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# Module Catalogue

**M.Sc.Computer Science, PO 2018**

**Faculty of Applied Computer Science**

**Applicable when you started your studies in summer term 2026.**

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**You can see the other use cases of the modules in Digicampus.**

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Dear Students,

welcome to the University of Augsburg!

Every semester, we are hosting a **presentation of all Computer Science courses**, with a focus on elective courses. Our objective is to give you an overview of the course offerings. Please join us on the first day of classes (**Monday, April 13th**) at **5:30 p.m. in Lecture Hall 1001 in Building T**.

You can find all further information at

[https://digicampus.uni-augsburg.de/dispatch.php/course/details?sem\\_id=ca9863bb42ffe78b2b12e7ccb8e8d8a2](https://digicampus.uni-augsburg.de/dispatch.php/course/details?sem_id=ca9863bb42ffe78b2b12e7ccb8e8d8a2)

When you have questions about a specific module, ask the person responsible for the module. You can find this person at the top of each module description.

Since the module handbook is a service for you as students, we work closely with the student council. If you have any suggestions, questions, feedback, or ideas for improvement regarding the new module handbook, please feel free to share them with the Student Council of the Department of Computer Science ([stura@informatik.uni-augsburg.de](mailto:stura@informatik.uni-augsburg.de)). You can also meet with the representatives in person in room N-1007.

Have a great start!

Your Module Handbook Coordinator

Martin Frieb

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Version 1 (since WS18/19)

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\* = At least one course for this module is offered in the current semester

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Version 11 (since SoSe26)

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**Version 16 (since SoSe26)**

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#### Version 14 (since SoSe26)

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Die hier aufgeführten Veranstaltungen sind freiwillig und geben keine Leistungspunkte. Ihre Inhalte sind jedoch eine sinnvolle Ergänzung zum bestehenden Lehrangebot.

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Version 1.0.0 (since WS13/14) Person responsible for module: Alle Professorinnen und Professoren, die Veranstaltungen für diesen Studiengang anbieten.		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students are familiar with the scientific methodology and techniques of literature research, are able to use in-depth practical or theoretical methods to work on a given topic under guidance and have the competence to work on a scientifically demanding problem of computer science within a given period largely independently with scientific methods and to present the results in writing and orally in a comprehensible and convincing manner.</p> <p>In addition, students have in-depth knowledge and skills in the field of the master's thesis, can further develop concepts, methods, procedures, techniques and technologies of this field in research or application projects, and are able to apply innovative methods in solving problems. This allows them to build on international research and make their own scientific contribution in this field. The students have the skill to analyze and structure problems in the field of the Master's thesis and the skill to develop and implement solution strategies, and know practical tasks. They know the advantages and disadvantages of solution alternatives, can evaluate them scientifically meaningfully in the respective application context with suitable methods and can safely select suitable solution alternatives. Students have the ability to independently expand and deepen their knowledge in the field of the master's thesis and related fields.</p> <p>In addition, students can develop advanced strategies, methods, and clear ideas about their objectives and priorities, evaluate their personal working style, and create an efficient use of their resources. They use tools and techniques of self-organization that correspond to their personal working style.</p> <p><b>Key qualifications:</b> Skills for logical, analytical and conceptual thinking, team and communication skills, perseverance, written and oral presentation of own (practical or theoretical) results, skills of efficient use of resources, assessment of the relevance of own results, principles of good scientific practice, ability to self-reflection and a reflective working style, skills of comprehensible, safe and convincing (written and oral) presentation of own and foreign (practical or theoretical) ideas, concepts and results and their documentation, quality awareness, meticulousness</p>		
<p><b>Workload:</b> Total: 900 h 900 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 0,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Master's Thesis</b> <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 0,00</p>		
<b>Contents:</b> according to the chosen topic		

**Literature:**

The definition of the literature depends on the specific topic of the work in consultation with the supervisor.

**Examination**

**Master's Thesis**

Master's thesis, graded

**Test Frequency:**

each semester

<b>Module INF-0130: Formal Methods in Software Engineering</b> <i>Formale Methoden im Software Engineering</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Fachbezogene Kompetenzen:</b></p> <p>Die Studierenden können mathematisch-formale Methoden für die Programmverifikation, speziell bei sicherheitskritischer Software einsetzen. Durch das Verständnis von Kalkülen trainieren sie die Fertigkeit zum logischen, konzeptuellen und analytischen Denken. Sie können Spezifikationen von Datenstrukturen entwerfen und deren Eigenschaften formal beweisen. Sie sind in der Lage, funktionale Eigenschaften von sequentiellen und nebenläufigen Programmen zu formulieren und dafür Beweise zu erstellen. Sie erwerben die Fertigkeit zur abstrakten, modularen Modellierung von Softwaresystemen und zur systematischen Entwicklung von korrekten Programmen aus diesen Modellen. Sie erwerben dadurch die Fertigkeit zur Analyse und Strukturierung komplexer Informatikproblemstellungen und können mit geeigneten Methoden wissenschaftlich aussagekräftige Bewertungen abgeben. Sie erwerben Fähigkeiten, um Beiträge zur Wissenschaft zu leisten.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Training des logischen Denkens</li> <li>• Analytisch-methodische Kompetenz</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Fähigkeiten zur Modellbildung für Softwaresysteme</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Formale Methoden im Software Engineering (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

Übergeordnetes Ziel ist die Produktion beweisbar korrekter Software. In der Vorlesung werden verschiedene klassische Methoden für die Programmverifikation im Kleinen behandelt. Darüber hinaus werde innovative Techniken für die formale Modellierung und Verifikation großer Systeme vermittelt. Als Werkzeug kommt das KIV-System zum Einsatz, das die formale Spezifikation und Verifikation von Systemen ermöglicht. Konkrete Inhalte sind: Algebraische Spezifikationen, interaktives Theorembeweisen, Hoare-Logik, Dynamische Logik, Temporallogik

**Literature:**

- Sperschneider, Antoniou: Logic: A Foundation for Computer Science, Addison Wesley 1991
- Loeckx, Ehrich, Wolf: Specification of Abstract Data Types, Wiley 1996
- Ausführliche Dokumentation
- Folienhandout

**Assigned Courses:**

**Formale Methoden im Software Engineering (lecture)**

*\*(in attendance) \**

**Part of the Module: Formale Methoden im Software Engineering (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Formale Methoden im Software Engineering (exercise course)**

*\*(in attendance) \**

**Examination**

**Formale Methoden im Software Engineering**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0243: Process Mining</b> <i>Process Mining</i>		6 ECTS/LP
Version 1.2.0 (since SoSe17) Person responsible for module: Prof. Dr. Robert Lorenz		
<p><b>Learning Outcomes / Competences:</b> Participants understand the following essential concepts of computer science at an advanced scientific level, including their mathematical and formal foundations: event log, partial order, Petri net, concurrency, sequential and causal semantics of a concurrent system, synthesis of a concurrent system, business process, process mining, process discovery, conformance checking. They can model concurrent systems of medium complexity in a suitable modeling language, as well as generate, evaluate, and convert different models for analysis and simulation for a given concurrent system. They are familiar with the various process mining use cases with appropriate solution techniques and quality criteria for their evaluation. Participants will have advanced mathematical formal methodology for the analysis and formalization of complex process discovery problems. They will be able to confidently select suitable algorithms for their solution with regard to qualitative and quantitative criteria, apply them, and interpret and evaluate the results.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically, conceptually, and algorithmically; Independent work with textbooks and English-language specialist literature; Clear presentation of results; Quality awareness; Meticulousness; Principles of good scientific practice; Scientific methodology;</p>		
<p><b>Remarks:</b> The teaching materials are written in English (lecture notes and exercises). If foreign students with insufficient German language skills participate, the language of instruction will be English.</p>		
<p><b>Workload:</b> Total: 180 h 45 h lecture (attendance) 15 h exercise course (attendance) 23 h studying of course content using literature (self-study) 75 h studying of course content through exercises / case studies (self-study) 22 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Process Mining (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 3,00</p>		

**Contents:**

The lecture provides a comprehensive overview of the field of process mining research:

- Modeling techniques: Petri nets, workflow nets, process trees, direct follows graphs
- Discovering algorithms: Alpha-Algorithm, Inductive Miner, Direct Follows Miner, Synthesis based discovery techniques
- Conformance checking: fitness, precision, generalization, simplicity
- Tools: PROM, Celonis

**Literature:**

English-language lecture notes

Wil M. P. van der Aalst:

Process Mining - Data Science in Action, Second Edition. Springer 2016, ISBN 978-3-662-49850-7

Wil M. P. van der Aalst, Boudewijn F. van Dongen: Discovering Petri Nets from Event Logs. Trans. Petri Nets and Other Models of Concurrency 7: 372-422 (2013)

Robin Bergenthum, Jörg Desel, Robert Lorenz, Sebastian Mauser: Process Mining Based on Regions of Languages. BPM 2007: 375-383

Wil M. P. van der Aalst, Josep Carmona:

The Process Mining Handbook. Springer 2022, ISBN 978-3-031-08848-3

**Assigned Courses:**

**Process Mining** (lecture)

*\*(in attendance) \**

**Part of the Module: Process Mining (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 1,00

**Assigned Courses:**

**Übung zu Process Mining** (exercise course)

*\*(in attendance) \**

**Examination**

**Process Mining (Klausur)**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0371: Approximation Algorithms</b> <i>Approximation Algorithms</i>		5 ECTS/LP
Version 1.3.0 (since WS20/21) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b> Developing an understanding of central topics in the field of approximation algorithms; acquiring powerful mathematical tools to analyze algorithms; improve the ability to abstract and systematically solve optimization problems. <b>Key Skills:</b> Ability to build intuitive understanding of mathematical formalisms; ability to identify core properties of optimization problems; deep understanding of powerful mathematical tools		
<b>Remarks:</b> <b>You can take this course only when you did not visit the course <i>INF-0420: Approximationsalgorithmen!</i></b>		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Basic knowledge of Algorithms and Data Structures (e.g., "INF-0111: Informatik 3") and Theoretical Computer Science (e.g., "INF-0110: Einführung in die Theoretische Informatik").		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Approximation Algorithms (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00
<b>Contents:</b> Given an NP-hard optimization problem, how well can it be approximated in polynomial time? It is exciting and challenging to understand the approximability of fundamental optimization problems. This course mainly focuses on upper bounds, i.e., designing efficient approximation algorithms.  In this course, we will study several classes of problems, such as packing problems, network design, and graph problems. We will cover central algorithmic techniques for designing approximation algorithms, including greedy algorithms, dynamic programming, linear and semi-definite programming, and randomization.
<b>Literature:</b> <ul style="list-style-type: none"> <li>• David P. Williamson and David B. Shmoys, The Design of Approximation Algorithms, Cambridge University Press.</li> <li>• Vijay V. Vazirani, Approximation Algorithms, Springer.</li> </ul>

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**Part of the Module: Approximation Algorithms (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 2,00

**Examination**

**Approximation Algorithms**

portfolio exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0383: Algorithms for Big Data</b> <i>Algorithmen für Big Data</i>		5 ECTS/LP
Version 1.1.0 (since SoSe21) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b> Development and understanding of central competences in algorithm design for situations, where there are large amounts of data such that not all of them can be accessed without restrictions; acquisition of knowledge of mathematical tools to analyze algorithms; improvement of competences in abstract thinking and analyzing problems in a systematic manner.  <b>Key Qualifications:</b> Ability to develop an intuitive understanding of mathematical formalisms; ability to identify the core properties of algorithmic problems; deep understanding of useful mathematical tools		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)		
<b>Conditions:</b> Basic knowledge in algorithms and data structures (for example Informatik 3 (INF-0111)) and in probability theory (for example Stochastik für Informatiker (MTH-6040)).		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Algorithms for Big Data (lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00	
<b>Contents:</b> In modern data processing, we increasingly have the problem that there are large quantities of data which can only be stored on cheap and slow mass storage media. Algorithmically, this poses the problem that at each point in time, we can only access a snapshot of the data, for example in a sequential manner. In the course, we study algorithms that despite such limitations provably yield high quality results.	
<b>Literature:</b> Wissenschaftliche Papiere, Surveys, Skripte	
<b>Assigned Courses:</b> <b>Algorithmen für Big Data</b> (lecture) *(in attendance) *	

**Part of the Module: Algorithms for Big Data (exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Algorithmen für Big Data** (exercise course)

*\*(in attendance) \**

**Examination**

**Algorithms for Big Data**

portfolio exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0408: Extremal Combinatorics</b> <i>Extremal Combinatorics</i>		5 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b>		
<b>Knowledge</b> Developing an understanding of central topics in the field of combinatorics; acquiring powerful mathematical tools to analyze performance of algorithms; improve the ability to abstract and systematically solve counting problems.		
<b>Methodical Competences</b> The students are able to develop and write mathematical proofs in the context of advance combinatoric problems. They are able to understand complex reasoning and judge the correctness of mathematical arguments. The students are able to develop novel solution approaches, as solutions to relevant questions are usually not unique		
<b>Key Skills</b> Ability to build intuitive understanding of mathematical formalisms; ability to identify core properties of optimization problems; deep understanding of powerful mathematical tools; Skills of mathematical thinking		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance)		
<b>Conditions:</b> Basic knowledge in mathematics, in particular linear algebra is necessary. Basic knowledge in graph theory is recommended.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Extremal Combinatorics (Vorlesung)</b>		
<b>Mode of Instruction:</b> lecture <b>Language:</b> English / alle Sprachen <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		
<b>Contents:</b> How many people do you need to invite for your party, in order to have 3 strangers or a group of 3 friends? If 10 people have keys to a safe, how many locks are necessary to make sure any 5 of them can open it? What is the dictator paradox, and should you be worried about it? This course provides an introduction to extremal combinatorics, which helps us to find answers to the questions above.		
<b>Literature:</b>		

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**Part of the Module: Extremal Combinatorics (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / alle Sprachen

**Frequency:** irregular

**Contact Hours:** 2,00

**Examination**

**Extremal Combinatorics**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0432: Isabelle-Lab</b> <i>Isabelle-Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Kirstin Peters		
<b>Contents:</b> The general idea of interactive theorem proving is introduced and the tool Isabelle/HOL is discussed. Several common features of Isabelle/HOL are studied: e.g. basic concepts such as data structures and functions, modelling mechanisms such as locales, proof techniques such as structural induction, and the proof language Isar.		
<b>Learning Outcomes / Competences:</b> <b>Knowledge:</b> Students will get to know the key concepts, definitions, and techniques of interactive theorem proving with Isabelle/HOL. They will get insights and practical knowledge about the design of models in Isabelle/HOL such as the conception of data structures and functions or the abstraction of concepts into a locale. They will learn strategies to tackle complex and technically very detailed proofs. They will learn about automated reasoning mechanisms as well as interactive proof tactics; their respective advantages and typical areas of application. Finally, students learn about the guarantees provided by machine checked proofs and the additional complexity that comes with such projects. <b>Skills:</b> Students will be familiar with the basic concepts of modelling and proving in Isabelle/HOL. Students will be able to formally and correctly model applications and concepts in Isabelle/HOL. They are able to select appropriate proof methods and carry out complex proofs with the assistance of Isabelle/HOL. They understand the hints provided by the proof assistance, can analyse the current state of a proof and its proof obligations, and can carry out the next relevant steps. They understand under which circumstances the automatic proof methods are useful and how to apply them. Moreover, they are able to plan and carry out a project and meet the time restrictions that come with such a project. Finally, they will practice logical and conceptual thinking as well as the abstraction and formalisation of concepts in a stringent mathematical framework. <b>Competences:</b> Students are prepared to work on verification projects. Students are able to plan and carry out the modelling as well as the proof obligations of such a project in an interactive theorem prover. They understand the nature of the correctness guarantees provided by machine checked proofs, but also the additional complexity that is necessary to carry out such proofs. Furthermore, they know how to characterise and judge on the quality and suitability of existing models and theories in Isabelle/HOL. More abstractly, they are able to reason more concretely about the correctness of a formalisation and proofs. <b>Key skills:</b> Formal methods; Knowledge of advantages and disadvantages of different design alternatives in modelling; Ability to carry out very detailed proofs; Ability to work on and organise projects; Ability to work autonomously; Quality awareness; Scientific working.		
<b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Isabelle-Lab (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00
<b>Contents:</b> We discuss the basic design of Isabelle and how to work with this interactive theorem prover. In particular we study: <ul style="list-style-type: none"><li>• higher-order logic (HOL)</li><li>• isabelle syntax and semantics</li><li>• proof strategies</li><li>• induction and induction principles</li><li>• formalisation of theories in Isabelle/HOL</li><li>• proof support (proof tactics and external assistance)</li><li>• proof language Isar</li></ul>
<b>Literature:</b> <a href="https://isabelle.in.tum.de/documentation.html">https://isabelle.in.tum.de/documentation.html</a>
<b>Part of the Module: Isabelle-Lab (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4,00
<b>Examination</b> <b>Isabelle-Lab</b> practical exam, graded <b>Test Frequency:</b> when a course is offered

<b>Module INF-0440: Quantum Algorithms</b> <i>Quantum Algorithms</i>		5 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann		
<b>Contents:</b> Foundations of Quantum Information Processing: <ul style="list-style-type: none"> <li>• qubits and their representation</li> <li>• BraKet notation and necessary structures from linear algebra</li> <li>• operations on qubits: circuits and gates</li> </ul> Quantum Algorithms <ul style="list-style-type: none"> <li>• quantum search and amplitude amplification</li> <li>• quantum fourier transform and it's applications</li> <li>• quantum simulation</li> <li>• variational quantum algorithms</li> <li>• differentiable quantum algorithmic procedures</li> <li>• quantum heuristics</li> <li>• usecases from current day research</li> </ul>		
<b>Learning Outcomes / Competences:</b> Students acquire basic knowledge of quantum algorithms and are able to explain fundamental principles and describe their use in algorithmic structures. They can describe established algorithmic structures from the field of quantum algorithms, such as search, Fourier transform, and phase estimation, and determine and compare potential areas of application. After attending the course, they will be able to construct quantum algorithmic approaches and translate them into discrete operations on qubit systems. Students will have a sound basic knowledge of fundamental quantum algorithmic structures and variational heuristics. They will be able to identify, analyze, and evaluate quantum algorithmic elements in current literature.		
<b>Workload:</b> Total: 150 h 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literarture (self-study) 15 h studying of course content using provided materials (self-study) 30 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> Linear Algebra (basics)		<b>Credit Requirements:</b> Passing the exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Quantum Algorithms (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Foundations of Quantum Information Processing:

- qubits and their representation
- BraKet notation and necessary structures from linear algebra
- operations on qubits: circuits and gates

Quantum Algorithms

- quantum search and amplitude amplification
- quantum fourier transform and it's applications
- quantum simulation
- variational quantum algorithms
- differentiable quantum algorithmic procedures
- quantum heuristics
- usecases from current day research

**Literature:**

**Basics of Quantum Information/Quantum Computation:**

- Michal Nielsen; Isaac Chuang: Quantum Computation and Quantum Information

**Basics of quantum mechanics:**

- Richard P. Feynman; Robert B. Leighton; Matthew Sands: Feynman-Vorlesungen über Physik: Band III, Quantenmechanik
- original scripts are online: <https://www.feynmanlectures.caltech.edu/info/>

**Overview over variational quantum algorithms:**

- <https://doi.org/10.1103/RevModPhys.94.015004>
- <https://doi.org/10.1038/s42254-021-00348-9>

**More on quantum algorithms:**

- <http://theory.caltech.edu/~preskill/ph229/> (chapter 5 provides a good summary of the well-known "traditional" quantum algorithms)

**Assigned Courses:**

**Quantum Algorithms** (lecture)

*\*(in attendance) \**

**Part of the Module: Quantum Algorithms (Übung)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Quantum Algorithms** (lecture)

*\*(in attendance) \**

**Examination**

**Quantum Algorithms**

oral exam / length of examination: 25 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3011: Conformance Checking</b> <i>Conformance Checking</i>		6 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Robert Lorenz Patrizia Schalk		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successful participation, participants will have mastered the formal basics of using process models (using Petrinets as an example) to represent and analyze real business processes and will have a good overview of the measures of fitness, precision, generalization, and simplicity for evaluating the quality of such process models. They will be familiar with various algorithms for the automated calculation of these measures, as well as their strengths and weaknesses. They will learn to critically question process models and algorithms for their evaluation and to analyze them using formal and scientific methods.</p> <p>Key qualifications: Ability to think logically, analytically, conceptually, and algorithmically; Independent work with textbooks and English-language specialist literature; Clear presentation of results; Quality awareness; Meticulousness; Principles of good scientific practice; Scientific methodology;</p>		
<p><b>Remarks:</b></p> <p>The teaching materials are written in English (lecture notes and exercises). If foreign students with insufficient German language skills participate, the language of instruction will be English.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>22 h studying of course content using provided materials (self-study)</p> <p>75 h studying of course content through exercises / case studies (self-study)</p> <p>23 h studying of course content using literature (self-study)</p> <p>15 h exercise course (attendance)</p> <p>45 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>none</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. winter semester)</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>4,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Conformance Checking (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 3,00</p>
<p><b>Contents:</b></p> <p>The event provides a comprehensive overview of the subfield of conformance checking in the research area of process mining:</p> <ul style="list-style-type: none"> <li>- Modeling techniques: workflow nets, partial languages</li> <li>- Event logs</li> <li>- Fitness metrics and their limitations</li> <li>- Precision metrics and their limitations</li> <li>- Generalization metrics and their limitations</li> <li>- Simplicity metrics and their limitations</li> </ul>

**Literature:**

- English-language lecture notes
- Josep Carmona, Boudewijn van Dongen, Andreas Solti and Matthias Weidlich:
- Conformance Checking - Relating Processes and Models, Springer 2018, ISBN 978-3-319-99413-0
- Anja F. Syring, Niek Tax, Wil M. P. van der Aalst:
- Evaluating Conformance Measures in Process Mining using Conformance Propositions (Extended version), <https://arxiv.org/abs/1909.02393>

**Part of the Module: Conformance Checking (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 1,00

**Examination**

**Conformance Checking**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3027: Algorithmic Game Theory</b> <i>Algorithmic Game Theory</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b></p> <p>The goal of the lecture is to use suitably chosen examples to give a broad overview over the field of Algorithmic Game Theory. For this, we will encounter classical results from Game Theory along with recent results from Algorithmic Game Theory.</p> <p>The students will learn how to model and analyse the interaction of strategic agents in various settings. They will be able to understand and explain different game-theoretic concepts as well as their application in different domains. They will also be able to compute equilibrium solutions for many game variants and they will be able to understand and apply several practical algorithms for solving allocation problems. For this we will formally analyze the efficiency and other properties of the employed algorithms. Moreover, the students will learn how to evaluate the impact of selfishness in optimization problems and how to prove quality guarantees for game-theoretic settings.</p> <p><b>Key skills:</b> Advanced mathematical-formal methodology, subject-specific specializations, quantitative aspects of computer science, ability to analyze and structure complex computer science problems, ability to develop and implement solution strategies for complex problems, knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context, Ability to think logically, analytically and conceptually, selection and reliable application of suitable methods, ability to work in teams, knowledge of practical tasks, ability to present and document results in a comprehensible manner, ability to expand existing knowledge independently, quality awareness, meticulousness</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <p>No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in complexity theory from the Bachelor studies will be assumed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Algorithmic Game Theory (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

Algorithmic Game Theory is a young and thriving research area in the intersection of Mathematics, Algorithmics and Economics. Motivated by the rise of the Internet and its related new kinds of problems, Algorithmic Game Theory was established within the last two decades to tackle classical problems from Game Theory with an algorithmic perspective.

