a detailed thesis, present their results, and respond to questions in a scientific discussion.



The compulsory part is complemented by elective modules. These modules focus on specific aspects of the development of autonomous systems, automotive applications, innovation management, or engineering processes applied in tech companies as well as language courses.

2.2 Graduation

After successful completion of the Master´s Programme, the Technische Hochschule Ingolstadt awards the academic degree:

Master of Engineering (M.Eng.)

2.3 Advisor and Programme Coordinator

For all technical and functional questions and problems with regards to contents of the Master‘s programme as well as for questions concerning the organisational execution of the study programme please contact:

Prof. Dr.-Ing. Alen Turnwald, building A, room 105, phone +49 841 9348-7919

The office hours during the semester will be announced via Moodle.

2.4 Dual Studies

In cooperation with selected industry partners, the study program AI Engineering of Autonomous Systems can also be completed in dual studies model. The dual study model is offered as a study program with in-depth practice, in which the regular study program is supplemented by intensive practical phases in a com-pany.

In dual study model, university and practical phases (especially during semester breaks and for the final thesis) regularly alternate during the course of study. The lecture times in the dual study model correspond to the standard study and lecture times at the THI.

By systematically linking the learning locations of university and company, students gain professional practical experience with selected practice partners as an integral part of their studies.

The curriculum of the two dual degree program models differs from the regular degree program con-cept in the following points:

- Final thesis in the cooperation company

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

Organizationally, the two dual degree program models are characterized by the following components:

- Mentoring

  The central contact persons for dual students in the faculty are the respective program head of studies. They organize an annual mentoring meeting with the dual students of the respective study program.

- Quality management

  In the evaluation and surveys at the THI on the quality assurance of the dual study separate question blocks are included.

- „Forum dual“

  Organized by the Career Service and Student Counselling (CSS), the “Forum Dual” takes place once a year. The “Forum Dual“ promotes the professional-organizational exchange between the dual coopera-tion partners and the faculty and serves to ensure the quality of the dual study programs. All coopera-tion partners in the dual study program as well as representatives and dual students of the faculty are invited to the meeting.

Formal-legal regulation for dual studies for all degree programs of the THI is regulated in the APO (see §§ 17, 18 and 21) and the enrolment statutes (see §§ 8b and 18).

According to the above description, the following modules are different for dual students:

- Thesis

More detailed description can be found in the corresponding module description.

3 Curricular structure

The standard period of study for the Master's degree course in AI Engineering of Autonomous Systems comprises three semesters. Semester 1 and semester 2 (and vice versa) are independent of each other. They do not build on each other. The 3rd semester is intended for the preparation of the Master's thesis. This ensures that it is possible to start this Master's degree program in both the summer and winter semesters.

To complete the Master’s programme, students are required to select two Science Elective modules and one General Elective module over the course of their studies. The list of available modules in both areas is published in the study guide at the beginning of each semester. All modules are taught in English and in presence at the Technische Hochschule Ingolstadt (THI). Science and General Elective can be offered in German.

The following two tables show the respective curriculum for a winter semester or summer semester start.

3.1 General compulsory subjects

Start of studies in the winter term

SPO-No.	Module	1st-Semester			2nd Semester			3rd Semester		
		SWS	ECTS	Exam	SWS	ECTS	Exam	SWS	ECTS	
1	Machine Perception and Cognition				4	5	schrP			
2	System Identification, Modeling and Simulation	4	5	schr P						
3	Data Engineering and Analytics	4	5	schrP						
4	Scientific Seminar	2	2.5	SA						
5	Ethical Considerations in Autonomous System Design	2	2.5	mdlP						
6	Sensor Networks Technologies and Sensor Data Fusion	4	5	schrP						
7	Principles of Autonomy and Decision Making				4	5	prP			
8	Computing and Connectivity Technologies				4	5	mdlP			
9	Systems Engineering and Architecting for Edge Computing	4	5	schrP						
10	Team Project				4	5	Proj			
11	General Elective				4	5	LN			
12	Science Elective	4	5	LN	4	5	LN			
13.1	Master's Thesis							0	30	MA
13.2	Colloquium									Koll
	Sum	**24**	**30**		**24**	**30**		**0**	**30**	

Start of studies in summer term

SPO-No.	Module	1st-Semester			2nd Semester			3rd Semester		
		SWS	ECTS	Exam	SWS	ECTS	Exam	SWS	ECTS	
1	Machine Perception and Cognition	4	5	schrP						
2	System Identification, Modeling and Simulation				4	5	schrP			
3	Data Engineering and Analytics				4	5	schrP			
4	Scientific Seminar	2	2.5	SA						
5	Ethical Considerations in Autonomous System Design	2	2.5	mdlP						
6	Sensor Networks Technologies and Sensor Data Fusion				4	5	schrP			
7	Principles of Autonomy and Decision Making	4	5	prP						
8	Computing and Connectivity Technologies	4	5	mdlP						
9	Systems Engineering and Architecting for Edge Computing				4	5	schrP			
10	Team Project				4	5	Proj			
11	General Elective	4	5	LN						
12	Science Elective	4	5	LN	4	5	LN			
13.1	Master's Thesis							0	30	MA
13.2	Colloquium									Koll
	Sum	**24**	**30**		**24**	**30**		**0**	**30**	

schrP Written Exam
mdlP Oral Exam
prP Practical Exam
SA Seminar Paper (incl. Presentation)
Proj Project Work, Presentation and Paper
MA Master´s Thesis, written form
Koll Colloquium
LN Certificate of Achievement (Written, Oral, or Practical Exam)

4 Description of Modules

4.1 Compulsory modules

Machine Perception and Cognition			
Module abbreviation	AI_MachPerception	**Reg.-Nr.**	1
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only summer term	**Module duration**	1 semester

Responsible for module	Schall, Martin		
Lecturer(s)	Schall, Martin		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Machine Perception and Cognition		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

knowledge in linear algebra and logic, graph representations

Objectives

Upon completion of the module, students will be able to:

- Understand the effects of converting physical signals to digital signals.
- Understand digital cameras and radiometric camera calibration.
- Understand stereo vision, time-of-flight cameras and LiDAR.
- Understand convolutional neural networks (CNNs), recurrent neural networks (RNNs) and their application in computer vision.
- Understand face recognition and handwriting recognition.
- Understand attention networks and transformers.
- Understand large language models (LLMs), vision-language models (VLMs), vision-language-action models (VLAs) and their applications in robotics.
- Understand reinforcement learning and its applications in robotics.

Content

- Sampling, discretization, frequency domain and Nyquist-Shannon theory.

- Pinhole cameras, CCD sensors, radiometric camera calibration and rolling shutter effects.
- Stereo vision, time-of-flight cameras and LiDAR.
- Artificial neural networks, gradient descent and backpropagation.
- Convolutional neural networks (CNNs) and Gabor filters.
- CNNs for object detection, classification and as autoencoders.
- Triplet loss, metric learning and face recognition.
- U-Nets and image segmentation.
- Evaluation metrics for deep neural networks.
- Recurrent neural networks (RNNs) and backpropagation-through-time.
- Handwriting recognition and connectionist temporal classification (CTC).
- Attention networks, transformer and large language models (LLMs).
- Vision-language models (VLMs) and vision-language-action models (VLAs).
- Basics of reinforcement learning.