Among others we will discuss the following questions:

- How can we solve assignment problems (e.g. assigning talks/projects to students) such that all participants are happy with their assignment?
- Are there auctions in which all bidders want to bid honestly?
- How does the perfect voting system look like?
- Does every game have an equilibrium, that is, an outcome in which all players are happy?
- Is it easy to find an equilibrium for a specific game?
- How good/bad are equilibria reached via egoistic behavior compared to the best centrally enforced solution?

Answers to the above questions have been awarded with 7 "Nobel Prizes" in Economics (most recently, the 2020 Economics Nobel Prize!) and some of the most prestigious awards in Mathematics and Computer Science.

**Literature:**

- Nisan et al.: Algorithmic Game Theory, Cambridge University Press
- Shoham and Leyton-Brown: Multitagent Systems, Cambridge University Press
- Roughgarden: 20 Lectures on Algorithmic Game Theory, Cambridge University Press
- Easley and Kleinberg: Networks, Crowds and Markets, Cambridge University Press
- Brandt et al.: Handbook of Computational Social Choice, Cambridge University Press

**Part of the Module: Algorithmic Game Theory (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination**

**Algorithmic Game Theory**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3037: Graph Algorithms</b> <i>Graph Algorithms</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b></p> <p>The goal of the lecture is to use suitably chosen examples to give a broad overview over the field of Graph Algorithms. The students will learn how to design and analyse graph algorithms for various settings . They will be able to understand and explain different graph-theoretic concepts as well as their application in different domains. They will also be able to understand and apply several practical algorithms for computing shortest paths, flows, matchings, cuts, and embeddings. For this we will formally analyze the efficiency and other properties of the employed algorithms. Moreover, the students will learn how to evaluate the impact of graph properties on complexity of graph problems.</p> <p><b>Key skills:</b> Advanced mathematical-formal methodology, subject-specific specializations, quantitative aspects of computer science, ability to analyze and structure complex computer science problems, ability to develop and implement solution strategies for complex problems, knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context, Ability to think logically, analytically and conceptually, selection and reliable application of suitable methods, ability to work in teams, knowledge of practical tasks, ability to present and document results in a comprehensible manner, ability to expand existing knowledge independently, quality awareness, meticulousness</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in complexity theory from the Bachelor studies will be assumed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Graph Algorithms (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

Graphs play a central role in the world of algorithms. For example, navigation devices use an algorithm to compute shortest paths on a graph to answer a route query. Many planning and assignment problems can also be easily modeled as problems on graphs. In principle, it is true that a great many problems can be thought of as graph problems, so designing efficient algorithms for such problems is an important subfield of theoretical computer science.

In this lecture we will enter the world of graph algorithms. On the one hand, we will learn about important algorithmic problem classes on graphs and efficient algorithms to solve them. Among other things, we will look at finding shortest paths, flows, cuts, separators, and matchings in graphs. Algorithms for these problems have a wide variety of applications, making them an important and useful tool for any algorithmicist. On the other hand, we will also study how constraints on the graphs at hand affect the complexity of the problems and their algorithmic solution. For example, many algorithmic problems are more efficiently solvable on trees and planar graphs (i.e., graphs that can be embedded in the plane without intersection) than on general graphs. We will also explore some properties of graphs that we can exploit specifically for designing efficient algorithms. For example, trees and planar graphs have small separators (sets of nodes whose removal causes the graphs to decompose into multiple context components), which helps design efficient divide & conquer algorithms.

The goal of the lecture is the development and training of a structured approach to algorithmic problems on graphs. In doing so, we will jointly develop efficient graph algorithms with appropriate data structures, prove their correctness, and analyze their resource requirements (runtime and memory). In addition, the lecture will highlight special graph classes and other important concepts in graph theory and their impact on the world of algorithms.

**Part of the Module: Graph Algorithms (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination****Graph Algorithms**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module MTH-2650: Homotopy Type Theory</b> <i>Homotopietypentheorie</i>		9 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
<b>Contents:</b> Initially, mathematical work within an intuitionistic type theory is taught. A special focus is placed on the concept of equality. Equality in elementary types is characterised. Homotopy theory concepts, the axiom of univalence and examples of higher inductive types are introduced. Higher inductive types are introduced. This homotopy-theoretic extension of the type theory is used to calculate selected homotopy groups and to develop abstract variants of classical results of algebraic topology.		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Mathematical reasoning and proving in a dependent type theory. This knowledge is a basis for the use of most computer-assisted proof systems.</li> <li>• Fundamental understanding of issues and techniques in abstract homotopy theory. The ideas gained are transferable to other approaches such as higher category theory.</li> <li>• Application of univalence and higher inductive types to homotopy theory problems. A study of advanced topics homotopy type theory becomes possible.</li> </ul>		
<b>Workload:</b> Total: 270 h		
<b>Conditions:</b> Experience with abstract mathematics, such as that gained in the context of introductory modules in the fields of topology and algebra. Elementary knowledge of these areas is helpful, but not required.		<b>Credit Requirements:</b> Pass the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> 1. - 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Homotopietypetheorie****Mode of Instruction:** lecture**Language:** German / English**Frequency:** Wintersemester**Contact Hours:** 4,00**Part of the Module: Übungen zur Homotopietypentheorie****Mode of Instruction:** exercise course**Language:** German / English**Contact Hours:** 2,00**Examination****Modulprüfung**

portfolio exam, graded

**Test Frequency:**

not this semester

<b>Module PHM-0291: Quantum Computing</b> <i>Quantum Computing</i>		6 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Markus Heyl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Qbits, quantum gates and quantum circuits</li> <li>• Physical realizations</li> <li>• Quantum noise</li> <li>• Quantum error correction</li> <li>• Quantum algorithms</li> <li>• Digital quantum simulation</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students acquire basic understanding of the principles of quantum computers and their applications.</li> <li>• They have the skills to construct concrete quantum circuits and algorithms.</li> <li>• They have the competence to identify the advantages of quantum information processing as well as to follow the modern developments in the field.</li> <li>• Integrated acquisition of key qualifications: Abstraction skills through the translation of physics problems onto quantum computing language, familiarization with English professional language.</li> </ul>		
<b>Workload:</b> Total: 180 h 40 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 40 h studying of course content using provided materials (self-study) 20 h exam preparation (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of quantum mechanics such as acquired in lectures PHM-0017 Theoretische Physik II, INF-0437 Grundlagen der Quanteninformationsverarbeitung, or INF-0440 Quantum Algorithms.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> every 4th semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Quantum Computing</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2,00		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Part of the Module: Quantum Computing (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Contact Hours:** 2,00

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- D. DiVincenzo, Quantum Computation, Science **270**, 255-261 (1995)
- M. Nielsen and I. Chuang, Quantum Computation and Quantum Information (Cambridge University Press, 2000)
- J. Stolze and D. Suter, Quantum Computing (Wiley-VCH, 2004)
- E. Grumbling and M. Horowitz, Quantum Computing: Progress and Prospects (The National Academies Press, 2019)

**Examination**

**Quantum Computing**

oral exam / length of examination: 30 minutes, graded

<b>Module INF-0066: Organic Computing II</b> <i>Organic Computing II</i>		5 ECTS/LP
Version 1.3.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Participants will be able to reproduce the essential concepts and methods of the research field of Organic Computing (OC).</p> <p>These include: Self-Organisation, Self-Adaptation, Robustness, Flexibility, Observer/Controller architectures (O/C), Self-X properties, Learning Classifier Systems (most notably, XCS), Genetic Algorithms (GA), Particle Swarm Optimisation, Influence Detection and Trust. They will also be able to justify the consideration of OC systems-based solutions and give examples for practical scenarios in which OC techniques should be applied.</p> <p>The students will be able to develop larger software systems using the O/C architecture as well as select suitable OC techniques for the architecture's components. They will be able to learn by themselves further OC techniques if solving a given problem requires it. Further, students will be able to solve practical problems using XCS, swarming and a GA. They will also be able to develop and evaluate OC system architectures and perform scientific evaluations related to OC systems.</p> <p><b>Key qualifications:</b> Ability to present and document results in a comprehensible way, ability to present ideas and concepts confidently and convincingly, knowledge of the way of thinking as well as the language of application-relevant disciplines, skill of working in teams.</p>		
<p><b>Remarks:</b> Lecture and exercise course in English Lecture slides in English Exams can be taken in either German or English Questions can be asked in either German or English</p>		
<p><b>Workload:</b> Total: 150 h 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Organic Computing II (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture "Organic Computing" teaches approaches to the organisation of complex networked systems that consist of a large number of autonomous subsystems. To this end, the requirements and goals of such systems are first defined and discussed. In addition, concepts from the field of system architectures and approaches from the field of nature-inspired algorithms are presented and evaluated. References to concrete application areas are given in all parts. The associated practice deepens the understanding of the approaches learned by applying them in an exemplary manner.

**Literature:**

- Slides
- Müller-Schloer und Tomforde: Organic Computing - Technical Systems for Survival in the Real World, Springer International Publishing, 2018, ISBN 978-3-319-68477-2
- Müller-Schloer et al.: Organic Computing - A Paradigm Shift for Complex Sys-tems, Birkhäuser Verlag, Basel, 2011, ISBN 978-3034801294
- Würtz (ed.): Organic Computing (Understanding Complex Systems), SpringerVerlag Berlin, 2008, ISBN 978-3540776567
- Mitchell: Machine Learning, The McGraw-Hill Companies, 1997, ISBN 978-0071154673
- Goldberg: Genetic Algorithms in Search, Optimization and Machine Learning, Addison-Wesley, 1989, ISBN 978-0201157673
- Michalewicz, Fogel: How to Solve it: Modern Heuristics, Springer Verlag Berlin, 2004, ISBN 978-3540224945
- Tomforde: Runtime Adaptation of Technical Systems, Südwestdeutscher Verlag für Hochschulschriften, 2012, ISBN 978-3838131337

**Assigned Courses:**

**Organic Computing II** (lecture)

*\*(in attendance) \**

**Part of the Module: Organic Computing II (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Organic Computing II** (exercise course)

*\*(in attendance) \**

**Examination**

**Organic Computing II (mündliche Prüfung)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

The exam can be taken every semester at the beginning and end of the lecture-free period.

<b>Module INF-0067: Peer-to-Peer and Cloud Computing</b> <i>Peer-to-Peer und Cloud Computing</i>		5 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Successful participation in this course results in professional competences in two sub-areas: Peer-to-Peer systems and Cloud Computing.</p> <p><b>Peer-to-Peer systems</b> Students can describe different peer-to-peer system architectures and their advantages as well as disadvantages. In particular, they are able to select a suitable architecture for a given use case and justify this decision. Furthermore, they can classify common decentralised search algorithms and heuristics and compare them with regard to their efficiency. They understand abstract network models and can use them to analyse peer-to-peer networks.</p> <p><b>Cloud Computing</b> Participants can distinguish the underlying technologies of cloud computing and analyse cloud computing architectures based on this knowledge. They know the importance of load balancing in the context of large cloud computing applications and can explain and weigh up the different approaches to this. Students know modern approaches to concurrent computations over large data sets and can apply them to simple problems. They are able to develop simple applications using platform-as-a-service frameworks.</p> <p><b>Key qualifications</b> Ability to think logically, analytically and conceptually; ability to expand existing knowledge independently; competence to recognise significant technical developments.</p>		
<p><b>Remarks:</b> Lecture slides in English Exams can be taken in either German or English</p>		
<p><b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Peer-to-Peer und Cloud Computing (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This module teaches approaches to organising complex abstracted IT infrastructures that can be dynamically adapted to changing conditions of use and provide services such as computing capacity, data storage, network capacities or software at different levels. For this purpose, the requirements, properties and goals of such systems are defined and discussed. In addition, concepts from the field of system architectures and approaches from the field of self-organising algorithms are presented and evaluated. References to concrete application areas are given in all parts.

**Literature:**

- current scientific paper
- Mahlmann und Schindelbauer: Peer-to-Peer Netzwerke - Algorithmen und Methoden, Springer 2007
- Antonopoulos und Gillam: Cloud Computing - Principles, Systems and Applications, Springer 2010

**Part of the Module: Peer-to-Peer und Cloud Computing (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Peer-to-Peer und Cloud Computing (mündliche Prüfung)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

The exam can be taken every semester at the beginning and at the end of the lecture-free period.

<b>Module INF-0078: Database Programming (Oracle)</b> <i>Datenbankprogrammierung (Oracle)</i>		5 ECTS/LP
Version 1.2.0 (since SoSe14) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<b>Learning Outcomes / Competences:</b> After participating in the course, students are able to apply in-depth Oracle knowledge in real-life tasks. This requires extended knowledge in the areas of DB system architecture, DB design theory, administration, extended SQL, PL/SQL programming, tree structures, XML and OLAP. The students gain a subject-specific in-depth knowledge in the area of database systems and thus the skill to analyze and structure problems. In addition, students will be able to analyze, evaluate and solve these complex, practice-relevant tasks in the field of databases, especially using Oracle. They know the advantages and disadvantages of different ER modeling and can use logical and conceptual thinking to write a suitable solution for complex problems under practical constraints.		
<b>Workload:</b> Total: 150 h 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)		
<b>Conditions:</b> Fundamental knowledge on database systems recommended, e.g., from the lecture [INF-0073] Datenbanksysteme 1		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Database Programming (Oracle) (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00		
<b>Contents:</b> The lecture covers problem solving strategies with the help of an Oracle database. This includes Oracle architecture, access rights, transformation from ER to SQL, Oracle SQL, active content such as PL/SQL and Java in Oracle, XML support in Oracle, tree structures, tuning, backup and recovery.		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• R. Elmasri, S. Navathe: Fundamentals of Database Systems</li> <li>• S. Melton: Understanding the New SQL: A Complete Guide</li> <li>• Oracle 19g Online-Dokumentation</li> </ul>		
<b>Part of the Module: Datenbankprogrammierung (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		

**Examination**

**Database Programming (Oracle)**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0129: Software Engineering II</b> <i>Softwaretechnik II</i>		8 ECTS/LP
Version 2.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Fachbezogene Kompetenzen:</b></p> <p>Nach dem erfolgreichen Besuch des Moduls sind die Teilnehmer in der Lage, fortgeschrittene Verfahren der agilen Softwareentwicklung, des Requirements Engineerings, des Testens und des Refactorings von Softwaresystemen anzuwenden und miteinander zu verbinden. Sie können die Anwendbarkeit der verschiedenen Verfahren und Methoden situationsspezifisch beurteilen.</p> <p>Die Teilnehmer verstehen die Aufgaben des Requirements Engineering und sind in der Lage, wesentliche Methoden der Requirements-Erfassung und Dokumentation (Use-Cases, Satzschablonen, formale Modelle) anzuwenden und die Eignung der verschiedenen Dokumentationsformen im Projektkontext zu bewerten. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können so systematisch komplexe Kundenanforderungen analysieren und können diese formulieren und in geeigneten Modellen darstellen.</p> <p>Die Studierenden verstehen einen agilen Entwicklungsprozess und die Basisprinzipien agiler Vorgehensweisen. Sie können den agilen Entwicklungsprozess auf Projekte übertragen und seine Anwendbarkeit im Projektkontext beurteilen. Sie kennen agile Praktiken und deren Wechselwirkungen und können die Praktiken einsetzen. Sie verstehen die Aufgaben der beteiligten Rollen und die Bausteine des Entwicklungsprozesses.</p> <p>Die Studierenden verstehen die Aufgaben des Testens und die Teilschritte des Testprozesses. Sie kennen Verfahren zur Bestimmung von Testfällen und zur Bewertung der Adäquatheit von Testsuiten und können diese anwenden.</p> <p>Die Studierenden kennen die Prinzipien guten objektorientierten Designs und können durch Refactoring die Qualität des Designs eines Systems verbessern. Sie können Ideen und Konzepte sicher und überzeugend darstellen und haben die Fähigkeit zur Zusammenarbeit im Team.</p> <p>Die Studierenden erwerben insgesamt Kenntnisse in Methoden zur Entwicklung großer Softwaresysteme und der Konstruktion von Abstraktionen sowie die Fähigkeit zu deren Anwendung im Projektkontext. Sie können alternative Vorgehensweisen wissenschaftlich fundiert bewerten und für ein Projekt geeignete auswählen.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Abstraktionsfähigkeit</li> <li>• Moderieren fachlicher Sitzungen</li> <li>• Erlernen des eigenständigen Arbeitens mit Lehrbüchern und Arbeit in selbstorganisierten Teams</li> <li>• Kenntnisse von praxisrelevanten Aufgabenstellungen</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>Programmierkenntnisse in Java (empfohlen)</p> <p>Module Software Engineering (INF-0120) - recommended</p>		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Softwaretechnik II (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p><b>Agile Softwareentwicklung:</b></p> <ul style="list-style-type: none"> <li>• Entwicklungsmethoden (Scrum)</li> <li>• Agile Praktiken</li> <li>• Agile Werte, Prinzipien und Methoden</li> </ul> <p><b>Refactoring</b></p> <ul style="list-style-type: none"> <li>• Code Smells</li> <li>• Prinzipien des objektorientierten Designs</li> <li>• Wichtige Refactorings</li> </ul> <p><b>Testen</b></p> <ul style="list-style-type: none"> <li>• Testprozess und Ziele des Testens</li> <li>• Testarten</li> <li>• Methoden zur Testfallgewinnung</li> <li>• Adäquatheitskriterien beim Blackbox- und Whitebox-Testen</li> </ul> <p><b>Requirements Engineering</b></p> <ul style="list-style-type: none"> <li>• Aufgaben, Begriffe und Artefakte</li> <li>• RE-Prozess</li> <li>• Techniken zur Requirements-Elicitation, -Analyse und -Dokumentation</li> <li>• Qualitätskriterien für Software-Requirements</li> </ul>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Pohl, Rupp: Basiswissen Requirements Engineering, dpunkt Verlag 2009</li> <li>• U. Hammerschall, G. Benekean: Software Requirements, Pearson 2013</li> <li>• S. Robertson, J. Robertson: Mastering the Requirements Process, Addison-Wesley 2013</li> <li>• Bleek, Wolf: Agile Softwareentwicklung, dpunkt Verlag 2008</li> <li>• R. Pichler: Scrum, dpunkt.verlag 2008</li> <li>• Spillner, Linz: Basiswissen Softwaretest, dpunkt Verlag 2005</li> <li>• Fowler: Refactoring, Addison-Wesley 1999</li> <li>• Vorlesungsfolien mit schriftlichen Ergänzungen und Anmerkungen</li> </ul>
<p><b>Part of the Module: Softwaretechnik II (Übung)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 4,00</p>

**Examination**

**Softwaretechnik II**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0130: Formal Methods in Software Engineering</b> <i>Formale Methoden im Software Engineering</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Wolfgang Reif		
<b>Learning Outcomes / Competences:</b> <b>Fachbezogene Kompetenzen:</b> <p>Die Studierenden können mathematisch-formale Methoden für die Programmverifikation, speziell bei sicherheitskritischer Software einsetzen. Durch das Verständnis von Kalkülen trainieren sie die Fertigkeit zum logischen, konzeptuellen und analytischen Denken. Sie können Spezifikationen von Datenstrukturen entwerfen und deren Eigenschaften formal beweisen. Sie sind in der Lage, funktionale Eigenschaften von sequentiellen und nebenläufigen Programmen zu formulieren und dafür Beweise zu erstellen. Sie erwerben die Fertigkeit zur abstrakten, modularen Modellierung von Softwaresystemen und zur systematischen Entwicklung von korrekten Programmen aus diesen Modellen. Sie erwerben dadurch die Fertigkeit zur Analyse und Strukturierung komplexer Informatikproblemstellungen und können mit geeigneten Methoden wissenschaftlich aussagekräftige Bewertungen abgeben. Sie erwerben Fähigkeiten, um Beiträge zur Wissenschaft zu leisten.</p> <b>Schlüsselqualifikationen:</b> <ul style="list-style-type: none"> <li>• Training des logischen Denkens</li> <li>• Analytisch-methodische Kompetenz</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Fähigkeiten zur Modellbildung für Softwaresysteme</li> </ul>		
<b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Formale Methoden im Software Engineering (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Übergeordnetes Ziel ist die Produktion beweisbar korrekter Software. In der Vorlesung werden verschiedene klassische Methoden für die Programmverifikation im Kleinen behandelt. Darüber hinaus werde innovative Techniken für die formale Modellierung und Verifikation großer Systeme vermittelt. Als Werkzeug kommt das KIV-System zum Einsatz, das die formale Spezifikation und Verifikation von Systemen ermöglicht. Konkrete Inhalte sind: Algebraische Spezifikationen, interaktives Theorembeweisen, Hoare-Logik, Dynamische Logik, Temporallogik

**Literature:**

- Sperschneider, Antoniou: Logic: A Foundation for Computer Science, Addison Wesley 1991
- Loeckx, Ehrich, Wolf: Specification of Abstract Data Types, Wiley 1996
- Ausführliche Dokumentation
- Folienhandout

**Assigned Courses:**

**Formale Methoden im Software Engineering (lecture)**

*\*(in attendance) \**

**Part of the Module: Formale Methoden im Software Engineering (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Formale Methoden im Software Engineering (exercise course)**

*\*(in attendance) \**

**Examination**

**Formale Methoden im Software Engineering**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0133: Self-Organising, Adaptive Systems</b> <i>Selbstorganisierende, adaptive Systeme</i>		8 ECTS/LP
Version 3.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b> Die Studierenden haben vertiefte Fachkenntnisse über die Eigenschaften und den Aufbau selbst-organisierender Systeme aus der Biologie, Soziologie, Physik und anderen Bereichen und der systematischen Modellierung und Konstruktion adaptiver Systeme in der Informatik und können solche Systeme analysieren und selbst entwerfen. Sie kennen Vor- und Nachteile verschiedener Entwurfsalternativen und können sie im Kontext der Problemstellung bewerten. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können geeignete Methoden auswählen und anwenden und wissenschaftlich aussagekräftige Bewertungen abgeben. Die Studierenden sind in der Lage, adaptive Systeme adäquat zu modellieren und dokumentieren.</p> <p>Außerdem kennen die Studierenden praxisrelevante Fragestellungen.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Grundsätze guter wissenschaftlicher Praxis</li> </ul>		
<p><b>Workload:</b> Total: 240 h 30 h lecture (attendance) 60 h exercise course (attendance) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Selbstorganisierende, adaptive Systeme (Vorlesung)</b>  <b>Mode of Instruction:</b> lecture  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b>          In der Vorlesung werden die Grundlagen verschiedener Selbst-Organisationsmechanismen sowie das Handwerkszeug, um diese in IT-Systemen einsetzen zu können, vermittelt. Im Verlauf der Veranstaltung werden verschiedene Beispiele für selbstorganisierende Systeme vorgestellt, untersucht und Anwendungen der erlernten Organisationsprinzipien auf Beispiele aus der Informatik erläutert. Schließlich werden Methoden betrachtet, mit deren Hilfe sich Selbst-Organisation und Adaptivität in die Entwicklung komplexer Computersysteme integrieren lassen. Konkrete Themen sind: Selbst-Organisation, Emergenz, Chaostheorie, zelluläre Automaten, Spieltheorie, Multi-Agentensysteme, Autonomic Computing, Organic Computing.</p>

**Literature:**

- Gleick: Chaos: Making a New Science, Penguin 2008
- Strogatz: Sync : The Emerging Science of Spontaneous Order, Hyperion 2003
- Miller, Page: Complex Adaptive Systems: An Introduction to Computational Models of Social Life, Princeton University Press 2007
- Dawkins: The Selfish Gene, Oxford University Press, 3rd Revised Edition
- Wolfram: A New Kind of Science, Wolfram Media Inc. 2002
- von Neumann, Morgenstern: Theory of Games and Economic Behavior, 2004
- Folienhandout

**Part of the Module: Selbstorganisierende, adaptive Systeme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Selbstorganisierende, adaptive Systeme**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0179: Introduction to Game Programming</b> <i>Einführung in die Spieleprogrammierung</i>		8 ECTS/LP
Version 1.2.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts for developing a game. They are able to implement their own gameplay concepts and to use suitable AI methods for decision-making as well as sequence control. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate AI components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Selection and confident application of appropriate methods, Interdisciplinary knowledge, Skill in analyzing and structuring complex computer science problems, Skill in developing and implementing solution strategies for complex problems, Understanding team processes, Skill in working in teams, Self-reflection; Acting responsibly in the face of inadequacy and conflicting interests, Quality awareness, Meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)</p>		
<b>Conditions:</b> Vacation task		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Foundations of Game Programming (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b> Game engines, AI character decision making, wayfinding and navigation, group behavior and dynamics, animations, physics, storytelling, input/output methodology, audio, game design, graphics and shader programming.</p>		
<p><b>Literature:</b> Script</p>		
<p><b>Assigned Courses:</b> <b>Einführung in die Spieleprogrammierung</b> (lecture) <i>*(in attendance) *</i></p>		

**Part of the Module: Foundations of Game Programming (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zur Einführung in die Spieleprogrammierung** (exercise course)

*\*(online/digital) \**

**Examination**

**Einführung in die Spieleprogrammierung**

portfolio exam, graded

**Test Frequency:**

when a course is offered

**Description:**

Exception summer term 2020: Portfolio exam

<b>Module INF-0182: Practical Module Multimodal Real Time Signal Processing</b> <i>Praktikum Multimodale Echtzeitsignalverarbeitung</i>		8 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students are familiar with the basic concepts of signal processing and machine learning. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. During the internship, they also learn to plan larger project tasks (development of software modules) in small teams, to solve them according to a self-developed project plan and to discuss the results appropriately in plenary sessions and present them as a team. The ability to evaluate suitable methods in a scientifically meaningful way, to develop the methods and algorithms independently and to implement them technically is also particularly encouraged.</p> <p><b>Key qualifications:</b> Advanced knowledge of signal processing and machine learning, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b> Programming experience  Module Foundations of Multimedia I (INF-0087) - recommended Module Foundations of Multimedia II (INF-0166) - recommended</p>		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Practical Module Multimodal Real Time Signal Processing</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 6,00</p>
<p><b>Contents:</b> The specific task from the wide field of multimodal real-time signal processing is designed every year.</p>
<p><b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.</p>

<p><b>Examination</b> <b>Practical Module Multimodal Real Time Signal Processing</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-0183: Practical Module Game Programming</b> <i>Praktikum Spieleprogrammierung</i>		8 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<b>Contents:</b> In this lab, several games are developed. It has a different focus every year.		
<b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of game development. They are able to plan larger project tasks in small teams, to solve them according to a self-developed project plan and to discuss and present the results appropriately in plenary sessions. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. During the internship, they learn to evaluate various components of a game in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results as well as logical, analytical and conceptual thinking are also particularly promoted in this context. <b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.		
<b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Module Introduction to Game Programming (INF-0179) - recommended		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Practical Module Game Programming</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00
<b>Contents:</b> A game is to be developed within the internship. The content focus of the internship is determined each year.
<b>Literature:</b> References will be announced at the beginning of the semester.

**Examination**

**Practical Module Game Programming**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0207: Reinforcement Learning</b> <i>Reinforcement Learning</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of reinforcement learning. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills for confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Advanced mathematical-formal methodology, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Reinforcement Learning (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> Markov decision problem, Dynamic programming, Monte Carlo methods, TD learning, Eligibility traces, Hierarchical reinforcement learning, Planning and learning, Generalization.</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Script</li> <li>• Richard S. Sutton und Andrew G. Barto. Reinforcement Learning: An Introduction. MIT Press, 1998</li> </ul>

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**Part of the Module: Reinforcement Learning (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Reinforcement Learning**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0217: Practical Module Autonomous Driving</b> <i>Praktikum Autonomes Fahren</i>		10 ECTS/LP
Version 2.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Bernhard Bauer Prof. Dr. Lars Mikelsons		
<p><b>Learning Outcomes / Competences:</b></p> <p>After participating in the practical course on autonomous driving, students will be able to solve practical problems of high complexity in conceptual design, development, and safeguarding of highly automated/autonomous vehicles using current methods and tools of model-based development. The students acquire in-depth subject-specific and interdisciplinary knowledge and skills, for example, from hardware-related computer science, software engineering, and the underlying driving physics and mathematics. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine, present and document intermediate results and innovative ideas understandably.</p> <p>Key qualification: Ability to think logically, analytically, and conceptually; Independent work with English-language specialist literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Ability to work in teams and understand team processes; Project management skills.</p>		
<p><b>Remarks:</b></p> <p>The practical course is offered alternately by the two chairs mentioned above.</p>		
<p><b>Workload:</b></p> <p>Total: 300 h 150 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <p>Participation in one of the two seminars is recommended.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>10,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module:</b> <i>Praktikum Autonomes Fahren</i>  <b>Mode of Instruction:</b> internship  <b>Language:</b> German / English  <b>Frequency:</b> irregular  <b>Contact Hours:</b> 10,00</p>		

**Contents:**

In this practical course, the participants learn how various selected partial aspects of autonomous driving can be implemented, simulated, and analyzed.

In addition, the participants will get to know, among other things, development tools frequently used in the automotive environment.

After an introductory course, the participants will implement autonomous driving functions in small groups with the help of the tools mentioned.

The developed results are finally demonstrated and evaluated.

**Examination**

**Practical Module Autonomous Driving**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0233: Industrial Robotics</b> <i>Industrierobotik</i>		8 ECTS/LP
Version 2.2.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage Industrieroboter zu programmieren, kennen das dafür erforderliche methodische Vorgehen und können die Eignung verschiedener Vorgehensweise bewerten. Sie können fachliche Lösungskonzepte in Roboterprogramme umsetzen und dabei Entwurfsalternativen bewerten und anwenden. Sie haben Kenntnisse von praxisrelevanten Aufgabenstellungen in der automatisierten Fertigung. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> </ul>		
<p><b>Remarks:</b> Dieses Modul ersetzt das Modul "INF-0132: Software in Mechatronik und Robotik". Sofern dieses bereits belegt wurde, ist eine erneute Belegung <b>nicht</b> möglich.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Industrierobotik (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> Ziel der Veranstaltung ist es, an Beispielen die Programmierung und der Entwurf von Software für Industrieroboter, wie sie z.B. in der Automobilindustrie verwendet werden, zu erlernen. Dazu werden im ersten Teil der Vorlesung Grundlagen wie Kinematik und Bahnplanung mit Hilfe simulationsbasierter Programmieransätze behandelt. Im zweiten Teil der Vorlesung werden verschiedene, kleine Programmieraufgabenstellungen bearbeitet und auf einem KUKA Roboter evaluiert. Die Programmierung erfolgt mit der Roboterprogrammiersprache KRL.</p>

**Literature:**

- L. Sciavicco, B. Siciliano: Modelling and Control of Robot Manipulators. Reihe: Advanced Textbooks in Control and Signal Processing. Springer 2000 (2nd Ed.)
- Handbücher von KUKA
- Folienhandout

**Assigned Courses:**

**Industrierobotik** (lecture)

*\*(in attendance) \**

**Part of the Module: Industrierobotik (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Industrierobotik** (exercise course)

*\*(hybrid/mixed) \**

**Examination**

**Industrierobotik**

portfolio exam / length of examination: 45 minutes

work period for assignment: 3 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0235: Software for Industry 4.0</b> <i>Software für Industrie 4.0</i>		5 ECTS/LP
Version 1.2.0 (since WS16/17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage die praktischen und methodischen Herausforderungen, die Industrie 4.0 für die Automatisierung und deren Softwareentwicklung bedeutet, zu verstehen. Sie werden sowohl in Techniken der klassischen Automatisierung als auch modernen Softwaretechnologien im Umfeld von Industrie 4.0 eingeführt und kennen so unterschiedliche anwendungsrelevante Disziplinen. Sie sind in der Lage Lösungskonzepte zu erstellen und dabei Entwurfsalternativen bewerten und anwenden.		
<b>Schlüsselqualifikationen:</b> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenzen</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> </ul>		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Software für Industrie 4.0 (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00		
<b>Contents:</b> Die Vorlesung behandelt aktuelle Themen im Kontext von Industrie 4.0. Dazu zählen folgende Inhalte: <ul style="list-style-type: none"> <li>• Einführung in die Automatisierung</li> <li>• Referenzarchitekturen für Industrie 4.0</li> <li>• Einführung in die (mobile Service) Robotik</li> <li>• OPC UA</li> <li>• AutomationML</li> <li>• Data Analytics für Industrie 4.0</li> </ul>		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0 - Abschlussbericht des Arbeitskreises Industrie 4.0; acaTech</li> </ul>		

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**Part of the Module: Software für Industrie 4.0 (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination**

**Software für Industrie 4.0**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0248: Collaborative Robotics</b> <i>Kollaborative Robotik</i>		8 ECTS/LP
Version 1.1.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage kollaborative Roboter zu programmieren und verstehen die regulatorischen Randbedingungen (vgl. ISO/TS 15066:2016). Sie verstehen die grundlegenden Konzepte und Methoden der kollaborativen Robotik. Sie können dementsprechend fachliche Lösungskonzepte umsetzen und Entwurfsalternativen bewerten und anwenden. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können grundlegende Bewertungen der Risiken eines kollaborativen Robotersystems durchführen. Die Studierenden können abwägen, für welche praxisrelevanten Problemstellungen kollaborative Roboter eingesetzt werden können.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Erwerb von Grundlagen für die Sicherheitsbewertung</li> </ul>		
<p><b>Remarks:</b> <b>Voraussetzungen (empfohlen):</b> Software für Industrie 4.0 oder Industrierobotik oder Grundlagen der Robotik</p>		
<p><b>Workload:</b> Total: 240 h</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Kollaborative Robotik (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 4,00</p>		

**Contents:**

Die Digitalisierung dringt mittlerweile in viele Bereiche des täglichen Lebens vor. Von Industriemaschinen und Robotersystemen (*Smart Factory, Industrie 4.0*) bis hin zu intelligenten Hausgeräten oder Heizungsanlagen (*Smart Home*) findet eine immer stärkere Vernetzung dieser Geräte im Internet der Dinge statt. Hierbei spricht man von cyber-physischen Systemen, die einerseits durch ein komplexes Zusammenspiel von vernetzten eingebetteten Systemen entstehen und andererseits geprägt sein werden von einer vollkommen neuen Art der Mensch-Technik-Interaktion in den Anwendungen.

Eine besondere Rolle unter den cyber-physischen Systemen nehmen Assistenz- oder Serviceroboter ein, da sie durch einen geteilten Arbeitsraum in eine direkte, auch physische Interaktion mit dem Menschen treten können. Diese robotischen Systeme können den Menschen in seiner täglichen Arbeit unterstützen bzw. entlasten. Das gilt sowohl im häuslichen Umfeld als auch in der Fabrik. Im Kontext von Industrie 4.0 haben robotische Co-Worker (CoBots) vereinzelt bereits Eingang in die Produktion gefunden. Diese kollaborativen Einsatzszenarien werden jedoch in Zukunft noch weiter an Bedeutung gewinnen. Durch die in 2016 veröffentlichte Norm ISO/TS 15066:2016 zur Mensch-Roboter-Kollaboration stehen dem Einsatz innovativer Robotersysteme neue Möglichkeiten offen.

Während die grundlegende Hardware, d.h. die Roboter, mobilen Plattformen, Greifer und Sensoren, bereitgestellt wird, liegt der Schwerpunkt der Veranstaltung auf der Entwicklung von Software für kollaborative (mobile) Manipulatoren. Durch die intelligente Vernetzung von Aktuatorik und Sensorik, neuartige Algorithmen für die Sensorauswertung und kreative Konzepte zur (physischen) Interaktion mit dem Menschen entstehen innovative, kollaborative Robotersysteme im praktischen Teil der Veranstaltung.

Infolgedessen liegt der thematische Fokus der Veranstaltung auf

- der Umsetzung multi-modaler Benutzerschnittstellen,
- der Gestaltung neuartiger, auch physischer Interaktionsmöglichkeiten,
- der Realisierung intelligenter Verhaltensweisen durch Techniken der Künstlichen Intelligenz bzw. des Machine Learnings und
- der Entwicklung kognitiver Fähigkeiten des Robotersystems.

Diese Kernelemente bieten die Grundlage, um eine praktische Aufgabenstellung prototypisch umzusetzen. Die Programmierung erfolgt dabei in objektorientierten Programmiersprachen. So können kollaborative Roboter bspw. in Java mit der Robotics API programmiert werden, einem am ISSE in Kooperation mit KUKA entwickelten Roboterframework. Alternativ oder ergänzend kann das Robot Operating System (ROS) verwendet werden, das in den Programmiersprachen C++ und Python programmiert werden kann.

**Part of the Module: Kollaborative Robotik (Vorlesung)**

**Mode of Instruction:** lecture

**Language:** German

**Frequency:** irregular

**Contact Hours:** 2,00

**Literature:**

- ISO/TS 15066:2016. 2016-02-15. Robots and robotic devices - Collaborative robots
- DIN EN ISO 13849-1:2016-06. 06.2016. Sicherheit von Maschinen - Sicherheitsbezogene Teile von Steuerungen - Teil 1: Allgemeine Gestaltungsleitsätze (ISO 13849-1:2015); Deutsche Fassung EN ISO 13849-1:2015
- DIN EN ISO 10218-1:2012. 01.2012. Industrieroboter - Sicherheitsanforderungen - Teil 1: Roboter (ISO 10218-1:2011); Deutsche Fassung EN ISO 10218-1:2011

**Examination**

**Kollaborative Robotik**

practical exam / length of examination: 60 minutes

work period for assignment: 3 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0250: Practical Module Reinforcement Learning</b> <i>Praktikum Reinforcement Learning</i>		8 ECTS/LP
Version 1.3.0 (since SoSe17) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of reinforcement learning. They are able to plan larger project tasks in small teams, to solve them according to a self-developed project plan and to discuss and present the results appropriately in plenary sessions. You are able to translate technical solution concepts into programs and models and are proficient in the selection and confident application of appropriate methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. During the internship, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking are also particularly promoted in this context.</p> <p><b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 150 h studying of course content through exercises / case studies (self-study) 90 h internship / practical course (attendance)</p>		
<b>Conditions:</b> Programming experience		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Practical Module Reinforcement Learning</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 6,00</p>
<p><b>Contents:</b> The specific task from the field of "reinforcement learning" is designed anew each semester.</p>

<p><b>Examination</b> <b>Practical Module Reinforcement Learning</b> practical exam, graded <b>Test Frequency:</b> when a course is offered <b>Description:</b> Exception summer term 2020: practical exam</p>
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<b>Module INF-0277: Analysing Massive Data Sets</b> <i>Analyzing Massive Data Sets</i>		8 ECTS/LP
Version 1.2.0 (since SoSe18) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<p><b>Learning Outcomes / Competences:</b> After attending the course, students will be able to understand and evaluate the concepts and methods, procedures, techniques, and technologies for analyzing massively large data sets. Possible content includes:</p> <ul style="list-style-type: none"> <li>• Fundamentals of information retrieval</li> <li>• Similarity search and clustering</li> <li>• Analysis of data streams and temporal data</li> <li>• Web graphs: Link analysis and social networks</li> <li>• Dynamic networks and information diffusion</li> <li>• Recommender systems and online advertising</li> <li>• Computational methods for massive data sets</li> </ul> <p>Students will also be able to implement technical solution concepts for analyzing large data sets in programs. <b>Key Skills:</b> Ability to think logically, analytically and conceptually, weigh up approaches to solutions, acquire abstraction skills; subject-specific in-depth knowledge; implement subject-specific solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives and evaluation in the respective application context; selection and confident application of suitable methods; ability to make scientifically meaningful evaluations using suitable methods; ability to solve problems under practical boundary conditions; competence in recognizing significant technical developments;</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 60 h lecture (attendance) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b> Module Database Systems (INF-0073) - recommended Module Discrete structures for computer science (INF-0109) - recommended Module Computer Science 3 (INF-0111) - recommended</p>		
<b>Frequency:</b> Sommersemester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Analyzing Massive Data Sets (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b> The lecture covers basic concepts for the analysis of massively large data sets such as information extraction, similarity search, clustering, link and network analysis as well as their implementation.</p>

**Literature:**

- Mining of Massive Datasets. J. Leskovec, A. Rajaraman, J.D. Ullman. Cambridge University Press, 2014
- D. Easley, J. Kleinberg. Networks, Crowds, and Markets: Reasoning About a Highly Connected World. Cambridge University Press, 2010.
- R. Baeza-Yates, B. Ribeiro-Neto: Modern Information Retrieval

Weitere Literatur wird in der Vorlesung bekannt gegeben

**Assigned Courses:**

**Analyzing Massive Data Sets** (lecture)

*\*(in attendance) \**

**Part of the Module: Analyzing Massive Data Sets (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Analyzing Massive Data Sets** (exercise course)

*\*(in attendance) \**

**Examination**

**Analyzing Massive Data Sets**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0293: Advanced Deep Learning</b> <i>Advanced Deep Learning</i>		8 ECTS/LP
Version 1.1.0 (since WS18/19) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After participating in the practical module, students have detailed and up-to-date knowledge in the field of machine learning, can identify significant technical developments and can implement a complete pipeline for multimodal data processing with deep neural networks. They can precisely describe and discuss problems and results in the field and apply learned concepts and methods to similar problems in machine learning. In addition, the students analyse advanced concepts, methods, procedures, techniques and technologies from the field of machine learning to apply them in research projects, transfer them to current industry-related tasks and actively participate in them. The students learn to transfer scientifically challenging topics in the field of machine learning to other research questions and, building on this, to work out a complex project in group work. They also have the teamwork and communication skills to discuss problems in the field, to discuss, describe and present questions and interim results. In addition, students can conduct detailed experiments and assess, compare and check results for plausibility.</p> <p><b>Key qualifications:</b> Advanced mathematical-formal methodology; Translating subject-specific solution concepts into programs and models; Methods for developing larger software systems, construction of abstractions and architectures; Interdisciplinary knowledge; Systematic further development of design methods; Skill of confident and convincing presentation of ideas and concepts; Understanding of team processes; Skill of working in teams; Ability to lead teams; Familiarity with procedures and processes in the application environment of computer science; Skill of solving problems under practical boundary conditions; Self-reflection; Responsible action against the background of inadequacy and conflicting interests; Ability to expand existing knowledge independently; Quality awareness, meticulousness</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 20 h lecture (attendance) 40 h exercise course (attendance)</p>		
<p><b>Conditions:</b> Fundamental knowledge in computer vision (basic studies lectures "Multimedia Grundlagen 1", "Grundlagen der Signalverarbeitung und des Maschinellen Lernens", "Multimedia Grundlagen 2" as well as master's lectures "Multimedia 2" and "Machine Learning and Computer Vision")</p>		<p><b>Credit Requirements:</b> Passing the portfolio examination</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Advanced Deep Learning (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Deep Learning in general
- Deep Convolutional Neural Networks
- Transfer Learning
- Recurrent Neural Networks / LSTM Networks
- Natural Language Processing
- Multimodal Fusion (Vision+Language)
- Application: Image Captioning

**Part of the Module: Advanced Deep Learning (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Advanced Deep Learning**

portfolio exam, The final grade is made up of assessed exercise sheets and an assessed team project., graded

**Test Frequency:**

when a course is offered

**Description:**

Die Endnote setzt sich aus bewerteten Übungsblättern und einem bewerteten Teamprojekt zusammen.