Literature

Will be specified at the beginning

Additional remarks

None

System Identification, Modeling and Simulation			
Module abbreviation	AI_SysIdent	**Reg.-Nr.**	2
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Turnwald, Alen		
Lecturer(s)	Turnwald, Alen		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	System Identification, Modeling and Simulation		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

Engineering mathematics
Basics of physics: kinematics, mechanics, electricity
Relationships between describing variables (force, torque, current, ...) of the mechanical and electrical energy domain
Basics of programming
Basics of control engineering

Objectives

Upon completion of the module, students will be able to:

- Derive and analyze mathematical models of dynamic systems relevant to robotics and autonomous systems.
- Apply both analytical and numerical methods to simulate system behavior.
- Identify and estimate model parameters from experimental or simulated data.
- Implement and validate models using computational tools, e.g. Matlab/Simulink.

Content

The following topics are covered:

- Fundamentals and objectives of system modelling in robotics and autonomous systems
- Introduction to Matlab/Simulink

- Mathematical representations and analysis of linear dynamic systems: ODEs, state-space, and transfer functions
- Analytical and numerical solution methods for simulating system behavior (Euler, Runge-Kutta, etc.)
- Techniques for parameter estimation, model fitting, and validation using experimental or simulated data
- Modelling, simulation, and identification of nonlinear systems, including linearisation approaches

Literature

- ESHKABILOV, Sulaymon L., 2020. *Practical MATLAB modeling with Simulink: programming and simulating ordinary and partial differential equations* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-5799-9. Available via: https://doi.org/10.1007/978-1-4842-5799-9.
- BROWN, Forbes T., 2007. *Engineering system dynamics: a unified graph-centered approach*. Boca Raton, FL [u.a.]: CRC, Taylor & Francis. ISBN 978-0-8493-9648-9, 0-8493-9648-4
- KARNOPP, Dean, Donald L. MARGOLIS and Ronald C. ROSENBERG, 2012. *System dynamics: modeling, simulation, and control of mechatronic systems*. Hoboken: Wiley. ISBN 978-1-118-15982-8
- PALM III, William John, 2021. *System dynamics* . New York, NY: McGraw-Hill. ISBN 978-1-260-57076-2
- BERTSEKAS, Dimitri P., 2019. *Reinforcement learning and optimal control*. Belmont, Massachusetts: Athena Scientific. ISBN 978-1-886529-39-7

Additional remarks

None

Data Engineering and Analytics			
Module abbreviation	AI_DataEng	**Reg.-Nr.**	3
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Schmidtner, Stefanie		
Lecturer(s)	Akmal, Muhammad Uzair		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Data Engineering and Analytics		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

Probability and Statistics, Concept of Random Variables; Linear Algebra; Analysis

Objectives

Upon completion of the module, students will be able to:

- choose and calculate appropriate metrics and visualizations for describing a data set.
- understand and master fundamental data analysis and machine learning methods.
- acquire deep knowledge about model assessment and inference techniques for linear and non-linear models.
- know fundamentals of data engineering.

Content

- Data visualization
- Data cleaning and data quality
- Fundamentals of statistical learning and machine learning
- Linear Regression
- Classification
- Model assessment, selection and inference: Cross-Validation & Bootstrap
- Decision Trees
- Unsupervised Learning
- Neural networks (ANN, ResNet, CNN)

- Fundamentals of data engineering (data modeling, data warehouse, data lake, parallel and distributed computing, data pipelines)

Literature

- WILKE, Claus, March 2019. *Fundamentals of data visualization: a primer on making informative and compelling figures*. Beijing: O'Reilly. ISBN 978-1-492-03108-6
- JAMES, Gareth, WITTEN, Daniela, HASTIE, Trevor, TIBSHIRANI, Robert, TAYLOR, Jonathan, 2023. *An Introduction to Statistical Learning: with Applications in Python* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-031-38747-0. Available via: https://doi.org/10.1007/978-3-031-38747-0.
- HASTIE, Trevor, TIBSHIRANI, Robert, FRIEDMAN, Jerome H., 2017. *The elements of statistical learning: data mining, inference, and prediction* [online]. New York, NY, USA: Springer PDF e-Book. ISBN 978-0-387-84858-7. Available via: https://doi.org/10.1007/978-0-387-84858-7.
- BISHOP, Christopher M., 2009. *Pattern recognition and machine learning*. New York [u.a.]: Springer. ISBN 0-387-31073-8, 978-1-4939-3843-8
- LESKOVEC, Jure, Anand RAJARAMAN and Jeffrey D. ULLMAN, 2020. *Mining of massive datasets*. Cambridge: Cambridge University Press. ISBN 978-1-108-47634-8
- RYZA, Sandy and others, 2017. *Advanced analytics with Spark: patterns for learning from data at scale*. Beijing: O'Reilly. ISBN 978-1-4919-7295-3

Additional remarks

No remarks.

Scientific Seminar			
Module abbreviation	AI_ScienSeminar	**Reg.-Nr.**	4
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1
Module frequency	winter and summer term	**Module duration**	1 semester

Responsible for module	Turnwald, Alen		
Lecturer(s)	Knorr, Alexander; Schlamp, Anna-Lena; Turnwald, Alen		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	2.5 ECTS / 2 SWS		
Workload	Contact hours		25 h
	Self-study		38 h
	Total		63 h
Subjects of the module	Scientific Seminar		
Lecture types	S - seminar		

Examinations

SA - Seminar paper with written elaboration (10-20 pages) and oral presentation (15-20 minutes)

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

Upon completion of the module, students will be able to:

- Acquire knowledge in a technical field by means of independent literature research and analysis.
- Summarise and explain a technical content in the form of a brief written elaboration following scientific referencing guidelines.
- Present this knowledge comprehensibly within the framework of an oral presentation using suitable supportive media.
- Understand a presentation and to critically and professionally discuss the contents with the speaker.
- Apply enhanced interdisciplinary knowledge and communicative skills in relevant contexts.

Content

- The respective lecturer compiles a collection of publications from the technical literature.
- In the course of the seminar, each student is required to present a paper/topic that was assigned by either lot or choice at the beginning of the semester.
- In the preparation phase, each student must conduct independent literature research on the topic and aggregate the results.
- The student will give an oral presentation(s) on the topic lasting in total about 30 minutes followed by a discussion with peers. Participation in the discussions is contributing to the final grade.

• In addition to an oral presentation, the student is required to prepare a written paper on the topic of the presentation. This paper should summarise the main contents. The respective instructor will communicate detailed information on topics, deadlines and expectations regarding the presentation as well as the written elaboration at the beginning of the semester.
Literature
• will be announced at the beginning of the semester
Additional remarks
Attendance is compulsory in this module.

Ethical Considerations in Autonomous System Design			
Module abbreviation	AI_Ethics	**Reg.-Nr.**	5
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1
Module frequency	winter and summer term	**Module duration**	1 semester

Responsible for module	Richter, Florian		
Lecturer(s)	Richter, Florian		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	2.5 ECTS / 2 SWS		
Workload	Contact hours		25 h
	Self-study		38 h
	Total		63 h
Subjects of the module	Ethical Considerations in Autonomous System Design		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

mdlP - oral exam - 15 - 30 min.