<b>Module INF-0307: Model-Based Development and Analysis of Software Systems</b> <i>Modellbasierte Entwicklung und Analyse von Software Systemen</i>		6 ECTS/LP
Version 1.1.0 (since SoSe19) Person responsible for module: Prof. Dr. Bernhard Bauer		
<b>Learning Outcomes / Competences:</b> Model-based development and analysis of software systems deals with increasing efficiency in software development through automation and reuse. In this course, participants learn to apply and compare methods for model-driven development of software systems. In doing so, they develop in-depth, subject-specific solution concepts for MDSD. They will be able to evaluate current technologies and standards for MDSD and analyse their applicability in practical tasks. Participants will develop skills for analysing and structuring complex IT problems when generating infrastructure code, subsystems, configurations or entire applications from models. In doing so, they will develop logical, analytical and conceptual thinking skills and will be able to systematically develop and evaluate solutions to problems.  Key qualifications: Interdisciplinary knowledge; ability to connect different subject areas; teamwork and communication skills; ability to independently expand existing knowledge; quality awareness; familiarity with the procedures and processes in the application environment of computer science; knowledge and understanding of formal quantitative fundamentals; ability to present and document results in a comprehensible manner.		
<b>Workload:</b> Total: 180 h 23 h studying of course content using literature (self-study) 22 h studying of course content using provided materials (self-study) 30 h exercise course (attendance) 45 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Knowledge of object-oriented programming</li> <li>• Fundamental knowledge of modeling languages (e.g., UML)</li> <li>• Fundamental knowledge of software architectures and design patterns</li> <li>• Frühere Veranstaltung "Modellgetriebene Softwareentwicklung" darf <b>nicht</b> belegt worden sein wegen Überschneidungen.</li> <li>• The previous course 'Model-Driven Software Development' must not have been taken due to overlaps.</li> </ul>		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 5,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Model-Based Development and Analysis of Software Systems (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 3,00		

**Contents:**

Model-based development and analysis of software systems deals with increasing efficiency in software development through automation and reuse. Infrastructure code, subsystems, configurations or entire applications are generated from models.

**Literature:**

- Slides
- Pohl et al. Software Product Line Engineering: Foundations, Principles, and Techniques
- Kleppe et al: MDA explained
- Hitz et al: UML@Work
- weitere Literatur in der Vorlesung zu speziellen Themen

**Part of the Module: Model-Based Development and Analysis of Software Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination**

**Model-Based Development and Analysis of Software Systems**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0308: Software-Intensive Systems</b> <i>Software-intensive Systeme</i>		6 ECTS/LP
Version 1.2.0 (since SoSe19) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students are able to design (K3), evaluate (K6), and document software architectures. For this purpose, they can transfer domain-specific solution concepts into models and are familiar with methods for developing such abstractions and architectures. They are able to describe the advantages and disadvantages of design alternatives (K4) and to evaluate them in the respective application context (K6). Problems can be independently identified (K4), and solutions can be systematically designed (K5) and implemented (K3). Furthermore, students have developed skills for analyzing and structuring problem domains within enterprise architectures and are familiar with the concepts and procedures for creating such architectures. Students are able to identify practice-relevant questions in enterprise architectures (K1). They can select appropriate methods for architecture design and evaluation and apply them confidently. Students are familiar with modeling languages and patterns for creating software and enterprise architectures. They have the competence to recognize significant technological developments.</p> <p><b>Key competencies:</b> Ability to integrate knowledge from different disciplines; teamwork and communication skills; ability to independently extend existing knowledge; quality awareness; ability to clearly present and document results; practical experience and professional qualification.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>22 h studying of course content using provided materials (self-study)</p> <p>23 h studying of course content using literature (self-study)</p> <p>45 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Knowledge of object-oriented programming</li> <li>• Fundamental knowledge of modeling languages (e.g., UML)</li> <li>• Fundamental knowledge of software architectures and design patterns</li> <li>• The previous course 'Software-intensive Systems' must not have been taken due to overlaps.</li> </ul>		
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 5,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<p><b>Part of the Module: Software-intensive Systeme (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> Sommersemester</p> <p><b>Contact Hours:</b> 3,00</p>
<p><b>Contents:</b></p> <p>The lecture content includes patterns, modelling techniques and the evaluation of software architectures. Furthermore, the area of enterprise architecture management is addressed.</p>

**Literature:**

- Bass et al: Software Architecture in Practice
- Clements et al: Documenting Software Architectures
- Clements et al: Evaluation of Software Architectures
- Kopetz: Real-Time Systems

**Part of the Module: Software-intensive Systeme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** Sommersemester

**Contact Hours:** 2,00

**Examination**

**Software-intensive Systeme**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0316: Machine Learning and Computer Vision</b> <i>Machine Learning and Computer Vision</i>		8 ECTS/LP
Version 1.0.0 (since SoSe19) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successful participation in this module, students possess advanced knowledge of machine learning (decision trees, neural networks and deep neural networks, hypothesis evaluation, instance-based learning, Bayesian learning, learning theory), data reduction (e.g. principal component analysis), advanced image processing and machine vision and are able to apply them. They can analyse, understand and programmatically implement scientifically complex procedures in the field of multimedia data processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of digital signal processing and multimedia data processing.</p> <p><b>Key qualifications:</b> advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each summer semester (except for summer term 2026)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Machine Learning and Computer Vision (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b></p> <p>The lecture gives a good overview of all aspects of machine learning and machine extraction of information from multimedia data (e.g. "Google Image Search", "Google Goggles"). The learned concepts will be practised, analysed, and evaluated in the exercises using successful examples from practice. At the end of the semester, advanced topics such as object detection and object recognition of faces and people will be covered. The contents of the lecture include: Machine Learning (Decision Tree Learning, Artificial Neural Networks, Bayesian Learning, Discrete Adaboost), Data Reduction (Quantization (K-Means Clustering, Affinity Propagation), Dimensionality Reduction Techniques (PCA, NMF, Random Projection, MDS)) and Image Processing &amp; Computer Vision (Salient Feature Points and Feature Descriptors, Object Detection (Face/Car/People Detection), Object Recognition (Face Recognition), Image Search with pLSA).</p>

**Literature:**

Literature references will be announced at the beginning of the semester.

**Assigned Courses:**

**Machine Learning and Computer Vision** (lecture)

*\*(in attendance) \**

**Part of the Module: Machine Learning and Computer Vision (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Machine Learning and Computer Vision** (exercise course)

*\*(in attendance) \**

**Examination**

**Machine Learning and Computer Vision**

written exam / length of examination: 120 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0318: Practical Module on Simulation of Autonomous Vehicles</b> <i>Praktikum Simulation von autonomen Fahrzeugen (Vertiefung)</i>		8 ECTS/LP
Version 1.0.0 (since WS19/20) Person responsible for module: Prof. Dr. Lars Mikelsons		
<b>Learning Outcomes / Competences:</b> Subject-related competencies: After participating in the internship, students understand problems of higher complexity in the field of simulation of autonomous vehicles and have deeper technical knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in small groups and are able to apply innovative methods in solving problems. This enables them to connect to international research and implement existing concepts. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate objectives, and critically evaluate, classify, combine and present intermediate results and innovative ideas.  Key Competencies: Skill in logical, analytical, and conceptual thinking; Validation of simulation results and software modules; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in collaborating in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;		
<b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Good programming skills Helpful: Python, C++, ROS, Game Engines		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Practice Model on Simulation of Autonomous Vehicles (Advanced)</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00 <b>ECTS Credits:</b> 8.0		
<b>Contents:</b> In the practical course, students work in small groups on application-oriented tasks for the simulation of autonomous vehicles. They are allowed to implement and validate individual software modules of a virtual vehicle themselves.		

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**Examination**

**Practice Model on Simulation of Autonomous Vehicles**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0367: Advanced Machine Learning and Computer Vision</b> <i>Advanced Machine Learning and Computer Vision</i>		5 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students have in-depth advanced knowledge of machine learning (support vector machines and deep neural networks and their basic building blocks) and machine vision (deep neural network architectures and systems) and can apply these. They can analyse, understand and programmatically implement scientifically complex procedures in the field of image, text, video and signal processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of machine learning and vision.</p> <p><b>Key qualifications:</b> advanced mathematical-formal logic; critical reading and analysis of scientific publications; implementation of technical solution concepts; interdisciplinary knowledge; development and implementation of solution strategies of complex problems; systematic further development of design methods; skills in solving problems under practical boundary conditions</p>		
<p><b>Workload:</b> Total: 150 h 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b> "Knowledge of Machine Learning and Computer Vision" (Master's lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")</p>		<p><b>Credit Requirements:</b> Passing the module examination</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b> from 2.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Advanced Machine Learning and Computer Vision (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p> <p><b>Contents:</b> The lecture gives an in-depth insight into all aspects of machine learning and machine vision. The concepts learned will be practiced, analyzed and evaluated in the exercises using successful real-world examples. The contents of the lecture include: support vector machines, basic building blocks of deep neural networks (layer structures, normalization, attention mechanisms), as well as current reference architectures and systems for image, text, video processing and their combination with further sensor signals.</p> <p><b>Literature:</b> Will be announced at the beginning of the semester.</p>
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**Part of the Module: Advanced Machine Learning and Computer Vision (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination**

**Advanced Machine Learning and Computer Vision (Examination)**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0379: Practical Module Simulation of Cyber-Physical Systems</b> <i>Praktikum Simulation cyber-physischer Systeme</i>		6 ECTS/LP
Version 1.0.0 (since SoSe21) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b> After successful participation in this module, students will be able to apply advanced methods of simulation to use virtual prototypes for model-based development of mechatronic systems. They know methods for different application areas along the development process and interpret their result.</p> <p><b>Methodological competences:</b> Students are able to evaluate different simulation methods for different application areas. They are also able to select and independently apply suitable simulation methods depending on the simulation purpose.</p> <p><b>Interdisciplinary competences:</b> Students are able to solve certain engineering problems with the help of information technology. They can use abstractions of physical systems and apply them in combination with information technology methods for the development of mechatronic systems.</p> <p><b>Key Competencies:</b> Advanced skill in answering engineering questions, particularly in the area of mechatronic systems design, using virtual prototypes; selection and application of advanced simulation methods; assessment and analysis of mathematical models.</p>		
<p><b>Workload:</b> Total: 180 h 90 h internship / practical course (attendance) 90 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b> Attendance of the course Mechatronics and/or object-oriented methods of modeling and simulation.</p>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b> from 4.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Praktical Module Simulation of Cyber-Physical Systems</b>  <b>Mode of Instruction:</b> internship  <b>Lecturers:</b> Prof. Dr. Lars Mikelsons  <b>Language:</b> German / English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 6,00</p>		

**Contents:**

Nowadays, the development of mechatronic systems is generally model-based. In doing so, the application of simulation in practice often encounters the following challenges:

- How do I improve a physical model when measurements become available?
- How do I know how much I can trust my model?
- How do I combine simulation of physical systems with virtual control units?
- How can I even use simulation to investigate the safety of the real system?

In this lab, students will learn methods for answering these (and other) questions and apply what they learn through hands-on exercises. Experts from industrial practice are brought in for some parts of the course.

**Examination**

**Praktical Module Simulation of Cyber-Physical Systems**

portfolio exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0409: Cyber Security</b> <i>Cyber Security</i>		6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.</p> <p>To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for</p> <p>They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.</p> <p>Key qualification: Competence to network different subject areas; team and ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>23 h studying of course content using literature (self-study)</p> <p>22 h studying of course content using provided materials (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>45 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Fundamental knowledge of software architectures and software development processes</li> <li>• Basic knowledge of IT systems, operating systems, and computer networks</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester SoSe 25 danach WiSe 26-27</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 5,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Cyber Security (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 3,00</p>
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**Contents:**

The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.

**Literature:**

- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

**Part of the Module: Cyber Security (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Examination**

**Cyber Security**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0410: Gesture-Based Communication in Human-Computer Interaction</b> <i>Gesture-Based Communication in Human-Computer Interaction</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of gesture-based communication in human-computer interaction. They are able to translate technical solution concepts into programs and models and master the selection and application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills for confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Advanced mathematical formal methodology, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in collaborating in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Gesture-Based Communication in Human-Computer Interaction (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b> HCI methods and principles, Interaction design, Nonverbal communication, Gestures, Gesture recognition systems, Collaboration, Applied computer vision, Ubiquitous computing</p>		
<p><b>Part of the Module: Gesture-Based Communication in Human-Computer Interaction (Exercise Course)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4,00</p>		

**Examination**

**Gesture-Based Communication in Human-Computer Interaction**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0418: Practical Module Conversational AI: Virtual Assistants and Chatbots</b> <i>Praktikum Conversational AI: Virtual Assistants and Chatbots</i>		5 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: Prof. Dr. Elisabeth André		
<b>Learning Outcomes / Competences:</b> Students are familiar with methods and techniques of interaction design and engineering for health care applications. After successful participation, they will have the necessary knowledge to analyze application scenarios according to the guidelines of the user-centered design process and to design software solutions tailored to the target group. They are able to translate current interaction paradigms and design guidelines into models and programs for novel interaction devices, as well as to independently familiarize themselves with the necessary technologies. Furthermore, they are able to apply practice-relevant evaluation methods to assess the quality of the created software prototype. They are able to plan larger project tasks in small teams, solve them according to a self-developed project plan and discuss the results appropriately in plenary sessions and present them as a team.  <b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the mindset and language of application-relevant disciplines; understanding of team processes; skill in collaborating in teams; skill in leading teams; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.		
<b>Workload:</b> Total: 150 h 90 h studying of course content through exercises / case studies (self-study) 60 h internship / practical course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Practical Module Interaction Design and Engineering for Health Care Applications</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4,00
<b>Contents:</b> The specific assignment for student projects is designed each year.
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.

<b>Examination</b> <b>Practical Module Interaction Design and Engineering for Health Care Applications</b> practical exam, graded <b>Test Frequency:</b> when a course is offered
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<b>Module INF-0425: Cyber Security 2</b> <i>Cyber Security 2</i>		6 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.</p> <p>To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for</p> <p>They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.</p> <p>Key qualification: Competence to network different subject areas; team and ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>30 h exercise course (attendance)</p> <p>45 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>23 h studying of course content using literature (self-study)</p> <p>22 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Solid knowledge of software development and software engineering</li> <li>• Good knowledge of software and IT architectures</li> <li>• Knowledge of secure software development processes</li> <li>• Basic knowledge of operating systems, computer networks, and IT security mechanisms</li> </ul>		
<p><b>Frequency:</b> each summer semester erst wieder ab SoSe 26</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 5,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Cyber Security 2 (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 3,00</p>		
<p><b>Contents:</b></p> <p>The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.</p>		

**Literature:**

- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

**Assigned Courses:**

**Cyber Security 2** (lecture)

*\*(in attendance) \**

**Part of the Module: Cyber Security 2 (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Cyber Security 2** (exercise course)

*\*(in attendance) \**

**Examination**

**Cyber Security 2**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0427: Deep Ubiquitous and Wearable Computing for Healthcare</b> <i>Deep Ubiquitous and Wearable Computing for Healthcare</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> Students are familiar with methods and techniques of interaction design and engineering for health care applications. After successful participation, they will have the necessary knowledge to analyze application scenarios according to the guidelines of the user-centered design process and to design software solutions tailored to the target group. They are able to translate current interaction paradigms and design guidelines into models and programs for novel interaction devices, as well as to independently familiarize themselves with the necessary technologies. Furthermore, they are able to apply practice-relevant evaluation methods to assess the quality of the created software prototype. They are able to plan larger project tasks in small teams, solve them according to a self-developed project plan and discuss the results appropriately in plenary sessions and present them as a team.</p> <p><b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the mindset and language of application-relevant disciplines; understanding of team processes; skill in collaborating in teams; skill in leading teams; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Practical Module Interaction Design and Engineering for Health Care Applications</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> The specific assignment for student projects is designed each year.</p>
<p><b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.</p>

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**Part of the Module: Deep Ubiquitous and Wearable Computing for Healthcare (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Practical Module Interaction Design and Engineering for Health Care Applications**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0456: Content Creation for Virtual Environments</b> <i>Content Creation for Virtual Environments</i>		8 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful completion of this module, students will understand essential concepts and techniques for making and integrating 2D/3D graphics and audio for virtual environments. They have the knowledge of the mindset and language of application-relevant disciplines. Within the framework of the lecture, they learn to create content by hand and generatively with procedural methods and algorithms, taking into account design principles, to integrate the content into applications, to develop algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as creative, aesthetic, musical, logical, analytical and conceptual thinking are also particularly promoted within this framework.</p> <p><b>Key Qualifications:</b> Aesthetic, design, artistic, and musical fundamentals, design of virtual worlds, selection and confident application of appropriate methods, interdisciplinary knowledge, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Content Creation for Virtual Environments (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<p><b>Part of the Module: Content Creation for Virtual Environments (Exercise Course)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4,00</p>		

**Examination**

**Content Creation for Virtual Environments**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0463: Embodied Characters and Interactive Virtual Worlds Lab</b> <i>Embodied Characters and Interactive Virtual Worlds Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> As part of the practical module, students implement interactive multimedia applications in the areas of 2D/3D/Virtual Reality/Serious Games/Simulations/Robotics. Essential concepts and techniques of embodied characters and virtual worlds include planning, making and integrating 2D/3D graphics, animations, user interfaces, storytelling and audio for virtual environments as well as conceptualizing and implementing user interaction. After successful participation, students will have the knowledge of the mindset and language of application-relevant disciplines. During the internship, they learn to create content by hand and generatively with procedural methods and algorithms, taking into account design and musical principles, to integrate the content into applications, to develop algorithms independently and to implement them technically. Particularly encouraged in this context are also the skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as creative, aesthetic, musical, logical, analytical and conceptual thinking.</p> <p><b>Key Qualifications:</b> Aesthetic, design, artistic and musical fundamentals, design of embodied characters and virtual worlds; skill in confident and convincing presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to make contributions to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Programming experience</li> <li>• INF-0456 Content Creation for Virtual Environments (recommended)</li> <li>• INF-0179 Einführung in die Spieleprogrammierung (optional)</li> <li>• INF-0183 Praktikum Spieleprogrammierung (optional)</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Practical Module Embodied Characters and Interactive Virtual Worlds</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00</p>		
<p><b>Contents:</b> The specific task from the field of "Embodied Characters and Interactive Virtual Worlds" is designed anew each semester.</p>		
<p><b>Literature:</b> Ändert sich jedes Jahr und wird daher in der Veranstaltung bekannt gegeben</p>		

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**Examination**

**Practical Module Embodied Characters and Interactive Virtual Worlds**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0464: Conversational Artificial Intelligence</b> <i>Conversational Artificial Intelligence</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> In the course of this lecture, the student seeks a general understanding of multimodal spoken dialogue systems technology. He acquires some basic knowledge in the field. He understands general problems of speech synthesis, speech recognition, semantic analysis and dialogue modelling. The presentation of current technologies, some selected solutions, applications and products will foster this knowledge. The student understands the interdisciplinary character of multimodal spoken dialogue systems technology. By way of analysing scientific papers, he synthesizes specific aspects of the research field.</p> <p><b>Key Qualifications:</b> Selection and confident application of appropriate methods, interdisciplinary knowledge, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 45 h exercise course (attendance) 45 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Conversational Artificial Intelligence (Lecture)</b>  <b>Mode of Instruction:</b> lecture  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 3,00</p>
<p><b>Literature:</b> wird in der Veranstaltung bekannt gegeben</p>
<p><b>Part of the Module: Conversational Artificial Intelligence (Exercise Course)</b>  <b>Mode of Instruction:</b> exercise course  <b>Language:</b> German  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 3,00</p>

**Examination**

**Conversational Artificial Intelligence**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0465: Machine Learning for Healthcare</b> <i>Machine Learning for Healthcare</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this course, students will have a grasp of the fundamentals of machine learning for healthcare. This course aims to give students a comprehensive insight into the application of machine learning for healthcare, encompassing numerous health data modalities (such as EHR, imaging, speech, mobile, and wearables) to enhance clinical workflows as machine learning methodologies and tools. We will be delving into a broad range of topics, including statistical machine learning, deep learning, transfer learning, fairness, interpretability, privacy-preserving ML, ethics, graphical models, and time series analysis.</p> <p><b>Key Qualifications:</b> Mathematical-formal basics; competence in networking different subject areas; knowledge of practice-relevant tasks; skill in analyzing and structuring computer science problems; skill in developing and implementing solution strategies; quantitative aspects of computer science; skill in logical, analytical and conceptual thinking; methods for developing larger software systems, construction of abstractions and architectures; skill in working in teams; skill in presenting and documenting results in an understandable way.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Machine Learning for Healthcare (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<p><b>Part of the Module: Machine Learning for Healthcare (Exercise)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4,00</p>		
<p><b>Examination</b> <b>Machine Learning for Healthcare</b> portfolio exam, graded <b>Test Frequency:</b> when a course is offered</p>		

<b>Module INF-0466: Biophotonics</b> <i>Biophotonics</i>		5 ECTS/LP
Version 1.3.0 (since WS23/24) Person responsible for module: Prof. Dr. Sebastian Zaunseder		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b></p> <p>After successful participation, students have knowledge and competences with regard to biophotonic methods for diagnostic applications. Students have basic knowledge from the field of photonics and know basic principles of light-tissue interaction. They are familiar with the functional principles of selected biophotonic methods for diagnostics, are able to work with them or with data from them and to interpret results. Students can also contribute to the (further) development of corresponding methods.</p> <p><b>Methodological competencies:</b></p> <p>Students are able to deal independently with the functionality and possible applications of biophotonic processes, to prepare biophotonic measurement data using common script languages such as Python, and to document and interpret the application of methods for data preparation appropriately. Students also have basic competencies in the area of modeling/simulation of biophotonic processes.</p> <p><b>Interdisciplinary Competencies:</b></p> <p>Students are able to apply the acquired knowledge in any area of study that deals with diagnostically relevant data. In addition, the module teaches essential problem-solving skills, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.</p> <p><b>Key skills:</b></p> <p>Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> basic math skills; basic programming skills		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Biophotonics (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture deals with the fundamentals, implementation and application of biophotonic methods. The following contents are covered:

- Fundamentals of photonics
- Basics of light-tissue interaction
- Selected biophotonic methods in medical diagnostics (e.g. optical coherence tomography, laser speckle imaging, pulse oximetry)
- Introduction to possibilities for modeling and simulation in the context of biophotonics

**Literature:**

- Bigio, I. J., & Fantini, S. (2016). Quantitative Biomedical Optics. Cambridge University Press. <https://doi.org/10.1017/CBO9781139029797>
- Keiser, G. (2016). Biophotonics. Springer Singapore. <https://doi.org/10.1007/978-981-10-0945-7>
- Boudoux, C (2017). Fundamentals of Biomedical Optics From light interactions with cells to complex imaging systems. Blurb

**Part of the Module: Biophotonics (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Contents:**

The exercise teaches practical skills in the context of biophotonic methods. The focus is on computational aspects of biophotonic methods and solving concrete problems related to diagnostically applicable biophotonic methods.