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

Upon completion of the module, students will be able to:

- Outline the most pressing questions currently discussed in the ethics of autonomous systems.
- Distinguish meta-ethical, normative, and empirical arguments in ethics.
- Know the most important normative theories and are able apply them to the field of autonomous system design.
- Apply ethical arguments to case studies from the field of autonomous systems, 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 autonomous systems deals with questions of machine ethics and ethics of human-machine interaction. We will tackle both fields in the course. Machine ethics asks which morality artificial systems 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 autonomous systems 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 behaviour through the design of human-machine interfaces?
Literature
Will be specified at the beginning
Additional remarks
None

Sensor Networks Technologies and Sensor Data Fusion			
Module abbreviation	AI_SensorNetworks	**Reg.-Nr.**	6
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Giesler, Björn		
Lecturer(s)	Giesler, Björn		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Sensor Networks Technologies and Sensor Data Fusion		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

(digital) signal processing, time-domain and frequency analysis

Objectives

Upon completion of the module, students will be able to:

- Demonstrate an understanding of the fundamental principles underlying sensor networks.
- Explain the key concepts and mechanisms of communication within sensor networks.
- Apply advanced linear and non-linear digital signal processing to a multitude of sensors.
- Describe and model the most common sensors used in sensor fusion applications.
- Implement basic algorithms for simultaneous localisation and mapping (SLAM).
- Apply sensor fusion to different sensors like cameras, radar, etc.
- Use AI methods like, e.g., federated learning to the field of sensor fusion and sensor networks.

Content

The module comprises the following aspects of sensor networks and sensor data fusion:

- basics and advanced concepts of wireless sensor networks,
- hardware aspects of sensor nodes,
- routing in wireless networks,
- time synchronisation and localisation in wireless networks,
- data/signal processing in wireless sensor networks,
- need for multi-sensor data fusion,

- various approaches to data fusion,
- representations of data and data fusion architectures,
- algorithmic approaches to data fusion,
- applications of wireless sensor networks.

Literature

- KARL, Holger and Andreas WILLIG, 2007. *Protocols and architectures for wireless sensor networks*. Chichester [u.a.]: Wiley. ISBN 978-0-470-51923-3, 0-470-51923-1
- KOCH, Wolfgang, 2014. *Tracking and Sensor Data Fusion: Methodological Framework and Selected Applications* [online]. Heidelberg: Springer PDF e-Book. ISBN 978-3-642-39271-9, 978-1-306-20127-8. Available via: https://doi.org/10.1007/978-3-642-39271-9.

Additional remarks

None

Principles of Autonomy and Decision Making			
Module abbreviation	AI_PrincAutonomy	**Reg.-Nr.**	7
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only summer term	**Module duration**	1 semester

Responsible for module	Turnwald, Alen		
Lecturer(s)	Gerner, Jeremias; Karpenahalli Ramakrishna, Chidvilas		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Principles of Autonomy and Decision Making		
Lecture types	SU/Ü/PR - seminar based teaching/Exercise course/laboratory		

Examinations

prP - practical examination (15 min)

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

knowledge and experience in Python (object-oriented) programming

Objectives

Upon completion of the module, students will be able to:

- Explain the fundamental concepts of Markov decision processes (MDPs) and stochastic games, and describe how these models are used in sequential decision making under uncertainty.
- Compare and evaluate statistical planning techniques and machine learning algorithms (including predictive models and reinforcement learning) for decision making in uncertain environments.
- Design and implement algorithmic decision-making systems using appropriate modeling and learning methods.
- Critically analyze the challenges and requirements for engineering autonomous systems, particularly regarding safety, verification, and testing.

Content

- probabilistic modeling
- optimization (heuristic, gradient-based)
- sequential decision making and search
- Markov decision processes
- dynamic programming
- statistical planning (bandits, stacked bandits, MCTS, cross-entropy planning)
- reinforcement learning

• multi-agent systems (games, stochastic games, MARL) • safety, testing and verification (risk, uncertainty, coevolution)
Literature
Will be specified at the beginning
Additional remarks
None

Computing and Connectivity Technologies			
Module abbreviation	AI_CompConn	**Reg.-Nr.**	8
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only summer term	**Module duration**	1 semester

Responsible for module	Festag, Andreas		
Lecturer(s)	Festag, Andreas; Hagerer, Andreas		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Computing and Connectivity Technologies		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

mdlP - oral exam - 15 - 30 min.

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

internet / OSI layer model; digital communications

Objectives

Upon completion of the module, students will be able to:

- Describe architecture, organisation and execution concepts of basic and advanced processing technologies (CPU, ISP, GPU, TPU) used to handle requirements of various applications of autonomous systems efficiently.
- Explain the execution of program elements by various processing technologies.
- Describe concepts of interconnection technologies for processor to memory communication and processor to processor communication.
- Describe the requirements, use cases, architectures and communication technologies for exchanging information among autonomous systems.
- Understand transmission and media access methods, communication protocols of the network, transport and facilities layer as well as data security and system management.
- Evaluate the advantages and disadvantages of current technological capabilities to deliver uninterrupted connectivity that is interoperable between different kind of mobile units, satellites and command centres and assess future developments.

Content

Computing Technology:

- organisation and architecture of computing systems: CPU, ISP, GPU, Multi-GPUs, distributed GPUs

- programming concepts for CPUs and GPUs
- interconnection structures
- domain-specific architectures like TPUs
- use case: distributed machine learning

Connectivity Technology:

- Car2X use cases and system architecture
- WLAN-V2X and Cellular-V2X
- Architecture, channel structure, synchronisation, resource management, scheduling and overload control
- IP mobility support and ad hoc networking for Car2X

Literature

- KUROSE, James F. and Keith W. ROSS, 2022. *Computer networking: a top-down approach*. Harlow, United Kingdom: Pearson. ISBN 978-1-292-40546-9, 1-292-40546-5
- GEETHA, T V, SENDHILKUMAR, S, 2023. *Machine Learning: concepts, techniques and applications* [online]. Boca Raton, London, New York: CRC Press, Taylor & Francis Group PDF e-Book. ISBN 978-1-003-29010-0. Available via: https://doi.org/10.1201/9781003290100.
- VAIDYA, Bhaumik, September 2018. *Hands-on GPU-accelerated computer vision with OpenCV and CUDA: effective techniques for processing complex image data in real time using GPUs*. Birmingham ; Mumbai: Packt. ISBN 978-1-78934-368-7
- TROPPENS, Ulf, 2009. *Storage networks explained: basics and application of Fibre Channel SAN, NAS, iSCSI, InfiniBand, and FCoE*. Hoboken, NJ: John Wiley. ISBN 978-0-470-74143-6
- CHAKRAVARTHI, Veena S., KOTESHWAR, Shivananda R., 2023. *System on Chip (SOC) Architecture: A Practical Approach* [online]. Cham: Springer Nature Switzerland PDF e-Book. ISBN 978-3-031-36242-2. Available via: https://doi.org/10.1007/978-3-031-36242-2.

Additional remarks

None

Systems Engineering and Architecting for Edge Computing			
Module abbreviation	AI_SystemsEng	**Reg.-Nr.**	9
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Membarth, Richard		
Lecturer(s)	Membarth, Richard		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Systems Engineering and Architecting for Edge Computing		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

Computer Architecture
C/C++ Programming
Graph Theory

Objectives

Upon completion of the module, students will be able to:

- Understand the characteristics of embedded architectures.
- Identify optimization potential for algorithms to meet resource constraints.
- Realize algorithms on embedded systems.
- Optimise deep learning networks for execution on edge devices.
- Evaluate the effect of programming alternatives on the execution speed.
- Explain concepts for performance enhancement in embedded systems and the problems associated with them.