The following contents are covered:

- Familiarization with and preparation of biophotonic measurement methods and their application
- Handling of biophotonic measurement data
- Modeling and simulation in the context of biophotonic methods

**Examination**

**Biophotonics**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0476: Computer Vision for Intelligent Systems</b> <i>Computer Vision für Intelligente Systeme</i>		5 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b> Students will understand the following methodological foundations of computer vision for intelligent systems at an in-depth scientific level and will be able to implement appropriate algorithms for advanced problems: Image formation, two-view geometry, deep learning basics for images and point clouds, image motion estimation and optical flow, keypoints and point correspondences, factor graphs and probabilistic state estimation, visual odometry and visual simultaneous localization and mapping, 3D object detection, 3D mapping. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring machine vision problems for intelligent systems and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b> Total: 150 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Advantageous: Basic knowledge in Deep Learning</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. winter semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Computer Vision for Intelligent Systems (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This lecture teaches basic methods and algorithms for computer vision for intelligent systems. The lecture covers the following topics:

- Image formation, geometric primitives and transformations.
- Two-view geometry
- Basics of deep learning for images and point clouds
- Motion estimation in images and optical flow
- Keypoints, descriptors and point correspondences
- Camera motion estimation from images
- Factor graphs and probabilistic state estimation
- Visual simultaneous localization and mapping
- 3D object detection
- 3D mapping

**Literature:**

Lecture slides will be provided. Additional literature will be provided in lecture and exercises.

Recommended textbooks:

- Yi Ma, Stefano Soatto, Jana Kos Košecká, S. Shankar Sastry. An Invitation to 3-D Vision
- R. Szeliski. Computer vision: algorithms and applications
- K. Murphy. Probabilistic Machine Learning: An Introduction. MIT Press, 2022
- C. Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Part of the Module: Computer Vision for Intelligent Systems (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Contact Hours:** 2,00

**Examination**

**Computer Vision for Intelligent Systems**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0499: Foundation Models in Deep Learning</b> <i>Foundation Models in Deep Learning</i>		5 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, participants understand basics and in-depth issues and algorithms of robotics (e.g. recursive state estimation, Gaussian and non-parametric filters, Kalman filters, motion and localisation, perception, mapping, SLAM) from a probabilistic point of view and can apply learned concepts to complex, practice-relevant tasks. Students can analyse and evaluate problems in this context. Participation in this module promotes skills in logical, analytical and conceptual thinking in the field of probabilistic robotics. Students can select suitable methods from the concepts learned in a targeted manner, apply them confidently and transfer them to new problems, including those from other disciplines. The module imparts competencies for recognising current research and significant technological developments in this field.</p> <p><b>Key qualifications:</b> advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.</p>		
<p><b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b> Knowledge in machine learning and machine vision (Master lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")</p>		<p><b>Credit Requirements:</b> Passing the module examination</p>
<p><b>Frequency:</b> each summer semester except summer term 2026</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Probabilistic Robotics (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester except summer term 2026 <b>Contact Hours:</b> 2,00</p>		

**Contents:**

1. Introduction to Probabilistic Robotics
2. Recursive State Estimation
3. Gaussian Filters
4. Nonparametric Filters
5. Robot Motion
6. Robot Perception
7. Mobile Robot Localization: Markow and Gaussian
8. Mobile Robot Localization: Grid and MonteCarlo
9. Occupancy Grid Mapping
10. SLAM

**Literature:**

References will be announced at the beginning of the semester.

**Part of the Module: Probabilistic Robotics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester except summer term 2026

**Contact Hours:** 2,00

**Examination**

**Probabilistic Robotics (Examination)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0504: Medical Monitoring and Advanced Sensor Data Processing</b> <i>Medical Monitoring and Advanced Sensor Data Processing</i>		8 ECTS/LP
Version 1.3.0 (since SoSe24) Person responsible for module: Prof. Dr. Sebastian Zaunseder Aublin, Pierre, Dr.		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b></p> <p>After successful participation, students have knowledge and competences with regard to the field of medical monitoring. Students have basic knowledge on the background of medical monitoring and common technical solutions for clinical and out-of-hospital use. They are familiar with the functional principles of various methods relevant to medical monitoring and their interpretation. Students can also contribute to the (further) development of monitoring applications.</p> <p><b>Methodological competencies:</b></p> <p>Students are able to deal independently with solutions to medical monitoring. In particular, they are able to process medical data using common script languages such as Python, to document their solutions and to interpret processing results appropriately. In addition, Students have basic competencies in the handling of monitoring data and devices for monitoring.</p> <p><b>Interdisciplinary Competencies:</b></p> <p>Students are able to apply the acquired knowledge in any area of study that deals with (medical) data. In addition, the module teaches essential problem-solving skills, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.</p> <p><b>Key skills:</b></p> <p>Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>60 h studying of course content using provided materials (self-study)</p> <p>60 h exercise course (attendance)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>basic math skills; basic programming skills; basic knowledge on handling digital signals</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<p><b>Part of the Module: Medical monitoring and advanced sensor data processing (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>The lecture deals with the fundamentals, implementations and applications of medical monitoring. The following topics, all of them elaborate with respect and in close connection to medical monitoring, are covered:</p> <ul style="list-style-type: none"> <li>• Fundamentals of medical monitoring (basic ideas, history, current solutions, trends)</li> <li>• Fundamentals of sensor data fusion</li> <li>• Preprocessing approaches (e.g. denoising by conventional filters, Kalman filters and autoencoders)</li> <li>• Dimension reduction and source separation (e.g. principal component analysis and independent component analysis)</li> <li>• Feature extraction by functional transforms (e.g. time-frequency transforms)</li> <li>• Basic detection/classification approaches</li> </ul>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• S. Bernhard, A. Brensing, and K.-H. Witte, <i>Biosignalverarbeitung</i>. De Gruyter, 2019. doi: 10.1515/9783110442434.</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Medical Monitoring and Advanced Sensor Data Processing</b> (lecture)  <i>*(in attendance) *</i></p>
<p><b>Part of the Module: Medical Monitoring and Advanced Sensor Data Processing (Exercise)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b></p> <p>The exercise teaches practical skills with relevance to the field of medical monitoring. The focus is handling and processing data from/for monitoring applications. The following contents are covered:</p> <ul style="list-style-type: none"> <li>• Familiarization with techniques of data acquisition and handling data</li> <li>• Denoising of data of variable origin</li> <li>• Application of feature extraction and dimension reduction techniques</li> <li>• Prediction/detection of (patho)physiological states</li> <li>• Techniques for visualization and interpretation of sensor data</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Exercise to Medical Monitoring and Advanced Sensor Data Processing</b> (exercise course)  <i>*(hybrid/mixed) *</i></p>
<p><b>Examination</b></p> <p><b>Medical Monitoring and Advanced Sensor Data Processing</b>  portfolio exam, graded</p> <p><b>Test Frequency:</b>  when a course is offered</p>

<b>Module INF-0506: Search Engines and Neural Information Retrieval</b> <i>Search Engines and Neural Information Retrieval</i>		8 ECTS/LP
Version 1.3.0 (since SoSe24) Person responsible for module: Prof. Dr. Annemarie Friedrich		
<b>Learning Outcomes / Competences:</b> Neural Information Retrieval leverages the power of neural networks to enhance the representation, understanding, and retrieval of information, addressing many of the challenges posed by the complexity and variability of natural language. With the recent development in the area of large language models (or more generally, foundation models), novel approaches to interactive information retrieval are developing.  After taking part in the course, students are able to explain the concepts and methods, procedures, techniques and technologies related to neural information retrieval. In particular, the course covers: <ul style="list-style-type: none"> <li>• Basics of traditional information retrieval methods</li> <li>• Vector-based document and query representations (topic modeling and neural representations)</li> <li>• Ranking with embeddings</li> <li>• Question answering, entity search, and knowledge graphs</li> <li>• Multimodal retrieval</li> <li>• Interactive information retrieval and personalization</li> </ul> Students will be able to recognise important technical developments in the field of information retrieval. They can apply machine learning procedures, such as feature extraction, embedding learning, and pattern recognition, to information retrieval problems. They will be able to perform literature research in the area of information retrieval, and identify gaps in the state-of-the-art. They know how to make scientifically meaningful evaluations of proposed systems. They will further learn how to document and present results and complex ideas in a reasonable and meaningful way. Participants will also deepen their programming skills in Python.  <b>Key skills:</b> Formal methods; Knowledge of advantages and disadvantages of different design alternatives; Ability to work in teams; Knowledge of workflows and processes; Ability to find solutions for practical problems; Ability to work autonomously; Quality awareness; Scientific working; Literature research.		
<b>Workload:</b> Total: 240 h 30 h exercise course (attendance) 60 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: linear algebra, basic probability theory, Python programming.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Search Engines and Neural Information Retrieval (Lecture)</b> <b>Language:</b> English / German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4,00		

**Contents:**

This first part of this interactive course will cover the basics of traditional search engine technology, topic modeling, query expansion, collaborative filtering, neural networks, word and document embeddings, transformers, text classification, ranking and learning to rank, question answering, and evaluation designs. The second part of the course will dive into the recent literature on neural information retrieval including (for example) multi-modal search, interactive retrieval systems, entity search, personalization, and retrieval-augmented generative artificial intelligence. We will also discuss aspects related to responsible information retrieval such as bias and transparency.

The course design is complementary to INF-0277 Analyzing Massive Datasets, which focuses on compute frameworks and algorithms for processing big data.

**Literature:**

- Bhaskar Mitra; Nick Craswell, An Introduction to Neural Information Retrieval, 2018. doi: 10.1561/15000000061.
- Tonello, Nicola. "Lecture Notes on Neural Information Retrieval." *ArXiv* abs/2207.13443 (2022): <https://arxiv.org/abs/2207.13443>
- Dan Jurafsky and James H. Martin. *Speech and Language Processing*. 3rd edition draft available here: <https://web.stanford.edu/~jurafsky/slp3/>
- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, *Introduction to Information Retrieval*, Cambridge University Press. 2008. <https://nlp.stanford.edu/IR-book/information-retrieval-book.html>

**Part of the Module: Search Engines and Neural Information Retrieval (Exercise)**

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination****Search Engines and Neural Information Retrieval**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0508: Probabilistic Machine Learning</b> <i>Probabilistic Machine Learning</i>		8 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students will understand the following methodological foundations of probabilistic machine learning at an in-depth scientific level and will be able to implement appropriate algorithms for advanced problems: Univariate and multivariate distributions, probabilistic graphical models, maximum likelihood and a-posteriori estimation, Bayesian inference and learning, information theory, expectation maximization, linear and logistic regression, probabilistic deep neural networks, Gaussian and Neural processes, probabilistic dimensionality reduction, deep generative models, and probabilistic state-space models. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring probabilistic machine learning problems and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant scientific and technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Basic knowledge of probability theory</li> <li>• Recommended: Basic knowledge in deep learning</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Probabilistic Machine Learning (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

This lecture teaches basic methods and algorithms for probabilistic machine learning. The lecture includes the following topics:

1. Univariate and multivariate distributions
2. Probabilistic graphical models
3. Maximum likelihood and a-posteriori estimation
4. Bayesian statistics and posterior predictive distribution
5. Bias-Variance tradeoff
6. Information theory
7. Linear and logistic regression
8. Variational inference
9. Expectation maximization and Gaussian mixture models
10. Probabilistic deep neural networks (deep ensembles, variational Bayesian neural networks, Laplace approximation)
11. Probabilistic dimensionality reduction (principal component analysis, variational autoencoders)
12. Deep generative models (probabilistic diffusion models)
13. Gaussian and Neural processes
14. Probabilistic state-space models

**Literature:**

Lecture slides will be provided. Additional references to literature will be provided in lecture and exercises.

Recommended textbooks:

- C. Bishop. Pattern Recognition and Machine Learning. Springer, 2006
- K. Murphy. Machine Learning: A Probabilistic Perspective. MIT Press, 2012
- K. Murphy. Probabilistic Machine Learning: An Introduction. MIT Press, 2022
- K. Murphy. Probabilistic Machine Learning: Advanced Topics. MIT Press, 2023
- C. Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Assigned Courses:**

**Probabilistic Machine Learning / Machine Learning** (lecture)

*\*(in attendance) \**

**Part of the Module: Probabilistic Machine Learning (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercises for Probabilistic Machine Learning / Machine Learning** (exercise course)

*\*(in attendance) \**

**Examination**

**Probabilistic Machine Learning**

written exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0509: Embodied Artificial Intelligence</b> <i>Embodied Artificial Intelligence</i>		8 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b> Students will understand fundamental and contemporary methods of embodied artificial intelligence (robot learning, reinforcement learning, visual scene perception, foundation models for robotics) at a scientific level and will gain practical experience by implementing appropriate algorithms for advanced problems in team projects. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring problems in embodied artificial intelligence and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant scientific and technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Basic knowledge in Deep Learning</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Embodied Artificial Intelligence (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00</p>		

**Contents:**

Embodied artificial intelligence is about intelligent robots which learn to solve tasks that require perception and interaction with the environment through the agent's embodiment (sensors and actuators). More specifically, the course will cover state-of-the-art methods for robot learning and perception.

The course consists of a lecture part, which teaches theoretical basics and contemporary methods in embodied artificial intelligence, and an exercise part, which deepens the contents of the lecture in the exercises in practical team projects. The course includes the following topics:

1. Introduction
2. Robot kinematics
3. Deep learning basics
4. Transformer and diffusion models
5. Model-free reinforcement learning
6. Model-based reinforcement learning
7. Imitation learning
8. Vision-language-action models
9. Object perception
10. Localization and mapping

**Literature:**

Lecture slides will be provided. Additional references to literature will be provided in the lecture.

Recommended textbooks:

- Sutton and Barto. Reinforcement Learning. Second Edition. MIT Press 2018
- Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Assigned Courses:**

**Embodied Artificial Intelligence** (lecture)

*\*(in attendance) \**

**Part of the Module: Embodied Artificial Intelligence (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 4,00

**Assigned Courses:**

**Exercises for Embodied Artificial Intelligence** (exercise course)

*\*(in attendance) \**

**Examination**

**Embodied Artificial Intelligence**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3013: Generative Artificial Intelligence for Human-Computer Interaction Lab</b> <i>Generative Artificial Intelligence for Human-Computer Interaction Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<b>Learning Outcomes / Competences:</b> Students will be familiar with methods and techniques of Generative AI for developing interactive systems. After successful participation, they will have the necessary knowledge to develop and evaluate generative models that can be used in various HCI application scenarios. They will be able to translate current artificial intelligence and machine learning methods into models and programs for novel interactive applications and independently work with the necessary technologies. Furthermore, they can apply practical evaluation methods to assess the quality of the created generative models. They will be capable of planning larger project tasks in small teams, solving them according to a self-developed project plan, and appropriately discussing and presenting the results as a team in the plenary.  <b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.		
<b>Workload:</b> Total: 240 h 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Generative AI for Human-Computer Interaction Lab (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		
<b>Contents:</b> The specific tasks for student projects are redesigned each year.		
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.		

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**Part of the Module: Generative AI for Human-Computer Interaction Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination**

**Generative Artificial Intelligence for Human-Computer Interaction Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3015: Interactive Machine Learning Lab</b> <i>Interactive Machine Learning Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students are familiar with basic concepts of interactive machine learning. They are able to translate domain-specific solution concepts into models and master the selection and safe application of suitable methods. In addition, they will gain an insight into current work in the research area. Furthermore, competencies in the areas of teamwork and communication skills as well as self-organization are taught through the processing of project tasks and their independent project planning. In the context of these project tasks, knowledge of the mindset and language of the research field is fostered through the discussion and presentation of project results.</p> <p><b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b> Cannot be taken if "INF-0296: Praktikum Interactive Machine Learning" has already been taken. Cannot be taken at the same time as "Interactive Machine Learning for Healthcare Lab".</p>		
<p><b>Workload:</b> Total: 240 h 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Interactive Machine Learning Lab (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> The specific tasks for student projects are redesigned each year.</p>
<p><b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.</p>

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**Part of the Module: Interactive Machine Learning Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Interactive Machine Learning Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3017: Interactive Machine Learning for Healthcare Lab</b> <i>Interactive Machine Learning for Healthcare Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>In contrast to the "Interactive Machine Learning Lab" event, the focus is on applications in the healthcare sector. After successful participation in this module, students are familiar with basic concepts of interactive machine learning. They are able to translate domain-specific solution concepts into models and master the selection and safe application of suitable methods. In addition, they will gain an insight into current work in the research area. Furthermore, competencies in the areas of teamwork and communication skills as well as self-organization are taught through the processing of project tasks and their independent project planning. In the context of these project tasks, knowledge of the mindset and language of the research field is fostered through the discussion and presentation of project results.</p> <p><b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b></p> <p>Cannot be taken if "INF-0296: Praktikum Interactive Machine Learning" has already been taken.</p> <p>Cannot be taken at the same time as "Interactive Machine Learning Lab".</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>Programming experience</p>		<p><b>Credit Requirements:</b></p> <p>Bestehen der Modulprüfung</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Interactive Machine Learning for Healthcare Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>The specific tasks for student projects are redesigned each year.</p>		
<p><b>Literature:</b></p> <p>Literature references will be announced at the beginning of the semester depending on the topic.</p>		

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**Part of the Module: Interactive Machine Learning for Healthcare Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Interactive Machine Learning for Healthcare Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3035: Autonomous and Self-Learning Systems</b> <i>Autonomous and Self-learning Systems</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Jörg Hähner		
<b>Contents:</b> Es werden Grundlagen des Reinforcement Learnings vermittelt und in zentrale Methoden wie Temporal Difference Learning eingeführt. Aufbauend darauf werden Ansätze aus dem Deep Reinforcement Learning behandelt. Es folgen policy-basierte Verfahren wie Actor-Critic-Methoden sowie weiterführende Themen wie Multi-Objective Reinforcement Learning zur Optimierung mehrerer Ziele und Multi-Agent Reinforcement Learning zur Modellierung von Interaktionen zwischen mehreren Agenten.		
<b>Learning Outcomes / Competences:</b> Nach erfolgreicher Teilnahme an diesem Modul verfügen die Studierenden über ein fundiertes Verständnis der grundlegenden und fortgeschrittenen Konzepte des Reinforcement Learnings, einschließlich Deep Reinforcement Learning, Multi-Agenten Reinforcement Learning und Multi-Objective Reinforcement Learning. Sie sind in der Lage, komplexe Problemstellungen in mathematische und algorithmische Modelle zu übersetzen, geeignete Methoden auszuwählen und diese sicher anzuwenden. Die Studierenden beherrschen die Implementierung, Simulation und Evaluierung moderner RL-Algorithmen und können diese auf realitätsnahe Szenarien anwenden. Sie erlernen, komplexe Modelle wissenschaftlich zu bewerten, zu dokumentieren und die Ergebnisse klar zu kommunizieren. Die Veranstaltung fördert insbesondere das logische und analytische Denken, die Fähigkeit zur Zusammenarbeit sowie die kreative Problemlösung. Ergänzend erwerben die Studierenden Kompetenzen im Umgang mit aktuellen Forschungsergebnissen und praktischen Tools zur Umsetzung von RL-Methoden.		
<b>Remarks:</b> Wenn <i>INF-0291: Praktikum Selbstlernende Systeme</i> bereits absolviert wurde, ist eine Belegung des Moduls nicht möglich.		
<b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)		
<b>Conditions:</b> Programmiererfahrung, Teamfähigkeit		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Autonomous and Self-learning Systems (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Die Vorlesung vermittelt die Grundlagen des Reinforcement Learnings und führt in zentrale Methoden wie Temporal Difference Learning ein. Aufbauend darauf werden Ansätze aus dem Deep Reinforcement Learning behandelt. Es folgen policy-basierte Verfahren wie Actor-Critic-Methoden sowie weiterführende Themen wie Multi-Objective Reinforcement Learning zur Optimierung mehrerer Ziele und Multi-Agent Reinforcement Learning zur Modellierung von Interaktionen zwischen mehreren Agenten.

**Literature:**

- Skript
- Sutton, Richard S. "Reinforcement learning: An introduction." A Bradford Book (2018).
- Hayes, Conor F., et al. "A practical guide to multi-objective reinforcement learning and planning." Autonomous Agents and Multi-Agent Systems 36.1 (2022): 26.
- Albrecht, Stefano V., et al. "Multi-agent reinforcement learning: Foundations and modern approaches." MIT Press, 2024.

**Assigned Courses:**

**Autonomous and Self-learning Systems** (lecture)

*\*(in attendance) \**

**Part of the Module: Autonomous and Self-learning Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Autonomous and Self-learning Systems** (exercise course)

*\*(in attendance) \**

**Examination**

**Autonomous and Self-learning Systems**

portfolio exam / length of examination: 30 minutes, graded

**Test Frequency:**

only in the summer semester

**Description:**

Die Prüfung kann jedes Sommersemester abgelegt werden.