Content

- embedded architectures
- energy efficiency
- resource constraints and scheduling
- programming for embedded architectures
- deep learning on edge devices

- algorithms for CNNs
- network quantization

- domain-specific architectures
  - Google TPU
  - NVIDIA Jetson
  - AMD AI Engine

Literature

- PATTERSON, David A. and John L. HENNESSY, 2020. *Computer Organization and Design: The Hardware Software Interface*. Cambridge, MA, USA: Morgan Kaufmann. ISBN 978-0-12-820331-6
- GOODFELLOW, Ian, Yoshua BENGIO and Aaron COURVILLE, 2016. *Deep Learning*. ISBN 978-0-262-03561-3

Additional remarks

Bonus points can be earned in this module by completing a programming assignment during the semester. Up to 10% of the points achievable in the examination can be additionally acquired for the programming task. Participation in the bonus system is voluntary. Bonus points will be awarded for:

- a correct, working implementation that passes the tests,
- performance aspects of the implementation (wall runtime),
- resource aspects of the implementation (memory usage).

Further details will be provided during the lecture. A clear git development history and documentation of the code development are mandatory for bonus points to be awarded. The programming assignment must undoubtedly be completed independently.

Team Project			
Module abbreviation	AI_Project	**Reg.-Nr.**	10
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Chandra Sekaran, Karthikeyan		
Lecturer(s)	Chandra Sekaran, Karthikeyan; De Borba, Thiago; Huber, Robert; Inderst, Maximilian; Jagtap, Abhishek Dinkar; Sezgin, Fatih; Streck, Egor; Thirugnanam, Vaishal		
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Team Project		
Lecture types	Proj - project		

Examinations

Proj - Project work (5-25 pages) with oral presentation (15 minutes)

Additional explanations regarding examinations

The team project is a group work in which several students work on a common task. Each student has to contribute individually to the task, submit a project report and present the results orally.

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

Upon completion of the module, students will be able to:

- Analyse a complex technical task and partition the task into several succesive or parallel work packages,
- Successfully participate, collaborate in and organise a team over the period of a whole semester,
- Discuss the project progress in varying but always appropriate detail, report in oral and/or written form,
- Deal with technical and non-technical problems that may occur during the implementation of a project lasting several weeks,
- Demonstrate teamwork and leadership skills,
- Utilise project and risk management to support target achievement,
- Critically question the objectives of the project and find a balance to support an overall success of the project,
- Convincingly present project results in front of an audience,
- Write a focused report containing analysis, solution concept and implementation of the project.

Content
Working on a team project in the field of AI engineering and autonomous systems. Potential topics are compiled every semester, according to current research topics of THI professors, assistants, lab or research facilities as well as project offers from companies. Project management and organisation are carried out by students. The lecturer only acts as a coach, mentor, and/or client. The project management method can be classical or agile. The decision about which method to use is up to the project team. At the beginning of the project, the lecturer clearly communicates expectations regarding the deadlines as well as type and scope of deliverables to be provided by the team. Frequency and duration of planning sessions as well as work meetings are to be discussed.
Literature
• will be announced by lecturer at the beginning of the project
Additional remarks
None

Master Thesis			
Module abbreviation	AI_MasterThesis	**Reg.-Nr.**	13
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Compulsory Subject	
Module frequency	winter and summer term	**Module duration**	1 semester

Responsible for module	Turnwald, Alen		
Lecturer(s)	All lecturers (AI_MasterThesis) All lecturers (AI_ThesisColl)		
Language of instruction	English	**Language of exams**	German/English
Credit points / SWS	30 ECTS / 0 SWS		
Workload	Contact hours		0 h
	Self-study		750 h
	Total		750 h
Subjects of the module	13.1: Master Thesis 13.2: Colloquium		
Lecture types	13.1: MA - Master's Thesis 13.2: S - seminar		

Examinations

13.1: Master-Thesis
13.2: Colloquium

Additional explanations regarding examinations

In general, students look for a topic for their Master's thesis on their own. Potential topics are either offered internally by university lecturers in notices/online or result from the cooperation of the student with a company.

In the case of an externally provided topic, the student must convince a university lecturer of his or her topic so that the lecturer assumes the role of first examiner. For this purpose, it is advisable to outline the topic and the planned approach in a short exposé.

Prerequisites according examination regulation

The topic of the Master's thesis will be assigned no earlier than the beginning of the second semester of study. The assignment of the Master's thesis topic requires that study and examination achievements totalling at least 30 ECTS credits have been successfully completed.

Recommended prerequisites

Successful participation in Scientific Seminar as well as Team Project

Objectives

Upon successful completion of the master’s thesis and its colloquium, students will be able to:

- Independently address a complex engineering problem from the study program's subject area within a defined timeframe and, if applicable, a specified budget, using scientifically sound methods.
- Systematically and creatively develop solutions to similar or related problems.
- Identify and critically evaluate the limitations of the developed solution.

- Clearly define the problem, contextualise it within a broader framework, and present and discuss the solution and results in accordance with scientific writing standards (e.g., coherence, transparency) and formal academic criteria.
- Adhere to principles of good scientific practice and apply appropriate scientific research methods.
- Present the core content of their master thesis in a clear and comprehensible manner within a given time frame.
- Position their own scientific work in the existing knowledge environment.
- Carry out a scientific discussion with a critical audience.

Content

The master's thesis is a graduation thesis in engineering specific to the course of study. The topic of the master's thesis is set, supervised and accompanied in terms of content by a THI professor. The topic can be worked on in practice, e.g. in a company, or in research at the THI and includes

- scientific analysis of a complex problem specific to the course of study against the background of the state of the art in science and technology,
- literature research, especially considering current international publications in scientific journals,
- development of a creative solution concept appropriate to the context of the problem, taking into account current scientific, technical and operational aspects,
- comprehensive evaluation of alternative solution concepts and selection of the best solution concept (technical, economic evaluation),
- implementation of the selected solution concept of the complex problem specific to the course of study,
- critical and comprehensive analysis of the obtained results using appropriate engineering methods,
- project management (especially time and, if necessary, budget management),
- comprehensible and formally correct presentation and documentation of the solution and results,
- good scientific practice and scientific working methods.

In the colloquium the student presents the problem, approaches, solution and limits of the theses' topic and discusses them with fellow students and the lecturers.

Literature

Will be specified at the beginning

Additional remarks

Keep your supervisors and primary examiners regularly informed of your progress. In particular, clarify their expectations regarding the content of the thesis. A whole semester is estimated for working on the Master's thesis (30 ECTS) which in terms of scope and content of a Master's thesis has much higher requirements than a Bachelor's thesis. In particular, the scientific character should be emphasized more strongly in a Master's thesis:

- Statements should, wherever possible, be placed in the context of relevant technical literature,
- In addition to conventional technical literature, sources from current research (e.g., dissertations and conference papers) should be substantially included,
- The graduate's working methods should be purposeful, methodical, and systematic, and should be explicitly documented in the thesis,
- Quantitative statements, such as measurements, should be investigated and documented using the tools of mathematical statistics.
- The thesis can be written in English or German.

Note, in case of a Dual Study, the Master's Thesis must be completed with the cooperating company.

4.2 General Elective

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

Advanced Economics			
Module abbreviation	Adv_Econ_M-EGM	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Eisenberg, Andrea		
Lecturer(s)	Eisenberg, Andrea		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Advanced Economics		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

The students get to

- understand the importance of global economic system and problems for strategic business decisions in globally active companies.
- be able to evaluate challenges resulting from globalization and growing international business transactions.
- understand global economic problems, international economic relations and economic policy.
- understand how the international monetary system works.
- achieve an in-depth understanding of micro- and macroeconomic interrelationships.

Content

- Advanced Microeconomic theory: supply and demand, economic actors
- Advanced Macroeconomics: inflation, unemployment, economic growth
- Institutional economics and international economic organizations
- International trade and globalization
- Interest rates, international monetary policy and currency systems

Literature
• MANKIW, Nicholas Gregory and Mark P. TAYLOR, 2023. *Economics*. Andover, Hampshire: Cengage. ISBN 978-1-4737-8698-1 • MCDOWELL, Moore, 2012. *Principles of economics*. London [u.a.]: McGraw-Hill Education. ISBN 0-07-713273-4, 978-0-07-713273-6 • TAYLOR, Timothy, 2022. *Principles of Economics. PDF* [online]. PDF e-Book.
Additional remarks
The course is held on-site. However, under special circumstances, it may also take place virtually. Course selection varies depending on availability and demand. The actual selection for each semester can be found in the timetable. Courses may be canceled at the beginning of the semester. Participation is limited in some cases.

Engineering Processes in Automotive Industry			
Module abbreviation	EngineeProcAuto_M-APE	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	1
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Neumann, Alexander		
Lecturer(s)	Neumann, Alexander; Triveni, Prashant		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Engineering Processes in Automotive Industry		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

The students are able to

- know the strong networked and parallel processes in the product and process development of automobiles.
- recognise, assess and include in the work interactions between production and product.
- know the significance and working methods of Simultaneous Engineering (SE) including the involvement of suppliers in product design and product and process quality to meet the requirements of production.
- handle tools of project and process management and know the working methods and processes (e.g. for networking, decision-making, escalation, etc.) in large automotive and supplier companies.
- know the significance of prototype, pilot production and release processes and here applied tools.
- know about the significance of lean development methods and cost management.

Content

- Product and process development in the automotive industry
- Automotive project- and process-management and according methods
- Requirements and quality management tools
- Pre-series process
- Cost management
- Lean development

- Aspice

Literature

- STAMATIS, Diomidis H., 2001. *Advanced quality planning: a commonsense guide to AQP and APQP*. New York, NY: Productivity Press. ISBN 1-56327-258-X
- COOPER, Robert G., 2017. *Winning at new products: creating value through innovation*. New York, NY: Basic Books. ISBN 0-465-09332-9, 978-0-465-09332-8
- WOMACK, James P., Daniel T. JONES and Daniel ROOS, 2007. *The machine that changed the world: [how lean production revolutionized the global car wars]*. London [u.a.]: Simon & Schuster. ISBN 978-1-84737-055-6, 1-8473-7055-1
- WOMACK, James P. and Daniel T. JONES, 2003. *Lean thinking: banish waste and create wealth in your corporation*. London [u.a.]: Simon & Schuster. ISBN 978-0-7432-3164-0
- ROTHER, Mike and John SHOOK, 2009. *Learning to see: value-stream mapping to create value and eliminate muda*. Version 1. edition. Cambridge, Mass.: Lean Enterprise Inst.. ISBN 978-0-9667843-0-5, 0-9667843-0-8
- MORGAN, James M. and Jeffrey K. LIKER, 2006. *The Toyota product development system: integrating people, process, and technology*. New York, NY: Productivity Press. ISBN 1-56327-282-2, 978-1-563-27282-0
- REINERTSEN, Donald G., 2009. *The principles of product development flow: second generation lean product development*. Redondo Beach, Calif: Celeritas. ISBN 978-1-935401-00-1, 1-935401-00-9
- CHANG, Kuang-Hua, 2013. *Product manufacturing and cost estimating using CAD/CAE*. Amsterdam [u.a.]: Elsevier. ISBN 978-0-12-401745-0
- MITAL, Anil, 2014. *Product development: a structured approach to consumer product development, design, and manufacture*. Amsterdam [u.a.]: Elsevier. ISBN 978-0-12-799945-6

Additional remarks

Bonus system:

In the course, tasks can be set that lead to bonus points for the examination performance for each qualitatively completed task. The maximum crediting of bonus points takes place according to the APO.

German A2 intensive			
Module abbreviation	AI_German_A2	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Scientific Elective Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Ekici, Gülsüm		
Lecturer(s)	Ekici, Gülsüm; Ghasemi, Neda; Seyfferth, Heike; Steinert-Pindrys, Lyubov; Wickern, Barbara		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	German A2 intensive		
Lecture types	SU - lecture		

Examinations
LN - written exam, 90 minutes
Additional explanations regarding examinations
None
Prerequisites according examination regulation
None
Recommended prerequisites
None
Objectives
To be determined
Content
To be determined
Literature
Will be specified at the beginning
Additional remarks
None

German B1 Intensive			
Module abbreviation	SZ_AVE_GERM_INTENS_B1	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Klingenberg, Lothar		
Lecturer(s)	Klingenberg, Lothar; Nehir, Mehmet; Pohl, Esther; Seitz, Daniela		
Language of instruction	English	**Language of exams**	English
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 AVE		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

Nach dem Besuch des Moduls sind die Studierenden in der Lage, in schriftlicher wie mündlicher Form

- über Vergangenes zu berichten
- Sachverhalte zu beschreiben
- über Irreales zu sprechen
- Beschwerden zu formulieren und darauf zu reagieren
- Arbeitsabläufe zu beschreiben und über Fehler zu sprechen
- Vergleiche anzu stellen sowie eine strukturierte Diskussion zu führen

Content

- Veränderungen im Leben, Werbung, Fernweh und Heimat
- Regeln für höfliches Benehmen
- Einbürgerung
- Verkehr der Zukunft
- Grammatik: Konjunktionen, Plusquamperfekt, Konjunktiv II, Passiv, indirekte Fragen, Adjektivdeklination, Relativsätze, Infinitivsätze mit "zu", Vergleichssätze, Futur I

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*. 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

Sustainability, CSR and Compliance Management			
Module abbreviation	GBM_SCSR&CM	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	4
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Loza Adaui, Cristian Rolando		
Lecturer(s)	Loza Adaui, Cristian Rolando		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Sustainability, CSR and Compliance Management		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

At the end of the course the students:

Knowledge

- Understand the concepts of compliance, sustainability, and corporate social responsibility (CSR) and explain their theoretical foundations within a global business context.
- Identify the connection between CSR and sustainable development, both in general and specifically within business administration.
- Distinguish between the shareholder and stakeholder approaches and critically evaluate their implications for the purpose of business and its role in society.

Methodology

- Apply the fundamental principles of sustainability controlling and reporting, with a particular focus on key performance indicators (KPIs) used in measuring sustainability efforts.
- Analyze practical case studies to bridge theoretical knowledge with real-world CSR activities, developing a critical perspective on corporate social responsibility practices.
- Utilize compliance frameworks to understand how laws and company regulations shape ethical business practices on a global scale.

Personality

- Develop a personal understanding of the ethical implications of compliance and sustainability practices and apply them in both professional and personal decision-making.
- Reflect on individual responsibility in maintaining compliance and promoting ethical behavior within the business environment.