<b>Module INF-3039: Human-Robot Interaction</b> <i>Human-Robot Interaction</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>In this course, the students will learn the core concepts regarding the field of human-robot interaction as well as the latest developments drawing examples from recent literature. After successful participation in this course, the students will gain the skills to design, and evaluate solutions to real-world Human-Robot Interaction (HRI) challenges across diverse scenarios. Within the framework of this lecture, the students will learn where does HRI fit into the increasingly technological world of HCI, the history of social robotics, physical versus social HRI, various dimensions of interactions such as proxemics, verbal, and non-verbal interaction modes and how these modalities interplay. They will further learn about the autonomy spectrum and the various technical methods for perception and generation of human and robot behaviors in HRI. They will also acquire the knowledge about design principles of effective HRI and how a complete HRI design cycle looks like. The students will apply these concepts in real world problems situated in, for example, educational, healthcare, in-home, public, entertainment scenarios through case studies and exercises.</p> <p><b>Schlüsselqualifikationen:</b> Technical foundation with basics of cognitive systems/AI/ML; interdisciplinary awareness on computer science, multimodal human behavior analysis, psychology, ethics and society, design thinking; practical skills such as analytical thinking and ability to both work independently and in teams; attitudes such as curiosity to create impactful and creative HCI solutions; interest in communicating research ideas and latest technological developments; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Human-Robot Interaction (Lecture)</b></p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Social and physical HRI
- Dimensions of interaction (spacial, verbal, non-verbal)
- Autonomy in interaction
- Technical methods for perception and generation
- Cognitive models of HRI such as mental models, engagement, trust, transparency
- Design principles for effective HRI
- Evaluation in HRI
- HRI design cycle
- Prevalent software and hardware

**Literature:**

- Bartneck, Christoph, Tony Belpaeme, Friederike Eysel, Takayuki Kanda, Merel Keijsers, and Selma Šabanovi#. Human-robot interaction: An introduction. Cambridge University Press, 2020
- Thomaz, Andrea, Guy Hoffman, and Maya Cakmak. "Computational human-robot interaction." Foundations and Trends in Robotics 4, no. 2-3 (2016): 105-223.
- Cynthia Brezeal: Social robots: beyond tools to partners

**Part of the Module: Human-Robot Interaction (Exercise Course)**

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Examination**

**Human-Robot Interaction**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3041: Digital Forensics</b> <i>Digital Forensics</i>	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Frank Breitingger Dr. Janine Schneider	
<b>Contents:</b> The lecture is aimed at computer science students and teaches both theoretical knowledge and practical methods for conducting digital investigations efficiently and systematically. In order to participate in the exercise, students are required to have a laptop with sufficient free storage space (min. ~30 GB) and internet. A tablet or smartphone is not sufficient. If no laptop is available, the exercise must be completed independently on a suitable computer outside the exercise sessions.	
<b>Learning Outcomes / Competences:</b> Objectives: <ol style="list-style-type: none"> <li>1. Remembering <ul style="list-style-type: none"> <li>- Define what digital forensics is and what types exist.</li> <li>- Describe which digital traces may arise in different systems.</li> <li>- Reproduce the legal framework (e.g. §202a-d StGB).</li> </ul> </li> <li>2. Understanding <ul style="list-style-type: none"> <li>- Explain why digital forensics is important for law enforcement and IT security.</li> <li>- Illustrate how HDDs, SSDs, USB sticks and cloud storage differ technologically.</li> <li>- Summarize how the forensic process works and what documentation is required.</li> </ul> </li> <li>3. Applying <ul style="list-style-type: none"> <li>- Perform a forensic data acquisition (e.g. imaging of a drive).</li> <li>- Identify relevant digital traces in a given scenario.</li> <li>- Apply forensic tools to analyze data carriers.</li> </ul> </li> <li>4. Analyzing <ul style="list-style-type: none"> <li>- Distinguish between different types of digital traces and their relevance to an investigation.</li> <li>- Evaluate the significance of timestamps in a file system.</li> <li>- Break down an investigation into individual forensic questions.</li> </ul> </li> <li>5. Evaluating <ul style="list-style-type: none"> <li>- Critically assess which investigation methods are appropriate in a particular case.</li> <li>- Assess the forensic probative value of certain data sources.</li> <li>- Discuss the challenges of current and future forensic methods.</li> </ul> </li> <li>6. Creating <ul style="list-style-type: none"> <li>- Formulate a forensic report for a fictitious case.</li> </ul> </li> </ol>	
<b>Remarks:</b> The lecture and exercise will be given in EN. In case all participants are German speaking, this may change.	
<b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)	
<b>Conditions:</b> none	<b>Credit Requirements:</b> Passing the Module Exam

<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>		
<b>Part of the Module: Digital Forensics (Lecture)</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Frequency:</b> each summer semester		
<b>Contact Hours:</b> 2,00		
<b>Contents:</b>		
<p>Digital forensics deals with the identification, securing and analysis of digital evidence for use in legal proceedings. The starting point in each case is the suspicion of a computer crime or an offense that has been committed with the help of digital devices. The lecture provides a sound introduction to the basic concepts, methods and legal framework of digital forensics.</p> <p>After a brief introduction to forensics and its importance, the focus will be on technical aspects: What types of digital traces are there, how are they created and how can they be classified? Which storage media and file systems are relevant and how can data be forensically secured?</p> <p>A central component of the lecture is the technical analysis of digital evidence. In addition to methods for analyzing file systems, timestamps and other metadata are also considered in detail.</p> <p>Furthermore, the legal framework relevant to digital forensics is considered. The role of the expert witness is also explained, particularly with regard to court-proof documentation and communication of forensic findings.</p>		
<b>Assigned Courses:</b>		
<b>Digital Forensics</b> (lecture) <i>*(in attendance) *</i>		
<b>Part of the Module: Digital Forensics (Exercise)</b>		
<b>Mode of Instruction:</b> exercise course		
<b>Language:</b> English / German		
<b>Frequency:</b> each summer semester		
<b>Contact Hours:</b> 4,00		
<b>Contents:</b>		
<p>In the exercise, the topics of the lecture are practiced in the context of case studies</p>		
<b>Assigned Courses:</b>		
<b>Digital Forensics (Exercise)</b> (exercise course) <i>*(in attendance) *</i>		
<b>Examination</b>		
<b>Digital Forensics</b>		
written exam / length of examination: 90 minutes, graded		
<b>Test Frequency:</b>		
when a course is offered		

<b>Module INF-3049: Trustworthy Artificial Intelligence</b> <i>Trustworthy Artificial Intelligence</i>		5 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Bernhard Bauer Dr. Fabian Stieler		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students acquire knowledge of central concepts and principles of trustworthy AI, including ethical, legal and social framework conditions as well as technical requirements. They will understand how trustworthy AI systems can be designed, evaluated and documented and will be able to apply these theoretical principles to practical issues.</p> <p>The course presents methods and approaches that can ensure transparency, explainability, fairness, security, robustness and data protection in AI systems. These include, for example, methods of interpretable machine learning. Students learn to identify typical challenges such as bias, security risks and data protection issues and to develop suitable solutions. This also includes cybersecurity in the context of AI systems, whereby students become familiar with specific attack scenarios and develop suitable protection mechanisms conceptually.</p> <p>In addition, students gain in-depth insights into software engineering for AI systems. Key concepts such as machine learning operations (MLOps), AI lifecycle management and principles such as reproducibility, automation and scalability are taught. Other focal points include aspects of operating AI systems in production environments, including infrastructure, monitoring and concept drift.</p> <p>Furthermore, students are taught organizational and technical measures to ensure accountability, traceability and governance. They learn about relevant standards and procedures in the areas of auditing, certification and risk management of AI systems as well as approaches to the sustainable and responsible development of AI systems.</p> <p>Key qualifications: Understanding of interdisciplinary relationships between technology, ethics and law; teamwork and communication skills; independent acquisition of knowledge; quality awareness; ability to document AI systems in a comprehensible manner; sensitization to practical professional requirements.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p>		
<b>Conditions:</b> Basic knowledge of machine learning is an advantage.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Trustworthy Artificial Intelligence (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The course teaches the basics of trustworthy AI systems, including ethical and legal frameworks, as well as technical concepts for implementing transparency, fairness and interpretability in AI systems, MLOps practices, cybersecurity in the context of AI systems, and governance, accountability and sustainability.

**Literature:**

- Slides
- Further literature in the lecture on specific topics

**Part of the Module: Trustworthy AI Engineering (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Trustworthy Artificial Intelligence**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3051: Network and System Security</b> <i>Network and System Security</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Frank Breitingger		
<b>Learning Outcomes / Competences:</b> A course focusing on forensics on Linux, applications, and networks as well as current trends utilization instructions, demonstrations, and lab exercises. After this course, students will <ul style="list-style-type: none"> <li>• <b>Explain</b> key network and application protocols and how they influence system and network security.</li> <li>• <b>Differentiate</b> between encryption, anonymization, and their implications for secure communications and monitoring.</li> <li>• <b>Collect and interpret</b> host-based and network-based traces to support threat detection and security assessments.</li> <li>• <b>Configure</b> tools like the ELK Stack to visualize security data and detect suspicious activity in real time.</li> <li>• <b>Evaluate</b> network and system behaviors to identify intrusions, including advanced techniques like data exfiltration and tunneling.</li> </ul>		
<b>Remarks:</b> The lecture and exercise will be given in EN. In case all participants are German speaking, this may change.		
<b>Workload:</b> Total: 240 h 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Understanding of Networkin (IPs, subnets) as well as basic protocols (DNS, HTTP)</li> <li>• Basic understanding in Linux and the terminal</li> </ul>		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b> <b>Part of the Module: Network and System Security (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00
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**Contents:**

This course provides an in-depth study of modern network and system security concepts, focusing on the detection, analysis, and mitigation of threats across host and network environments. Students will explore core protocols and their interactions, examine the security challenges in contemporary systems, and gain hands-on experience with tools and techniques used in real-world security operations.

Topics include network and application-layer protocols, encryption and anonymization techniques, intrusion detection, data exfiltration, and tunneling. The course emphasizes both theoretical understanding and practical skills through demonstrations and labs, including the use of the ELK Stack (Elasticsearch, Logstash, Kibana) for visualizing and analyzing security events.

Students will develop the ability to assess system behavior, collect and interpret trace data, and respond effectively to security incidents. The course prepares students for roles in security operations, incident response, and infrastructure defense.

**Part of the Module: Network and System Security (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Contents:**

In the exercise, the topics of the lecture are practiced in the context of case studies

**Examination**

**Network and System Security**

portfolio exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3053: Evolutionary Computation</b> <i>Evolutionary Computation</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successfully completing this module, students will have a sound understanding of basic and advanced concepts in the field of Evolutionary Computation. In particular, they will be familiar with common techniques and how these can be applied to a variety of black-box optimisation problems. Students have learnt to apply this basic knowledge in several specific use cases, especially in the field of Evolutionary Machine Learning.</p> <p>They are able to identify and formulate optimisation problems and solve them without mathematical approaches by applying the most suitable techniques. In addition, students will be able to design experiments to evaluate various techniques and analyse them in a comprehensible manner.</p> <p>Students have in-depth knowledge of the application of these techniques to generate explainable Machine Learning models and are aware of the importance of transparent AI models.</p> <p>In addition to the theoretical aspects, students are able to put various Evolutionary Computation techniques into practice by implementing, evaluating and presenting them. They learn how to present experimental results in a stakeholder-specific (e.g. scientific) way and how to analyse, evaluate and present them statistically.</p> <p>In addition, students acquire skills in dealing with current research results and practical tools from the field of Evolutionary Computation.</p> <p>In particular, the course promotes logical and analytical thinking, the ability to work together and creative problem solving.</p>		
<p><b>Remarks:</b></p> <p>Lecture and exercise course in English</p> <p>Lecture slides in English</p> <p>Exams can be taken in either German or English</p> <p>Questions can be asked in either German or English</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <p>none</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Evolutionary Computation (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

In this course, students learn about the various areas of the field of Evolutionary Computation. These are divided on the one hand into the multitude of different optimisation algorithms (ES, GA, PSO, ACO, NSGA-II, ...), whereby various basic concepts of optimisation (e.g. single- vs multi-objective) are also introduced, and on the other hand into downstream/advanced techniques, such as: Genetic Programming, Learning Classifier Systems and Neuroevolution (in particular Neural Architecture Search) from the field of Evolutionary Machine Learning; automated algorithm design and hyperheuristics; benchmarking; and behaviour and landscape analysis.

**Literature:**

- Skript
- Patrick Siarry. 2017. Metaheuristics. Springer Cham. <https://doi.org/10.1007/978-3-319-45403-0>
- Sean Luke. 2013. Essentials of Metaheuristics. Lulu. ISBN: 978-1-300-54962-8. Available at <http://cs.gmu.edu/~sean/book/metaheuristics/>
- William B. Langdon, Riccardo Poli. 2002. Foundations of Genetic Programming. Springer Berlin, Heidelberg. <https://doi.org/10.1007/978-3-662-04726-2>
- Ryan J. Urbanowicz, Will N. Browne. 2017. Introduction to Learning Classifier Systems. Springer Berlin, Heidelberg. <https://doi.org/10.1007/978-3-662-55007-6>

**Part of the Module: Evolutionary Computation (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination****Evolutionary Computation**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3065: Machine Learning for Time Series</b> <i>Machine Learning for Time Series</i>		8 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successful participation in this course, students will have a thorough understanding of time series analysis, bridging classical statistical methods and modern machine learning. This course provides a comprehensive foundation in modelling temporal data, covering autoregression and dependence structures, preprocessing and feature engineering, spectral methods, state space models, latent space representations, and probabilistic forecasting. Students will learn how fundamental concepts from classical statistics underpin modern neural architectures such as RNNs, LSTMs, Transformers, and Variational Autoencoders, and will gain hands-on experience implementing and evaluating these methods on real-world datasets.</p> <p><b>Key Qualifications:</b> Mathematical-formal foundations in probability and statistical modelling; competence in connecting classical statistical theory with modern machine learning paradigms; knowledge of practice-relevant forecasting tasks; analytical and conceptual thinking for selecting appropriate modelling approaches for temporal data; practical experience developing and implementing time series models in Python/PyTorch and evaluating probabilistic forecasts using proper scoring rules; ability to critically assess model assumptions and justify architectural choices based on data properties; competence in designing end-to-end time series modelling pipelines and constructing probabilistic forecasting systems that account for uncertainty.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>60 h lecture (attendance)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <p>Basic familiarity with machine learning concepts and Python programming is beneficial.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Machine Learning for Time Series (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b></p> <p>Time series data is everywhere, from energy consumption and climate measurements to financial markets, medical signals, and speech. The ability to model and forecast temporal data is a highly relevant skill in modern machine learning, underpinning applications across science, industry, and policy. This course bridges the gap between classical statistical foundations and modern neural architectures, equipping students with the theoretical and practical tools to tackle the unique challenges that temporal data presents.</p>

**Literature:**

Bibliography will be given in the lecture

**Part of the Module: Machine Learning for Time Series (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Machine Learning for Time Series (Tutorial)** (exercise course)

*\*(in attendance) \**

**Examination**

**Machine Learning for Time Series**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3067: Deep Learning for Weather Forecasting</b> <i>Deep Learning for Weather Forecasting</i>		5 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of this course, students are able to independently analyse and evaluate the design choices underlying modern deep learning architectures for weather forecasting. They can explain how different architectural paradigms, including attention mechanisms, neural operators, and score-based generative models, are motivated by the structure of atmospheric data and the requirements of operational forecasting. They are able to critically compare models in terms of their assumptions, inductive biases, computational trade-offs, and forecast quality, and to implement and evaluate a deep learning approach for a weather forecasting task. They furthermore understand the relationship between data-driven and physics-based modelling and can assess the promises and limitations of current weather foundation models.</p> <p><b>Key Qualifications:</b> Systematic understanding of modern deep learning architectures and their application to spatiotemporal prediction problems; knowledge of the landscape of operational weather forecasting and the role of data-driven methods; competence in connecting architectural design choices with the physical structure of the atmosphere; practical experience implementing and evaluating deep learning models for weather prediction in Python/PyTorch; ability to critically assess model assumptions, inductive biases, and evaluation protocols; analytical thinking for situating individual contributions within a rapidly evolving research field.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h            30 h lecture (attendance)            60 h studying of course content through exercises / case studies (self-study)            15 h studying of course content using literature (self-study)            15 h studying of course content using provided materials (self-study)            30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>Students should have a solid foundation in deep learning and some practical experience with PyTorch is beneficial. No prior knowledge of numerical weather prediction or atmospheric science needed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>4,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Deep Learning for Weather Forecasting (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> English  <b>Frequency:</b> irregular  <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This course provides an advanced treatment of modern deep learning architectures for numerical weather prediction, tracing the rapid shift from classical physics-based models towards data-driven and hybrid approaches. Starting from the foundations of atmospheric modelling and the structure of weather data, students progressively engage with the family of architectures that have come to define the current state of the art, including transformer-based models, graph neural networks, neural operators, diffusion models, and hybrid physics-ML systems. The course places particular emphasis on global medium-range forecasting and situates each model within the broader landscape of operational weather prediction.

**Literature:**

Bibliography will be given in the lecture

**Assigned Courses:**

**Deep Learning for Weather Forecasting (Lecture)** (lecture)

*\*(in attendance) \**

**Part of the Module: Deep Learning for Weather Forecasting (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular

**Contact Hours:** 2,00

**Assigned Courses:**

**Deep Learning for Weather Forecasting (Tutorial)** (exercise course)

*\*(in attendance) \**

**Examination**

**Deep Learning for Weather Forecasting**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3835: ConceptHack "Development of Methods for Medical Data Analysis"</b> <i>ConceptHack "Development of Methods for Medical Data Analysis"</i>		5 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Sebastian Zaunseder Sahl, Fabienne		
<b>Contents:</b> The module ConceptHack "Development of Methods for Medical Data Analysis" combines conceptual knowledge and practical skills doing actual development. The module provides an introduction to the legal and regulatory framework for the development of medical software and introduces tools, which help to comply with the existing rules. It further covers the application of acquired knowledge as well as the development of practical skills within a hackathon dedicated to a current problem from the field of medical diagnostics.		
<b>Learning Outcomes / Competences:</b>		
<b>Subject-related competences:</b> After successful participation, students possess knowledge and practical competences regarding the development of software and algorithms to process medical images and signals. Students have basic knowledge on the development process and have experience using respective tools, e.g. for documentation and testing. They are familiar with the functional principles of selected methods to process images or signals and their evaluation.		
<b>Methodological competencies:</b> Students are able to deal independently with methods to handle medical data for diagnostics or prognostics. In particular, they are able to process medical data using common script languages such as Python, to document own solutions and to describe as well as interpret processing results appropriately.		
<b>Interdisciplinary Competencies:</b> Students are able to apply the acquired knowledge in any area of study that deals with (medical) data processing. In addition, the module teaches essential problem-solving skills in an interdisciplinary area, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.		
<b>Key skills:</b> Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.		
<b>Workload:</b> Total: 150 h 30 h lecture (attendance) 30 h exercise course (attendance) 60 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> basic mathematic knowledge; basic programming skills; basic knowledge/ experience in data processing		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<p><b>Parts of the Module</b></p>
<p><b>Part of the Module: ConceptHack “Development of Methods for Medical Data Analysis” (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>The lecture covers fundamental concepts regarding the development and documentation of medical software and algorithms. It further introduces the domain-specific background of a focus topic, which is chosen on a yearly basis. Both aspects are essential for the exercise that covers a practical data processing task (image and/or signal processing) related to the focus topic. The exercise is accomplished as a hackathon (i.e. as block course) in the lecture-free period (details see below).</p> <p>The part on the development and documentation of medical software and algorithms covers overviews on</p> <ul style="list-style-type: none"> <li>• Medical devices and software</li> <li>• Regulatory aspects in the development of medical software and algorithms</li> <li>• Basics on project management in the development of medical software</li> <li>• Relevant methods and tools to be used within the development of medical software (e.g. version control and unit testing)</li> </ul> <p>The lectures on the domain specific background convey the medical and algorithmic knowledge to successfully work on a practical data processing task related to the focus topic. Focus topics have a close relation to diagnostics or prognostics and address current challenges related to processing medical images and/or signals. They vary per year and are defined together with medical and/or industrial partners. Examples are, e.g., processing biophotonic data as video data, hyperspectral or photoplethysmographic data to assess tissue and hemodynamics, prediction of sleep phases from multimodal data and processing heavily distorted data from recorded by wearables.</p>
<p><b>Part of the Module: ConceptHack “Development of Methods for Medical Data Analysis” (Exercise)</b></p> <p><b>Mode of Instruction:</b> exercise course</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>Throughout the semester, students will attend lectures designed to convey general knowledge on the development of medical software and algorithms and to prepare them for the exercise. The exercise covers the application of gained knowledge by solving an individually assigned data processing task (medical images and/or signals) related to a focus topic from the field of diagnostic sensing (see above for more details).</p> <p>The exercise will be held as a week-long hackathon in the lecture-free period. If participant numbers permit (and according to participants’ interests), the hackathon will be held in Sion, located in the Swiss Alps. In this case, a fee will be charged to cover travel, food, and accommodation expenses. The total cost remains within a reasonable range (approximately 100 Euro for the entire week).</p> <p>The hackathon itself covers</p> <ul style="list-style-type: none"> <li>• the presentation of the individual tasks by the participants themselves including the presentation of their working plan</li> <li>• working on the own task and its documentation</li> <li>• a final presentation on the own task (within the hackathon or immediately after it)</li> </ul>

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**Examination**

**ConceptHack “Development of Methods for Medical Data Analysis”**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<p><b>Module ZCS-2000: Soft Skills</b> Softskills</p>	<p>2 ECTS/LP</p>
<p>Version 1.0.0 (since SoSe16) Person responsible for module: Claudia Lange-Hetmann</p>	
<p><b>Contents:</b> Die Studierenden erwerben in den Softskill-Kursen, die diesem Modul zugeordnet sind je nach Kurswahl entweder kommunikative, soziale oder methodische Fähigkeiten, die unerlässlich für ihre künftige Berufsfähigkeit sind. Daher wird bei der Auswahl empfohlen, einen Kurs aus einem der drei Kompetenzgebiete zu wählen, die zur Stärkung der eigenen Persönlichkeit sinnvoll und wichtig sind. Zudem bildet die interdisziplinäre Zusammensetzung der Teilnehmer aus unterschiedlichen Fachrichtungen den typischen Wirkungskreis im späteren Arbeitsumfeld ab. Detailbeschreibungen zu Kursen und Anmeldeverfahren befinden sich auf <a href="https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK">https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK</a> bzw. im digicampus.</p>	
<p><b>Learning Outcomes / Competences:</b> Die Studierenden werden - abhängig von der Kursthemenwahl - - neben dem Erwerb der Fertigkeit der verständlichen, sicheren und überzeugenden Darbietung von Ideen, Konzepten und Ergebnissen bzw. dem Verständnis der psychologischen Grundlagen von Dialogen und Verhandlungen dieses Wissen anwenden können, um Interesse, Verständlichkeit und Sympathie zu erzeugen und zielorientiert zu präsentieren bzw. zu argumentieren. - die Kommunikations-, Dialog- und Teamprozesse in Bezug auf Motivation, Effektivität und kennen die Entstehung, Dynamik, Lösung und Prävention von Konflikten verstehen und können Moderationstechniken und ihre Fertigkeit zur Selbstreflexion anwenden, sie beherrschen die Regeln bei der Teamarbeit, bei Besprechungen bis hin zur Führung von Teams oder kennen den Nutzen von gesellschaftlichem Engagement für sich und die Gesellschaft. - grundlegende Konzepte des Projektmanagements (u.a. Entwurf von strategischen Projektstrukturplänen, Analyse der Projektumwelt/-risiken, Projektcontrolling) verstehen und können die Grundlagen der Motivationspsychologie und zentrale Führungstechniken zur Erreichung des Projekterfolgs anwenden. Oder sie können grundlegende Strategien und Methoden für die Entwicklung und Absicherung einer Unternehmensführung anwenden, sie kennen Marketing- u. Vertriebsstrategien, bewerten deren Erfolgsaussichten und haben Kenntnisse in Personal- und Finanzmanagement. Sie verstehen Probleme zu analysieren und können konstruktiv im Team eine Lösung erarbeiten und kommunizieren oder vertiefen Teilaspekte wie u.a. Kreativität, Innovationsfähigkeit mit innovativen Methoden. Besonderer Wert wird - je nach Kurs - auf die Weiterentwicklung der eigenen Präsentations- und Kommunikationsfähigkeit, der Teamkompetenz sowie die Anwendung des Methodenwissens und die Erreichung realistischer Ziele gelegt. Die interdisziplinäre Herangehensweise an eine Problemstellung wird durch die interdisziplinäre Zusammensetzung der Kleingruppen in den Kursen trainiert, durch praktische Übungen in den Kursen gefestigt und durch Selbstreflexion und Feedbackmethoden verinnerlicht, und diese in einen neuen Kontext zu transferieren.</p>	
<p><b>Remarks:</b> <u>Anmeldungspflicht:</u> Für die Teilnahme an den Kursen ist eine Anmeldung über digicampus erforderlich. <u>Anmeldephase:</u> Jan (für das folgende SS) bzw. Juli (für das folgende WS). Die Kurse finden größtenteils ab März bis letzten Sa* im April (SS) bzw. ab Sep. bis letzten Sa* im Okt. *vor Vorlesungsbeginn statt sowie einige in der Vorlesungszeit (Fr/Sa). Die Kurse haben eine limitierte Teilnehmerzahl pro Semester.</p>	
<p><b>Workload:</b> Total: 60 h 20 h seminar (attendance) 10 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 10 h studying of course content using provided materials (self-study)</p>	