Social Competence

- Collaborate in discussions and team projects to evaluate CSR initiatives and compliance challenges from diverse perspectives, contributing to a broader understanding of business's role in society.
- Communicate effectively about sustainability, CSR, and compliance in professional contexts, addressing the diverse needs and interests of various stakeholders.

Content

- Historical perspectives on sustainability, CSR and Compliance Management
- CSR and the theory of business administration: Contradiction in terms?
- Is business part of society or “is the business of business business”?
- Definition of CSR and relation to the concept of sustainability/sustainable development
- Shareholder vs. Stakeholder approach
- The four theorethical perspectives on CSR
- Strategic Corporate Sustainability and Responsibility
- Is there a “business case” for CSR?
- Sustainable Circular Business Models
- CSR and sustainability standards
- CSR and sustainability reporting
- How to implement CSR: Examples/case studies from different industries
- Ethics and compliance
- Definition of compliance with an international scope
- Perception of compliance in different countries and companies
- Structure and concepts for corporate compliance
- Behaviour in compliance situation
- Compliance challenges when making business in a global environment
- Compliance cases in various industries and politics

Literature

- RASCHE, Andreas and others, 2023. *Corporate Sustainability: Managing Responsible Business in a Globalised World*. ISBN 9781009114929
- HAHN, Rüdiger, 2022. *Sustainability Management: Global Perspectives on Concepts, Instruments, and Stakeholders*. ISBN 978-3-9823211-1-0
- FRÖHLICH, Elisabeth and others, 2025. *Circular Economy in Sustainable Supply Chains: A Global Perspective on Challenges, Concepts and Cases*. Cham: Springer. ISBN 978-3-031-70748-3
- HAYWARD, Andrew and Tony OSBORN, 2019. *The Business Guide to Effective Compliance and Ethics*. ISBN 9780749482978
- PUFÉ, Iris, 2017. *Nachhaltigkeit*. Konstanz: UVK Verlagsgesellschaft mbH. ISBN 978-3-8252-8705-4, 3-8252-8705-X
- WEBER, Jürgen and others, 2012. *Nachhaltigkeit und Controlling*. Weinheim: Wiley-VCH. ISBN 978-3-527-50652-1
- HANDY, Charles, 2003. What’s a Business For? Harvard Business Review on Corporate Responsibility. In: *Harvard Business Review (HBR)*. , p.65-82.
- Without author. *Overcoming compliance fatigue. Reinforcing the commitment to ethical growth. 13th Global Fraud Survey* [online]. , 2014 [Accessed on:]. Available via: https://vdocuments.net/reader/full/overcoming-compliance-fatigue-reinforcing-the-commitment-to-ethical-growth-13th-global-fraud-survey-2014
- Without author. *Report from the Commission to the Council and the European Parliament. EU Anti-corruption report* [online]. [Accessed on:]. Available via: https://eur-lex.europa.eu/resource.html?uri=cellar:058aecf0-d9b7-11e3-8cd4-01aa75ed71a1.0012.01/DOC_1&format=PDF

- FOX, Thomas R.. *The Five Essential Elements of a Corporate Compliance Program - Part I* [online]. , 2012 [Accessed on:]. Available via: https://tfoxlaw.wordpress.com/2012/09/07/the-five-essential-elements-of-a-corporate-compliance-program-part-i/
- FOX, Thomas R.. *The Five Essential Elements of a Corporate Compliance Program - Part II* [online]. , 2012 [Accessed on:]. Available via: https://tfoxlaw.wordpress.com/2012/09/09/the-five-essential-elements-of-a-corporate-compliance-program-part-ii/
- CHERRY, Kendra. *The Psychology of Compliance* [online]. , 2021 [Accessed on:]. Available via: https://www.verywellmind.com/what-is-compliance-2795888
- FREEMAN, R. Edward and others, 2010. *Stakeholder theory: the state of the art*. Cambridge [u.a.]: Cambridge Univ. Press. ISBN 978-0-521-19081-7, 0-521-19081-9
- SINGH, Nitish and Thomas J. BUSSEN, 2015. *Compliance Management: A How-to Guide for Executives, Lawyers, and Other Compliance Professionals*. Santa Barbara, California: Praeger. ISBN 9781440833113

Additional remarks

None

Technical German in Professional Contexts			
Module abbreviation	SZ_TDBK	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Trufin, Ramona		
Lecturer(s)	Trufin, Ramona		
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Technical German in Professional Context		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations
LN - written exam, 90 minutes
Additional explanations regarding examinations
None
Prerequisites according examination regulation
None
Recommended prerequisites
None
Objectives
To be determined
Content
To be determined
Literature
Will be specified at the beginning
Additional remarks
None

eTHIcs_basic			
Module abbreviation	IB_ETHICS_en	**Reg.-Nr.**	11
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	General Elective	6,7
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Crompton, Laura		
Lecturer(s)	Crompton, Laura		
Language of instruction	English	**Language of exams**	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_basic		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - seminar paper (10-15 pages) and oral presentation (15-30 minutes)

Additional explanations regarding examinations

Grading is three quarters based on five papers (~ 2 pages each) that will be handed in over the course of the term. Paper submissions will be complemented by obligatory in-class presentations (~ 20 minutes).

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 technology.
- distinguish meta-ethical, normative, and empirical arguments in ethics.
- apply normative theories from ethics to the field of technology.
- 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.
- formulate their own research questions to inquire into the ethics of technology and outline research designs to address them.

Content

The ethics of technology deals with moral questions that concern the usage of technologies. It raises fundamental questions about our relationship with technologies.

- Should we delegate ethical tasks to machines?
- Which normative principles should guide the design of our artefacts?
- How does the interaction with artefacts influence our moral behavior?

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

Certain technologies may raise more specific questions.

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

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

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

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

Literature

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

Additional remarks

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

4.3 Science Elective

To illustrate the breadth of topics covered, some elective modules of the category ‘Science Elective’ currently offered are described below.

Model Predictive Control and Applications			
Module abbreviation		**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	1
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module			
Lecturer(s)			
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module			
Lecture types	Einsetzungstext ist leer!		

Examinations
Einsetzungstext ist leer!
Additional explanations regarding examinations
None
Prerequisites according examination regulation
None
Recommended prerequisites
None
Objectives
To be determined
Content
To be determined
Literature
Will be specified at the beginning
Additional remarks
None

Artificial Intelligence and Automotive Systems			
Module abbreviation	IAE_AIAS	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Zimmer, Alessandro		
Lecturer(s)	Zimmer, Alessandro		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Artificial Intelligence and Automotive Systems		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

After successfully completing the module the students shall be able to

- understand the basic principles that lie behind different Artificial Intelligence techniques that can be used in the context of automotive systems.
- identify the most suitable Artificial Intelligence techniques to be used in a given scenario.
- model a problem of automotive safety using Artificial Intelligence systems.
- implement basic intelligent algorithms in Matlab.

Content

- Introduction to AI. Problems and search space. Knowledge representation and Pattern Recognition.
- AI and Automotive Systems/Automotive Safety Systems.
- Theory, concepts and applications of Neural Networks. Neurodynamics, topology of Neural Networks and learning methods.
- Fuzzy sets and systems. Modelling of Fuzzy System's Applications.
- Concepts of Evolutionary Systems. Genetic Algorithms and optimization problems.

Literature

- RUSSELL, Stuart J. and Peter NORVIG, 2021. *Artificial intelligence: a modern approach*. Hoboken: Pearson. ISBN 978-0-13-461099-3

- MICHELUCCI, Umberto, 2018. *Applied deep learning: a case-based approach to understanding deep neural networks* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-3790-8. Available via: https://doi.org/10.1007/978-1-4842-3790-8.
- SINGH, Himanshu, LONE, Yunis Ahmad, 2020. *Deep Neuro-Fuzzy Systems with Python: With Case Studies and Applications from the Industry* [online]. Berkeley, CA: Apress PDF e-Book. ISBN 978-1-4842-5361-8. Available via: https://doi.org/10.1007/978-1-4842-5361-8.
- BUONTEMPO, Frances and Tammy CORON, January 2019. *Genetic algorithms and machine learning for programmers: create AI models and evolve solutions*. Book version: P 1. edition. Raleigh, North Carolina: The Pragmatic Bookshelf. ISBN 978-1-68050-620-4
- ESCALANTE, Hugo Jair, 2018. *Explainable and Interpretable Models in Computer Vision and Machine Learning* [online]. Cham: Springer PDF e-Book. ISBN 978-3-319-98131-4. Available via: https://doi.org/10.1007/978-3-319-98131-4.

Additional remarks

None

Automotive Control Engineering			
Module abbreviation	IAE_ACE	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Gregor, Rudolf		
Lecturer(s)	Gregor, Rudolf		
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Automotive Control Engineering		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

After successfully completing the module students are able to

- analyze and describe systems in time and frequency domain
- select and design controllers based on classical control engineering methods (root locus, bode diagram)
- model and analyze LTI-systems in state space
- design state space controllers for SISO and MIMO-systems using different methods (pole placement, modal control, optimal control)
- design observers for LTI-systems
- solve simple control tasks for non-linear systems

Content

- Repetition of classical control engineering methods
- State space representation of linear time invariant systems (SISO and MIMO)
- Analysis of system properties (dynamics, stability, (output) controllability, observability) in state space
- Calculation of the state transition matrix to solve the state equation
- Design of state feedback control (pole placement, modal control, optimal control) to improve system dynamics
- Design of prefilters and integral action for static accuracy

- Design of state observers
- Representation and analysis of non-linear control systems
- Lab work: Design and test of different types of control systems by use of Matlab-Simulink

Literature

- GREGOR, Rudolf, KRÄMER, Wolfgang, 2023. *Slides, exercises, supplementary material.* [online]. PDF e-Book.
- BOLTON, William, 2010. *Control engineering*. Harlow u.a.: Prentice Hall. ISBN 978-0-582-32773-3
- BURNS, Roland S., 2001. *Advanced control engineering*. Oxford [u.a.]: Butterworth-Heinemann. ISBN 0-7506-5100-8
- FRANKLIN, Gene F., J. David POWELL and Abbas EMAMI-NAEINI, 2020. *Feedback control of dynamic systems*. Upper Saddle River, NJ [u.a.]: Pearson. ISBN 978-1-292-27452-2, 1-292-27452-2
- DORF, Richard C. and Robert H. BISHOP, 2022. *Modern control systems*. Harlow, United Kingdom: Pearson. ISBN 978-1-292-42235-0

Additional remarks

None

Automotive Radar Systems			
Module abbreviation	IAE_ARS	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Talukder, Prodyut		
Lecturer(s)	Talukder, Prodyut		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Automotive Radar Systems		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

After successfully completing the module the students are able to

- describe and explain fundamentals, system aspects, digital signal processing techniques as well as hardware components of radar;
- evaluate practical design issues to assess radar parameters;
- evaluate requirements for automotive radar systems;
- design mini radars with the help of MATLAB scripts considering the design boundaries;
- describe vehicle applications that use radar sensors.

Content

- Radar wave propagation
- Radar signals and signal processing techniques, information from radar
- Detection of signals in noise
- Radar clutter: sea, land and weather clutter
- Radar system design considerations
- Automotive radar examples

Literature
• SKOLNIK, Merrill I., 2001. *Introduction to radar systems*. Boston [u.a.]: McGraw-Hill. ISBN 0-07-290980-3, 0-07-118189-X • RICHARDS, Mark A., 2014. *Fundamentals of radar signal processing*. New York [u.a.]: McGraw-Hill. ISBN 978-0-07-179832-7, 0-07-179832-3 • MAHAFZA, Bassem R., 2013. *Radar systems analysis and design using MATLAB*. Boca Raton, FL: CRC Press. ISBN 978-1-4398-8495-9, 978-1-62870-701-4 • LUDLOFF, Albrecht, 2002. *Praxiswissen Radar und Radarsignalverarbeitung* [online]. Wiesbaden: Vieweg+Teubner Verlag PDF e-Book. ISBN 978-3-322-99555-1, 978-3-322-99556-8. Available via: https://doi.org/10.1007/978-3-322-99555-1. • WINNER, Hermann, 2015. *Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort* [online]. Wiesbaden: Springer Fachmedien PDF e-Book. ISBN 978-3-658-05734-3, 978-3-658-05733-6. Available via: http://dx.doi.org/10.1007/978-3-658-05734-3.
Additional remarks
None

Intelligent Robotics			
Module abbreviation	AIN_IRobot	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Schweiger, Johann		
Lecturer(s)	Schweiger, Johann		
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		79 h
	Total		126 h
Subjects of the module	Intelligent Robotics		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

PR - Practical work incl. oral exam (30 min.) for acceptance

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

After successful completing the module, the students will be able to

- name the most important sensors and actuators for autonomous mobile robots.
- explain which forms of knowledge representation are suitable for intelligent robots.
- understand how to program with behavior patterns and master the common methods for map-based locomotion.
- use algorithms to record, merge and interpret sensor data and derive specifications for the actuators.
- apply the algorithms and concepts they have learned to practical applications in the fields of automobiles, service robotics, automation technology and care robotics.
- analyze practical tasks with regard to real-time conditions, safety requirements and the required behavior patterns.
- derive a strategic plan for the use of behavioral patterns from a problem.
- explain real-time cooperation methods for teams of autonomous mobile robots.
- evaluate the different types of algorithms in terms of performance, real-time capability, robustness and flexibility.
- work on topics together in small groups and present the results of their work.

Content

- Sensors and actuators for intelligent robots

- Software architectures for autonomous mobile robots
- Knowledge-based behavior pattern control
- Environment modeling
- Route and action planning
- Cooperation of autonomous mobile systems
- Practical exercises in the laboratory