<b>Conditions:</b> none		<b>Credit Requirements:</b> aktive Übungsteilnahme im Kurs
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<p><b>Part of the Module: Softskills</b></p> <p><b>Mode of Instruction:</b> course</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each semester</p> <p><b>Contact Hours:</b> 2,00</p> <p><b>ECTS Credits:</b> 2.0</p>	
<p><b>Contents:</b></p> <p>Zur Auswahl stehen nachfolgende Kurse/Themen:</p> <p><u>(1) Kommunikationskompetenz</u></p> <ul style="list-style-type: none"> <li>- Kommunikationstraining</li> <li>- Rhetorik (dt./engl)</li> <li>- Präsentation / Present your work purposefully (engl.)</li> <li>- Strategische Gesprächsführung</li> <li>- Kommunikation in Projekten</li> <li>- agile Meeting moderieren</li> </ul> <p><u>(2) Sozialkompetenz</u></p> <ul style="list-style-type: none"> <li>- Konfliktmanagement</li> <li>- Emotionale Intelligenz</li> <li>- Teams führen / Leadership Experience (engl).</li> <li>- Changemanagement</li> </ul> <p><u>(3) Methodenkompetenz</u></p> <ul style="list-style-type: none"> <li>- Zeit-/Selbstmanagement</li> <li>- Innovationen entwickeln</li> <li>- Projektmanagement (dt./ engl.)</li> <li>- Unternehmerisch Denken</li> <li>- nachhaltig Wirtschaften / Corporat Responsibility</li> </ul> <p>Weiterehin können auch Kompakt-Kurse gewählt werden, bei denen die Teilnehmer o.g. Fähigkeiten erlernen und eine Projektaufgabe im Team bearbeiten. Der höhere Zeitaufwand wird mit mehr Erfahrung honoriert.</p> <ul style="list-style-type: none"> <li>- Kompaktkurs Projekte real erleben</li> <li>- Startup-Challenge</li> </ul> <p>Detailbeschreibungen zu allen Kursen sowie die konkreten Kursthemen und Termine pro Semester im digicampus.</p>	
<p><b>Lehr-/Lernmethoden:</b></p> <p>Vortrag, Diskussion, Übungen, Praxisbeispiele, event. Projektarbeit unter Verwendung von multimedialen Techniken (Beamer, Flipchart, Pinwand)</p>	
<p><b>Literature:</b></p> <p>wird im Kurs bz. in die Kursbeschreibungen angegebenen bzw. vorab kommuniziert.</p>	
<p><b>Assigned Courses:</b></p> <p><b>Kompaktkurs - Startup Challenge</b> (course) *(hybrid/mixed) *</p> <p><b>Kurs Changemanagement</b> (course)</p>	

*\*(in attendance) \**

**Kurs Inner-Leadership** (course)

*\*(in attendance) \**

**Kurs Innovationen entwickeln** (course)

*\*(in attendance) \**

**Kurs Kommunikationstraining** (course)

*\*(in attendance) \**

**Kurs Konfliktmanagement (Option 1)** (course)

*\*(in attendance) \**

**Kurs Konfliktmanagement (Option 2)** (course)

*\*(in attendance) \**

**Kurs Leadership experience (English)** (course)

*\*(in attendance) \**

**Kurs Nachhaltiges Wirtschaften** (course)

*\*(in attendance) \**

**Kurs Present your work purposefully to an interdisciplinary audience** (course)

*\*(in attendance) \**

**Kurs Project management (English)** (course)

*\*(in attendance) \**

**Kurs Projektmanagement** (course)

*\*(in attendance) \**

**Kurs Rhetorik (Option 1)** (course)

*\*(in attendance) \**

**Kurs Rhetorik (Option 2)** (course)

*\*(in attendance) \**

**Kurs Strategische Gesprächsführung (Option 1)** (course)

*\*(in attendance) \**

**Kurs Strategische Gesprächsführung (Option 2)** (course)

*\*(in attendance) \**

**Kurs Teams führen** (course)

*\*(in attendance) \**

**Kurs Zeit- und Selbstmanagement** (course)

*\*(in attendance) \**

**Startup Challenge (Projektstudium) - Bachelor**

*\*(hybrid/mixed) \**

### **Examination**

**Anwesenheit und aktive Übungsteilnahme im Kurs**

confirmed participation, not graded

<b>Module INF-0067: Peer-to-Peer and Cloud Computing</b> <i>Peer-to-Peer und Cloud Computing</i>		5 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Successful participation in this course results in professional competences in two sub-areas: Peer-to-Peer systems and Cloud Computing.</p> <p><b>Peer-to-Peer systems</b> Students can describe different peer-to-peer system architectures and their advantages as well as disadvantages. In particular, they are able to select a suitable architecture for a given use case and justify this decision. Furthermore, they can classify common decentralised search algorithms and heuristics and compare them with regard to their efficiency. They understand abstract network models and can use them to analyse peer-to-peer networks.</p> <p><b>Cloud Computing</b> Participants can distinguish the underlying technologies of cloud computing and analyse cloud computing architectures based on this knowledge. They know the importance of load balancing in the context of large cloud computing applications and can explain and weigh up the different approaches to this. Students know modern approaches to concurrent computations over large data sets and can apply them to simple problems. They are able to develop simple applications using platform-as-a-service frameworks.</p> <p><b>Key qualifications</b> Ability to think logically, analytically and conceptually; ability to expand existing knowledge independently; competence to recognise significant technical developments.</p>		
<p><b>Remarks:</b> Lecture slides in English Exams can be taken in either German or English</p>		
<p><b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Peer-to-Peer und Cloud Computing (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This module teaches approaches to organising complex abstracted IT infrastructures that can be dynamically adapted to changing conditions of use and provide services such as computing capacity, data storage, network capacities or software at different levels. For this purpose, the requirements, properties and goals of such systems are defined and discussed. In addition, concepts from the field of system architectures and approaches from the field of self-organising algorithms are presented and evaluated. References to concrete application areas are given in all parts.

**Literature:**

- current scientific paper
- Mahlmann und Schindelhauer: Peer-to-Peer Netzwerke - Algorithmen und Methoden, Springer 2007
- Antonopoulos und Gillam: Cloud Computing - Principles, Systems and Applications, Springer 2010

**Part of the Module: Peer-to-Peer und Cloud Computing (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Peer-to-Peer und Cloud Computing (mündliche Prüfung)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

The exam can be taken every semester at the beginning and at the end of the lecture-free period.

<b>Module INF-0069: Advanced Operating System Concepts</b> <i>Weiterführende Betriebssystemkonzepte</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<b>Learning Outcomes / Competences:</b> Die Veranstaltung vermittelt den Studierenden bei erfolgreicher Teilnahme fundierte fachliche Kenntnisse über moderne Betriebssysteme und die dahinterstehenden grundlegenden Konzepte. Sie können danach die Geschichte der Betriebssysteme wiedergeben und deren primäre Typen erläutern. Der theoretische Teil konzentriert sich auf die Vertiefung des Verständnisses von Mechanismen aus den Bereichen Multiprogramming, Interprozesskommunikation, Speicher-Management und Virtualisierung. Die Studierenden können die kennengelernten Ansätze hinsichtlich ihrer Eignung für einen bestimmten Einsatzzweck beurteilen. Der praktische Teil befasst sich mit dem Transfer und der Anwendung des im theoretischen Teil vermittelten Wissens. Sie benutzen Programme und Programmierschnittstellen aus dem Unix-Umfeld, um ein erarbeitetes Lösungskonzept mit dem Schwerpunkt Ein-/Ausgabe durch einen Programmcode zu realisieren.  <b>Schlüsselqualifikationen:</b> Qualitätsbewusstsein, Akribie; Auswahl und sichere Anwendung geeigneter Methoden; Fertigkeit zum logischen, analytischen und konzeptionellen Denken; Kenntnisse der Vor-/Nachteile von Entwurfsalternativen, Bewertung im jeweiligen Anwendungszusammenhang; Fachspezifische Vertiefungen; Umsetzen fachlicher Lösungskonzepte in Programme und Modelle.		
<b>Workload:</b> Total: 240 h 30 h lecture (attendance) 60 h exercise course (attendance) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Weiterführende Betriebssystemkonzepte (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		

**Contents:**

Die Vorlesung beinhaltet u. a. folgende Themen:

- Grundlagen eines Betriebssystems
  - Aufgaben
  - Struktur und Aufbau
  - Historie
  - Shell
- Prozesse, Threads und Interrupts
  - Prozesse und Threads
  - HW-Interrupts
- Scheduling
  - Grundlagen des Scheduling
  - Echtzeit-Scheduling
- Speicher
  - Interaktion
  - Speicherkonzepte
  - Dateisysteme
- Virtualisierung

**Literature:**

- Folien
- Andrew S. Tanenbaum: "Moderne Betriebssysteme", Pearson Studium, ISBN:978-3-8273-7342-7

**Part of the Module: Weiterführende Betriebssystemkonzepte (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination**

**Weiterführende Betriebssystemkonzepte**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

Die Prüfung kann jedes Semester zu Beginn und Ende der vorlesungsfreien Zeit abgelegt werden.

<b>Module INF-0147: Processor Architecture</b> <i>Prozessorarchitektur</i>		5 ECTS/LP
Version 2.4.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer Dr. Martin Frieb		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students understand the principles of the structure of the following processors at an advanced, practical but scientific level: superscalar microprocessors, multi- and manycore processors, GPUs. They also learn current concepts of processor architecture and can assess and evaluate advantages/disadvantages of current and future processors based on their internal structure. They understand how different components of microprocessors work and how they interact. Thus, the students are able to classify the influence of different architecture extensions on the overall system. They will also be able to distinguish when it makes sense to use memory-coupled, message-coupled or data-parallel processors, and differentiate between techniques for energy-efficient or high-performance processors. In the practical exercise, students simulate different processor architectures and jump prediction techniques and evaluate their impact on runtime and energy consumption.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against a background of inadequacy and conflicting interests; skill in making scientifically meaningful assessments using appropriate methods; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b></p> <p>This course is bi-lingual: We provide english videos of the lecture, while the language of the live lecture is german. For the exercise, there are two courses: One in english and one in german.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>Basics of computer architecture (e.g. pipelining, memory hierarchy)</li> <li>Basics of assembly programming (e.g. RISC-V, DLX, MIPS, ARM, x86 assembly)</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>4,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Prozessorarchitektur (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

- CISC
- Simple and advanced Pipelines
- Superscalar & Out-of-Order Execution
- Multi-/Manycores
- Branch Prediction
- VLIW/EPIC
- Multithreading
- Vector Processors & GPUs

**Literature:**

- John L. Hennessy, David A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann, 7th edition, 2025
- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Heidelberg, 3rd edition, 2010

**Assigned Courses:**

**Prozessorarchitektur / Processor Architecture** (lecture)

*\*(in attendance) \**

**Part of the Module: Prozessorarchitektur (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercises for Processor Architecture (English)** (exercise course)

*\*(in attendance) \**

**Übung zu Prozessorarchitektur (Deutsch)** (exercise course)

*\*(in attendance) \**

**Examination**

**Processor Architecture**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0149: Practical Module Embedded Systems</b> <i>Praktikum Eingebettete Systeme</i>		5 ECTS/LP
Version 2.2.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Over the course of the semester, students develop a complete embedded system as a coherent semester assignment. A core task of the course is to analyse the characteristics and recognize the functionality of microcontrollers and peripherals based on data sheets and specifications. The students will have the opportunity to assemble the components needed for an assignment and to define suitable interfaces. Due to the required development and implementation on a microcontroller, the students apply the concepts learned directly in practice. The focus is on the interaction with sensors and actuators as well as on the communication with other parts of the system. To this end, they will identify and apply different types of flow control. During the lab, students learn to plan complex assignments, design solutions and test and evaluate their functionality. The exchange among the students aimed at during the course enables them to appropriately compare and discuss the results achieved.</p> <p>Students acquire competencies in the following areas at an advanced, practice-oriented, but scientific level: independent work with microcontrollers, data sheets and specifications, interfacing of analog and digital peripherals, design and modelling of embedded software with state charts and their implementation in code. Further focus is on the configuration of sequential interfaces as well as scheduling and task-based programming.</p> <p>Schlüsselqualifikationen:</p> <p>Ability to understand and document ideas, concepts and results; Consciousness of quality, meticulousness; Project-related work and time management; selection and correct application of appropriate methods; ability to expand existing knowledge independently; Self-reflection</p>		
<p><b>Workload:</b></p> <p>Total: 150 h 90 h studying of course content through exercises / case studies (self-study) 60 h internship / practical course (attendance)</p>		
<b>Conditions:</b> Knowledge in C-Programming.		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: <i>Praktikum Eingebettete Systeme</i></b></p> <p><b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 4,00</p>		

**Contents:**

The practical course "Embedded Systems" aims to learn the challenges of programming embedded systems. The central platform is a development board that offers a microcontroller as well as various sensors, actuators, displays and interfaces for further peripherals. The programming is done in C without the application of hardware abstraction layers and the created programs are supposed to read out different sensors and set corresponding actuators. In particular, the challenges of embedded systems, such as the timing of the software as well as working with data sheets, are to be learned. Towards the end of the course, the basic knowledge acquired at the beginning will be deepened and already existing sub-components will be assembled into a more complex embedded system.

**Literature:**

- Zhu, Yifeng: Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Third Edition, E-Man Press LLC, 2017
- White, Elecia: Making Embedded Systems, O'Reilly Media Inc., 2012
- Marwedel, Wehmeyer: Eingebettete Systeme, Springer Verlag, Heidelberg, 2007

**Examination**

**Praktikum Eingebettete Systeme**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0309: Real-Time Systems</b> <i>Echtzeitsysteme</i>		8 ECTS/LP
Version 1.11.0 (since WS19/20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture imparts basic and advanced knowledge of real-time systems as they occur in almost all embedded systems, but especially in the areas of automotive, aerospace and robotics. The theoretical foundations will be based on the current state of research and will enable students to further engage with the topic of embedded real-time systems at a scientific level.</p> <p>The lecture will provide students with the ability to distinguish and classify different embedded systems based on their real-time requirements. Students will learn to apply, compare, and critically analyze current methods for validation of timing behavior with respect to possible certification of timing behavior. This includes the optimization and selection of real-time schedules and their verification. The lecture will also cover different processor types, and will go into more detail about the specifics of single-core and multi-core processors in the real-time domain. Students will be able to classify processors based on their suitability for real-time systems and to investigate the impact of design decisions on real-time behavior and real-time behavior analysis.</p> <p>The course material will be exemplified by case studies from the automotive and aerospace fields and applied by the students using a simple real-time system.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against a background of inadequacy and conflicting interests.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>60 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Echtzeitsysteme (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

- WCET Analysis
- Scheduling Analysis
- Programming of real-time systems
- Processors for real-time systems
- Real-time operating systems
- Certification of real-time systems

**Literature:**

- Sanjoy Baruah, Marko Bertogna, Giorgio Buttazzo, Multiprocessor Scheduling for Real-Time Systems, Springer, 2015.
- Giorgio Buttazzo, Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications, Springer, 2011.
- Heinz Wörn, Uwe Brinkschulte, Echtzeitsysteme, Springer Verlag, Berlin/Heidelberg, 2005
- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Verlag, Heidelberg, dritte Auflage 2010

**Part of the Module: Echtzeitsysteme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Echtzeitsysteme**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

this semester

<b>Module INF-0335: Safety-Critical Systems</b> <i>Safety-Critical Systems</i>		5 ECTS/LP
Version 1.2.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students will learn about fault tolerance requirements in embedded systems and classify them using the underlying regulations and standards (e.g. ISO 26262) for designing safety-relevant systems. They are able to describe the causes and effects of hardware faults and are able to analyze and evaluate different redundancy techniques.</p> <p>The course also focuses on applying the stochastic principles of fault calculus, analyzing and modeling computing systems with reliability block diagrams and fault trees, and differentiating different types of redundancy and using them in various hardware and software techniques for fault detection.</p> <p>Techniques for error correction, fault diagnosis, and reconfiguration are also introduced and explored. Students learn to classify and compare different concepts of fault-tolerant computing systems from theory and practice, such as lockstep execution, process redundancy, ECC memory implementations, or control flow checking.</p> <p>In the practical exercises, students apply the methods of modeling and fault computation to various tasks, work out their solutions, and compare on a qualitative level various fault tolerance concepts from research and practice.</p> <p><b>Key qualifications:</b> Analytical-methodical competence in the analysis of fault-tolerant computational systems, consideration of solution approaches, comprehensible presentation of solutions to exercise problems, ability to extend existing knowledge independently, self-reflection.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Safety-Critical Systems (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture considers methods for maintaining functional safety in computing systems, as well as their design and analysis. First, different types of faults are characterized and the importance of fault models is emphasized. Then, different hardware and software methods for detecting and tolerating faults are presented. The measures discussed refer not only to structural, but also to temporal and informational redundancy (fault tolerant codes). After a brief review of probability theory and combinatorics, various analysis methods such as classical probability theory, reliability block diagrams, Markov chains, FMEA, and fault trees are presented, differences highlighted, and explained with practical examples. Various fault injection methods necessary for evaluating fault tolerant systems are briefly discussed.

**Literature:**

- D. Sorin: Fault Tolerant Computer Architecture, Morgan and Claypool, 2009
- S. Mukherjee: Architecture Design for Soft Errors, Morgan Kaufmann, 2008
- I. Koren, C.M. Krishna: Fault-Tolerant Systems, Morgan Kaufmann, 2007

**Part of the Module: Safety-Critical Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination****Safety-Critical Systems**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0368: Embedded Hardware</b> <i>Embedded Hardware</i>		5 ECTS/LP
Version 1.2.0 (since WS20/21) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides basic and advanced knowledge of hardware components (e.g. GPIO, hardware timer, ...) as they are found in almost all embedded systems. Furthermore, the functional principles of different sensors and actuators are presented. A special focus will be on their use to interact with the physical world and on particularities of their application. The theoretical foundations will be based on the current state of research and will allow students to further engage with the topic of embedded hardware at a scientific level.</p> <p>The lecture will provide students with the ability to distinguish and classify different embedded systems based on their hardware requirements. Students will learn to apply current component programming methods, compare them, and critically analyze them for efficient use. This includes selecting and evaluating hardware components relevant to the system, as well as developing a configuration of components optimized for an existing problem. The lecture will also cover various sensors and actuators, and will go into more detail about the conversion between an analog, physical quantity and a digital, electrical quantity. Here, students will be able to classify physical quantities based on their properties and make a decision about the sensors, actuators, and hardware components needed for the conversion.</p> <p>The subject matter is exemplified by means of case studies, e.g. from the automotive field, and applied by the students using a simple embedded system.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against the background of inadequacy and conflicting interests.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Embedded Hardware (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Modeling of sensors and actuators
- Basics in electronics
- Hardware components of embedded processors and SoC
- Serial interfaces
- Sensors and input devices
- Actuators and output devices

**Literature:**

- Yifeng Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, E-Man Press LLC, 2017
- Edward Ashford Lee, Sanjit Arunkumar Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, MIT Press, 2017
- Elecia White, Making Embedded Systems, O'Reilly Media, 2012
- John Catsoulis, Designing Embedded Hardware, O'Reilly Media, 2005
- Rüdiger R. Asche, Embedded Controller: Grundlagen und praktische Umsetzung für industrielle Anwendungen, Springer, 2016
- Hermann Winner, Stephan Hakuli, Felix Lotz, Christina Singer Hrsg., Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 2015
- Bernhard Grimm, Gregor Häberle, Heinz Häberle, u.a., Fachkunde Industrieelektronik und Informationstechnik, Europa Lehrmittel, 2003

**Part of the Module: Embedded Hardware (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Embedded Hardware**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0381: Embedded Systems - Advanced Course</b> <i>Embedded Systems - Vertiefung</i>		5 ECTS/LP
Version 1.3.0 (since SoSe21) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides in-depth knowledge on changing focus topics in embedded systems, which are used in nearly all areas of industry—such as automotive, aerospace, and robotics—as well as in everyday life. The focus topics are selected from the field of developing and analyzing safe, reliable, and high-performance embedded systems. In particular, current research questions are addressed, and discussions are held on how embedded systems might be developed and analyzed in the future.</p> <p>Students will, on the one hand, be enabled to identify and justify the specific requirements of embedded systems. On the other hand, they will learn to apply various development techniques and analysis methods for embedded systems to examples, and to evaluate and classify them with respect to reliability and practicality. Furthermore, the lecture imparts the ability to independently analyze scientific theses related to the focus topics, formulate their own theses, evaluate them, and, if necessary, refute them. The focus topics will be aligned with the current state of research and will enable students to further engage with the subject of embedded systems on a scientific level.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, scientific methodology; principles of good scientific practice; skill in presenting and documenting results in a comprehensible manner; independent work with English-language specialist literature; ability to independently expand existing knowledge; analytical-methodological competence; skill in clear and confident oral presentation of (practical or theoretical) ideas, concepts, and results.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>60 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>none</p>		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Embedded Systems - Advanced Course (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <ul style="list-style-type: none"> <li>• Development and analysis of safe, reliable, and high-performance embedded systems</li> <li>• Non-functional properties of embedded systems</li> <li>• Current research questions and topics in the field of embedded systems</li> </ul>		
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Selected literature and current scientific articles on embedded systems (varies each semester)</li> </ul>		
<b>Assigned Courses:</b>		

**Embedded Systems - Advanced Course** (lecture)

*\*(in attendance) \**

**Part of the Module: Embedded Systems - Vertiefung (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercise for Embedded Systems - Advanced Course** (exercise course)

*\*(in attendance) \**

**Examination**

**Embedded Systems - Advanced Course**

oral exam / length of examination: 20 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0428: Practical Module Programming Parallel Embedded Systems</b> <i>Praktikum Programming Parallel Embedded Systems</i>		5 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<b>Learning Outcomes / Competences:</b> The students analyse the particular requirements of embedded systems and optimise the software they develop regarding the available resources and mandatory time limits. They create parallel applications for embedded systems in an industry-typical programming language. The emerging problems of implementing multithreaded applications are identified and suitable solutions for those are developed. Different data structures for use in parallel applications are classified, their implementations are reviewed, and the performance is evaluated. Debugging and code-analysis techniques are applied, and different optimisation possibilities are investigated. The students apply the skills they learned in projects, building parallel applications independently. Further, the performance of the developed software is evaluated, and analysed regarding the project requirements. <b>Key qualifications:</b> Analytical and methodological competence; selection and confident use of appropriate methods; ability to expand existing knowledge independently; skill in presenting and documenting ideas, concepts and results in a comprehensible manner; self-reflection		
<b>Workload:</b> Total: 150 h 90 h studying of course content through exercises / case studies (self-study) 60 h internship / practical course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module:</b> <i>Praktikum Programming Parallel Embedded Systems</i> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. winter semester) <b>Contact Hours:</b> 4,00
<b>Contents:</b> In the practical module, essential techniques to develop software projects in an industry-typical programming language are investigated, as well as methods for code-analysis, and for testing and debugging. Special focus is on programming parallel and concurrent applications with tasks and threads for single- and multi-core processors, and on programming with GPGPUs. Platform-independent programming is demonstrated on different systems, from 8 bit microcontrollers to 64 bit workstations, while the effects of the instruction set architecture on the performance of the software are analysed, and the resulting potential performance optimisations are evaluated. After the introduction into the essential features of the programming language, the typically used tools, as well as relevant parallel data structures, the students implement a parallel application in a larger project.