Literature

- VINJAMURI, Ramana, May 2023. *Human-robot interaction: perspectives and applications* [online]. London, United Kingdom: IntechOpen PDF e-Book. ISBN 978-1-80356-412-8, 978-1-80356-411-1. Available via: https://directory.doabooks.org/handle/20.500.12854/113357.
- YANG, Huayong, LIU, Honghai, ZOU, Jun, YIN, Zhouping, LIU, Lianqing, YANG, Geng, OUYANG, Xiaoping, WANG, Zhiyong, 2023. *Intelligent robotics and applications: 16th international conference, ICIRA 2023, Hangzhou, China, July 5–7, 2023, proceedings, part II* [online]. Singapore: Springer PDF e-Book. ISBN 978-981-99-6486-4. Available via: https://doi.org/10.1007/978-981-99-6486-4.
- HERTZBERG, Joachim, LINGEMANN, Kai, NÜCHTER, Andreas, 2012. *Mobile Roboter: eine Einführung aus Sicht der Informatik* [online]. Berlin [u.a.]: Springer PDF e-Book. ISBN 978-3-642-01726-1. Available via: https://doi.org/10.1007/978-3-642-01726-1.
- WHITMORE, Eric D., 2025. *Physical AI: The Revolution of Intelligent Machines*. ISBN 978-1456662431
- HUDA, M. Nazmul, WANG, Mingfeng, KALGANOVA, Tatiana, 2025. *Towards autonomous robotic systems: 25th annual conference, TAROS 2024, London, UK, August 21-23, 2024, proceedings, part I* [online]. Cham, Switzerland: Springer PDF e-Book. ISBN 978-3-031-72059-8. Available via: https://doi.org/10.1007/978-3-031-72059-8.
- VILLALBA-DIEZ, Javier, ORDIERES MERÉ, Joaquin, 2022. *JIDOKA. Integration of human and AI within industry 4.0 cyber physical manufacturing systems* [online]. Basel ; Beijing ; Wuhan ; Barcelona ; Belgrade ; Manchester ; Tokyo ; Cluj ; Tianjin: MDPI PDF e-Book. ISBN 978-3-0365-3811-2. Available via: https://doi.org/10.3390/books978-3-0365-3811-2.

Additional remarks

No additional remarks.

Optimization Methods for Machine Learning

Module abbreviation	AI_Opt	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Specialised Elective Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Gründinger, Andreas		
Lecturer(s)	Gründinger, Andreas		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Optimization Methods for Machine Learning		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

- Knowledge of the basics of optimization in theory and practical experiments
- Teaching of technical terms and the ability to read relevant literature on the subject of optimization
- Solving classical optimization problems in exercises accompanying lectures
- Independently classifying optimization approaches and experimenting with different solution approaches in practical experiments
- Presenting, recording, and evaluating experimental results
- Strengthening communication, coordination and teamwork skills

Content

- Classification and feasibility of optimization problems
- Convex functions; linear, affine and convex combinations; convexity preserving transformations
- Unrestricted optimization; (sub-)gradient descent algorithms; stochastic gradient descent algorithms; applications in machine learning (backpropagation); regularization methods
- Restrictions and convex constraint sets; application in support vector machines
- Linear optimization; extremal points of linear sets; simplex method
- Nonlinear constrained optimization; gradient projection algorithms
- Applications

Lab Contents:

- Matlab and Optimization
- Gradient descent methods in machine learning
- Linear regression
- Interior-point solutions vs. gradient projection approaches

Literature

- BOYD, Stephen P. and Lieven VANDENBERGHE, 2014. *Convex optimization*. 16. edition. Cambridge [u.a.]: Cambridge Univ. Press. ISBN 978-0-521-83378-3
- SRA, Suvrit, Sebastian NOWOZIN and Stephen J. WRIGHT, 2012. *Optimization for machine learning*. Cambridge, Mass.: MIT Press. ISBN 978-0-262-29877-3, 0-262-29877-5

Additional remarks

None

Verification of Machine-Learning Algorithms			
Module abbreviation	AI_VerMLAlgo	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Specialised Elective Subject	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Giesler, Björn		
Lecturer(s)	Giesler, Björn		
Language of instruction	English	**Language of exams**	English
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Verification of Machine-Learning Algorithms		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

LN - oral exam, 20 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

Upon completion of the module, students will be able to:

- Distinguish between verification and validation of machine-learning (ML) systems.
- Understand the risks and consequences of false decisions by ML algorithms.
- Apply classical and contemporary verification techniques to ML models.
- Reflect critically on the societal and ethical ramifications of ML errors.

Content

- Introduction to ML Verification: The “black-box” nature of modern ML, correctness, robustness, interpretability
- Motivation and Challenges: Lack of formal specifications
- Verification vs. Validation: Definitions and examples, Role of statistical evaluation vs. formal guarantees
- False Decisions in ML Systems: Taxonomy of failures, Root causes: bias in data, model brittleness, distributional drift
- Techniques for Verifying Correctness: Probe points, Large-scale phenomenological testing
- Classical formal methods applied to ML (symbolic execution, model checking, SMT solvers),
- Societal and Ethical Implications: Accountability in algorithmic decisions, fairness, transparency, and justice

Literature
Will be specified at the beginning
Additional remarks
None

Knowledge Modeling and Machine Learning			
Module abbreviation	AUF_WissMod	**Reg.-Nr.**	12
Curriculum	**Study Programme**	**Module type**	**Semester**
	AI Engineering of Autonomous Systems	Science Elective	1,2
Module frequency	only winter term	**Module duration**	1 semester

Responsible for module	Botsch, Michael		
Lecturer(s)	Botsch, Michael		
Language of instruction	German	**Language of exams**	German
Credit points / SWS	5 ECTS / 4 SWS		
Workload	Contact hours		47 h
	Self-study		78 h
	Total		125 h
Subjects of the module	Knowledge Modeling and Machine Learning		
Lecture types	SU/Ü - lecture with integrated exercises		

Examinations

schrP90 - written exam, 90 minutes

Additional explanations regarding examinations

None

Prerequisites according examination regulation

None

Recommended prerequisites

None

Objectives

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

- understand and apply the mathematical foundations of statistical signal processing for knowledge modeling and machine learning
- mathematically describe, implement, and apply classical methods for classification and regression models
- mathematically describe, implement and apply advanced machine learning methods for classification and regression models
- understand generative machine learning models
- use machine learning methods in automated driving applications

Content

- Fundamentals of statistical signal processing (random variables, maximum likelihood and maximum a posteriori parameter estimation, kernel density estimators, bias-variance decomposition, model selection procedures)
- Bayes classifier and Bayes regression
- Linear classification and regression models (derivation, implementation, applications)
- Classification by means of "softmax", k-NN, Nadaraya-Watson regression function (derivation, implementation, applications)

- Gradient descent method and automatic differentiation in reverse mode (backpropagation)
- Multi-layer perceptron neural networks (derivation, implementation, applications)
- Deep Convolutional Neural Networks (derivation, implementation, applications)
- Radial basis function networks (derivation, implementation, applications)
- Autoencoder
- Generative Adverserial Neural Networks
- Applications in the field of automated driving

Literature

- BOTSCH, Michael, UTSCHICK, Wolfgang, 2020. *Fahrzeugsicherheit und automatisiertes Fahren: Methoden der Signalverarbeitung und des maschinellen Lernens* [online]. München: Hanser PDF e-Book. ISBN 978-3-446-46804-7. Available via: https://doi.org/10.3139/9783446468047.
- GOODFELLOW, Ian and others, 2018. *Deep Learning: das umfassende Handbuch : Grundlagen, aktuelle Verfahren und Algorithmen, neue Forschungsansätze*. Frechen: mitp. ISBN 978-3-95845-701-0
- BISHOP, Christopher M., 2009. *Pattern recognition and machine learning*. New York [u.a.]: Springer. ISBN 0-387-31073-8, 978-1-4939-3843-8
- BISHOP, Christopher M., BISHOP, Hugh, 2024. *Deep Learning: Foundations and Concepts* [online]. Cham: Springer International Publishing PDF e-Book. ISBN 978-3-031-45468-4. Available via: https://doi.org/10.1007/978-3-031-45468-4.

Additional remarks

None