**Examination**

**Praktikum Programming Parallel Embedded Systems**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0462: Embedded Hardware Lab</b> <i>Embedded Hardware Lab</i>		8 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Over the course of the semester, students develop a complete embedded system as a coherent semester assignment. A core task of the course is to analyse the characteristics and recognize the functionality of microcontrollers and peripherals based on data sheets and specifications. The students will have the opportunity to assemble the components needed for an assignment and to define suitable interfaces. Due to the required development and implementation on a microcontroller, the students apply the concepts learned directly in practice. The focus is on the interaction with sensors and actuators as well as on the communication with other parts of the system. To this end, they will identify and apply different types of flow control. During the lab, students learn to plan complex assignments, design solutions and test and evaluate their functionality. The exchange among the students aimed at during the course enables them to appropriately compare and discuss the results achieved.</p> <p>Students acquire competencies in the following areas at an advanced, practice-oriented, but scientific level: independent work with microcontrollers, data sheets and specifications, interfacing of analog and digital peripherals, design and modelling of embedded software with state charts and their implementation in code. Further focus is on the configuration of sequential interfaces as well as scheduling and task-based programming.</p> <p><b>Key Qualifikations:</b> Ability to understand and document ideas, concepts and results; Consciousness of quality, meticulousness; Project-related work and time management; selection and correct application of appropriate methods; ability to expand existing knowledge independently; Self-reflection</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b></p> <p>Module Foundations of Technical Computer Science (INF-0138) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Embedded Hardware Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> irregular</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The practical course "Embedded Hardware Lab" aims to learn the challenges of programming embedded systems. The central platform is a development board that offers a microcontroller as well as various sensors, actuators, displays and interfaces for further peripherals. The programming is done in C without the application of hardware abstraction layers and the created programs are supposed to read out different sensors and set corresponding actuators. In particular, the challenges of embedded systems, such as the timing of the software as well as working with data sheets, are to be learned. Towards the end of the course, the basic knowledge acquired at the beginning will be deepened and already existing sub-components will be assembled into a more complex embedded system.

**Literature:**

- Zhu, Yifeng: Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Third Edition, E-Man Press LLC, 2017
- White, Elecia: Making Embedded Systems, O'Reilly Media Inc., 2012
- Marwedel, Wehmeyer: Eingebettete Systeme, Springer Verlag, Heidelberg, 2007

**Part of the Module: Embedded Hardware Lab (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination****Embedded Hardware Lab**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0472: Management of Communication Networks</b> <i>Management von Kommunikationsnetzen</i>	5 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Michael Seufert	
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides students with knowledge and skills in the field of management of communication networks. The module covers various aspects of the efficient and secure operation of communication networks and prepares students to successfully plan, implement, and manage complex network infrastructures. Students gain a solid understanding of the fundamentals of network management, including the different management levels, protocols, and tools. They understand the significance of network management for the effective utilization of communication networks.</p> <p>The module provides students with comprehensive knowledge and skills to effectively manage network elements, deploy management systems, configure devices, and perform troubleshooting. Additionally, topics such as measurements in communication networks, active and passive network monitoring, Quality of Service (QoS)/Quality of Experience (QoE), automation of network management, virtualization and softwarization of communication networks, network security, and network neutrality are addressed.</p> <p>Students develop a deeper understanding of the relationships between theoretical concepts in network management and their practical application. They can analyze complex management challenges and develop solution strategies. Students can interpret performance data from communication networks, identify potential bottlenecks, and apply diagnostic procedures to analyze and resolve network issues.</p> <p>Students will be able to assess the effectiveness of network management solutions and analyze their impact on the performance and security of communication networks. They will be able to compare and evaluate different approaches and technologies in order to make informed decisions and provide recommendations for improvements.</p> <p>Students will be empowered to develop new approaches and concepts in the field of network management. They will be able to design innovative solutions that go beyond traditional methods and address the current challenges of network management. They will be capable of researching new management strategies and techniques and applying them in practice.</p> <p>Students will be able to assess the impact of network management on organizational goals and business processes. They will be able to quantify the added value of effective network management for businesses and society, and apply appropriate evaluation methods to analyze the costs, risks, and benefits of network management.</p> <p>The exercises in Management of Communication Networks complement the lecture and provide students with the opportunity to apply their acquired knowledge in practical scenarios within real or simulated environments. The exercises include practical tasks, case studies, and projects that allow students to further develop their skills in network management and strengthen their problem-solving capabilities.</p> <p><b>Key qualifications:</b> subject-specific specialization; knowledge of the approaches and terminology of application-relevant disciplines; understanding of the application domain as well as the advantages and disadvantages of alternative technologies and their evaluation in the respective context; competence in identifying significant technological developments; ability to select and confidently apply appropriate concepts and methods; capacity to implement discipline-specific solution strategies; proficiency in solving problems under practice-oriented conditions; ability to present and document results clearly; competence in effective teamwork.</p>	
<p><b>Remarks:</b></p> All materials are in English. The voice track will be in German or English depending on the audience.	
<p><b>Workload:</b></p> Total: 150 h 30 h lecture (attendance) 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)	

<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Basics of communication systems and networking</li> <li>• Familiarity with ISO/OSI layers 1–4</li> <li>• Knowledge of IP, routing, TCP/UDP and protocols for popular Internet applications (web browsing, video streaming)</li> <li>• Basics of network performance and network security</li> </ul>		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Management of Communication Networks (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00	
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Definitions and Models for Network Management</li> <li>• Network Elements and Management Systems</li> <li>• Configuration of Network Elements and Troubleshooting</li> <li>• Active and Passive Network Measurements</li> <li>• Quality of Service (QoS)</li> <li>• Data Models for and Automation of Network Management</li> <li>• Virtualization and Softwarization of Communication Networks</li> <li>• Network Security</li> <li>• Quality of Experience (QoE)</li> <li>• Network Neutrality</li> </ul>	
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Clemm A.: Network Management Fundamentals, Cisco Press, 2006</li> <li>• Claise B., Wolter R.: Network Management: Accounting and Performance Strategies, Cisco Press, 2007</li> <li>• Edelman J, Lowe S. S., Oswald M.: Network Programmability and Automation, O'Reilly, 2018</li> <li>• Capobianco J. W.: Automate Your Network, 2019</li> <li>• Garrett J.: Data Analytics for IT Networks, Cisco Press, 2019</li> <li>• Claise B., Clarke J., Lindblad J.: Network Programmability with YANG, Addison-Wesley, 2019</li> <li>• Chou E.: Mastering Python Networking, Packt, 2020</li> <li>• Kurose J.W., Ross K.W.: Computer Networking - A Top-Down Approach, 7th edition, Pearson, 2016</li> <li>• Göransson P., Black C., Culver T.: Software Defined Networks: A Comprehensive Approach, 2nd edition, Morgan Kaufmann, 2017</li> </ul>	
<b>Assigned Courses:</b> <b>Management von Kommunikationsnetzen (lecture)</b> <i>*(in attendance) *</i>	
<b>Part of the Module: Management of Communication Networks (Exercise)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00	
<b>Assigned Courses:</b>	

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**Übung zu Management von Kommunikationsnetzen** (exercise course)

*\*(in attendance) \**

**Examination**

**Management of Communication Networks**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0511: Processor Design Lab</b> <i>Processor Design Lab</i>		8 ECTS/LP
Version 1.1.0 (since SoSe24) Person responsible for module: Prof. Dr. Sebastian Altmeyer Dr. Martin Frieb		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students acquire competencies in the following areas at an advanced, practical but scientific level: design process for digital circuits, circuit logic and gates, physical principles of electronic components, description of hardware with a hardware description language.</p> <p>First, students learn how to link logic gates and build a half-adder and a full-adder. They understand the digital circuit design process and apply it directly in a practical way by designing their own RISC-V processor. They model and implement it independently using the hardware description language VHDL. They learn the advantages and disadvantages of schematic and textual hardware description and can decide when it makes sense to use which variant. Furthermore, they combine synchronous and asynchronous processes to achieve a good interaction of the components of their self-built microprocessor. Finally, students evaluate the efficiency of their implementation based on the clock frequency achieved and the hardware effort required. In a final project phase, they learn to plan a complex task, to solve it according to a self-developed sound project plan and to discuss and present the results appropriately in a plenary session.</p> <p><b>Key qualifications:</b> Skill in presenting and documenting ideas, concepts and results in a comprehensible manner; quality awareness, meticulousness; project-bound work and time management; selection and confident use of appropriate methods; ability to expand existing knowledge independently; self-reflection.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>15 h studying of course content using literature (self-study)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>30 h lecture (attendance)</p> <p>60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Grundlagen der Rechnerarchitektur (Pipelining, Zweierkomplement, Speicherhierarchie, z.B. "Systemnahe Informatik" an der Uni Augsburg)</li> <li>• Grundkenntnisse in Assemblerprogrammierung (z.B. RISC-V-, DLX-, MIPS-, ARM-, x86-Assembler)</li> </ul> <p>Module Processor Architecture (INF-0147) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Processor Design Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p>
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**Contents:**

The course "Processor Design Lab" presents methods of logical design of digital circuits, starting with the abstract description in a hardware description language (like VHDL) up to the physical implementation on transistor level. In the practical part of the course, hardware design is illustrated using the example of a five-stage processor pipeline. The result is an executable processor developed in VHDL for an FPGA prototype board.

**Literature:**

- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Verlag, Heidelberg, dritte Auflage 2010
- John L. Hennessy, David A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann, 5. Auflage, 2011

**Part of the Module: Processor Design Lab (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Examination**

**Processor Design Lab**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3047: Design and Development of Embedded Systems</b> <i>Design and Development of Embedded Systems</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<b>Learning Outcomes / Competences:</b> The course provides fundamental, practice-oriented knowledge for the development and analysis of embedded systems, which are used in almost all areas of industrial application—such as automotive engineering, aerospace, and robotics—as well as increasingly in everyday life. As part of the course, students will design and implement their own embedded system and systematically measure and evaluate the resulting system. This includes identifying relevant system requirements and precisely defining the desired functionality. Through this process, students are enabled to select and apply appropriate development methods in a targeted manner. In addition, they acquire the competence to analyze, compare, and select suitable system components based on well-founded criteria. In doing so, the complete development process of an embedded system is exemplified and conveyed both theoretically and practically. <b>Key qualifications:</b> Analytical and methodological competence; evaluation of alternative solution approaches; presentation of solutions to exercise problems; ability to independently expand existing knowledge; quality awareness and attention to detail; self-reflection.		
<b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 15 h preparation of presentations (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Design and Development of Embedded Systems (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> irregular (usu. winter semester) <b>Contact Hours:</b> 2,00		

**Literature:**

- Embedded System Design Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things, Peter Marwedel
- Making Embedded Systems: Design Patterns for Great Software, Elicia White
- Prototype to Product: A Practical Guide for Getting to Market, Alan Cohen
- Introduction to Embedded Systems— A Cyber-Physical Systems Approach, Edward A. Lee and Sanjit A. Seshia
- Hard Real-Time Computing Systems - Predictable Scheduling Algorithms and Applications, Giorgio Buttazzo
- Test-Driven Development for Embedded C, James W. Grenning

**Part of the Module: Design and Development of Embedded Systems (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 4,00

**Examination**

**Design and Development of Embedded Systems**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3055: Analytical Performance Evaluation of Communication Networks</b> <i>Analytische Leistungsbewertung von Kommunikationsnetzen</i>	5 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Michael Seufert	
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides students with knowledge and skills in the analytical performance evaluation of communication networks. The module focuses on quantitative methods for modeling, analyzing, and dimensioning communication systems, with an emphasis on queueing theory and network calculus, and prepares students to rigorously assess the performance of modern networked infrastructures.</p> <p>Students gain a solid understanding of the fundamentals of performance modeling, including traffic models, service models, and key performance indicators such as waiting times, blocking probability, throughput, and utilization. They understand the significance of analytical performance evaluation for the design, optimization, and operation of communication networks.</p> <p>The module provides students with comprehensive knowledge and skills to formulate and analyze queueing models, e.g., single and multi-server queues, and to apply network calculus for end-to-end delay and backlog bounds. Further topics include traffic characterization, scheduling and resource allocation, dimensioning of links and buffers, performance aspects of Quality of Service (QoS)/Quality of Experience (QoE), as well as model validation. Students develop a deeper understanding of the relationships between theoretical concepts in performance analysis and their practical application in real communication networks. They can analyze complex performance problems, select appropriate modeling techniques, and develop solution strategies. Students can interpret performance data, identify potential bottlenecks, and apply analytical and numerical methods to evaluate and improve network performance.</p> <p>Students will be able to assess the effectiveness of different designs, protocols, and resource management strategies of networked systems with respect to performance and reliability. They will be able to compare and evaluate alternative architectures and mechanisms based on analytical models and performance bounds, in order to make informed design decisions and provide recommendations for improvements.</p> <p>Students will be empowered to develop new analytical approaches and concepts for the performance evaluation of emerging communication technologies. They will be able to adapt existing and to design innovative models that go beyond standard queueing setups and network calculus techniques. They will be capable of researching advanced performance evaluation methods and applying them to novel scenarios.</p> <p>Students will be able to assess the impact of network performance on organizational goals, service-level agreements, and user experience. They will be able to quantify the added value of performance-aware design of networked systems, and apply appropriate evaluation methods to analyze the costs, risks, and benefits of different design and provisioning options.</p> <p>The exercises in Analytical Performance Evaluation of Communication Networks complement the lecture and provide students with the opportunity to apply their acquired knowledge to analytical problem sets, numerical experiments, and case studies in networking contexts. The exercises include derivations, model-based evaluations, and small projects that allow students to further develop their skills in queueing theory and network calculus, and to strengthen their analytical and problem-solving capabilities.</p> <p><b>Key qualifications:</b> subject-specific specialization; knowledge of the concepts, methods, and terminology of queueing theory, network calculus, and related application-oriented disciplines; understanding of the application domain as well as the advantages and disadvantages of alternative system designs and their modeling and evaluation in the respective context; competence in identifying significant technological and methodological developments; ability to select and confidently apply appropriate concepts and methods; capacity to implement discipline-specific solution strategies; proficiency in solving problems under practice-oriented conditions; ability to present and document results clearly; competence in effective teamwork.</p>	
<p><b>Remarks:</b></p> All materials are in English. The voice track will be in German or English depending on the audience.	

<b>Workload:</b> Total: 150 h 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 30 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Basics of communication systems and networking</li> <li>• Familiarity with ISO/OSI layers 1–4</li> <li>• Knowledge of IP, routing, TCP/UDP and protocols for popular Internet applications (web browsing, video streaming)</li> <li>• Basics of network performance and network security</li> </ul>		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>		
<b>Part of the Module: Analytical Performance Evaluation of Communication Networks (Lecture)</b> <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to Performance Modeling and Queueing Models for Communication Networks</li> <li>• Description of Traffic, Arrivals, and Service in Networks using Elementary Random Processes</li> <li>• Analysis of Markovian Systems (Loss Systems, Delay Systems, Processor Sharing Systems)</li> <li>• Outlook to Advanced Queueing Models and Applications</li> <li>• Introduction to Network Calculus to Analyze Real-time Networks</li> <li>• Modeling of Traffic and Resources using Arrival and Service Curves</li> <li>• Analysis of Worst-case Performance Bounds (Delay, Backlog)</li> <li>• Outlook to Advanced Network Calculus and Applications</li> </ul>		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Tran-Gia P., Hoßfeld T.: Performance Modeling and Analysis of Communication Networks – A Lecture Note, Würzburg University Press, 2021 (online:<a href="https://doi.org/10.25972/WUP-978-3-95826-153-2">https://doi.org/10.25972/WUP-978-3-95826-153-2</a>, 2021)</li> <li>• Tran-Gia P.: Einführung in die Leistungsbewertung und Verkehrstheorie, Oldenbourg Wissenschaftsverlag, 2009</li> <li>• Shortle J.F., Thompson J.M., Gross D., Harris C.M.: Fundamentals of Queueing Theory, Wiley, 2018</li> <li>• Giambene G.: Queueing Theory and Telecommunications – Networks and Applications, Springer, 2021</li> <li>• Le Boudec J.-Y., Thiran P.: Network Calculus – A Theory of Deterministic Queueing Systems for the Internet, Springer, 2001 (online:<a href="https://leboudec.github.io/netcal/">https://leboudec.github.io/netcal/</a>, 2022)</li> <li>• Boulliard A., Boyer M., Le Corronc E.: Deterministic Network Calculus: From Theory to Practical Implementation, Wiley, 2018</li> <li>• Van Bemten A, Kellerer W.: Network Calculus: A Comprehensive Guide, TUM Technical Report, 2016</li> <li>• Jiang Y., Liu Y.: Stochastic Network Calculus, Springer 2006</li> </ul>		
<b>Assigned Courses:</b> <b>Analytische Leistungsbewertung von Kommunikationsnetzen (lecture)</b> *(in attendance) *		

**Part of the Module: Analytical Performance Evaluation of Communication Networks (Exercise)**

**Language:** English / German

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Analytische Leistungsbewertung von Kommunikationsnetzen** (exercise course)

*\*(in attendance) \**

**Examination**

**Analytical Performance Evaluation of Communication Networks**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3611: Autonomous Robotics Lab 1</b> <i>Autonomous Robotics Lab I</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Contents:</b></p> <p>In the two-part course Autonomous Robotics Lab, students work together to develop an autonomous robot for use in domestic environments. The goal is to participate in RoboCup@Home each winter semester. The course focuses on software and mechatronic components.</p> <p>Autonomous Robotics Lab I focuses on requirements analysis, system design, and the subsequent implementation of autonomy functions.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of the course, students will be able to derive requirements for autonomous robots within specific framework conditions, select and model a system and modular architecture based on these requirements, and finally implement key functionalities of autonomous robots. Students will have knowledge of the use of the Robot Operating System (ROS) 2 and Docker, as well as the design and programming of autonomous robots. This includes, in particular, methods from:</p> <ul style="list-style-type: none"> <li>• Computer vision</li> <li>• Localization</li> <li>• Navigation, trajectory and path planning</li> <li>• Manipulation</li> <li>• Semantic understanding of domestic tasks</li> <li>• Task planning</li> <li>• Human-robot interaction</li> </ul> <p>The results of the course will be tested and validated using simulations and, if necessary, the real system.</p>		
<p><b>Key Qualifications</b></p> <ul style="list-style-type: none"> <li>• Acquisition of basic knowledge of autonomous robot systems</li> <li>• Independent work with primarily English-language technical literature</li> <li>• Analytical and methodological skills</li> <li>• Scientific methodology</li> <li>• Teamwork and communication skills</li> <li>• Determination and problem-solving skills</li> <li>• Time management and task prioritization</li> <li>• Creative thinking and abstract reasoning</li> <li>• Confident and precise presentation of own solutions</li> </ul> <p>The project is being carried out in cooperation with industrial companies. The project results will be presented publicly by the students at the RoboCup and then published.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h 150 h exercise course (attendance) 90 h lecture (attendance)</p>		
<b>Conditions:</b> keine		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Part of Module: Autonomous Robotics Lab I</b></p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p> <p><b>ECTS Credits:</b> 8.0</p>
<p><b>Contents:</b></p> <p>Work on course materials in small groups</p>
<p><b>Assigned Courses:</b></p> <p><b>Autonomous Robotics Lab I</b> (lecture) <i>*(in attendance) *</i></p>
<p><b>Part of the Module: Part of Module: Autonomous Robotics Lab I</b></p> <p><b>Language:</b> German / English</p> <p><b>Contact Hours:</b> 4,00</p>
<p><b>Assigned Courses:</b></p> <p><b>Übung zu Autonomous Robotics Lab I</b> (exercise course) <i>*(in attendance) *</i></p>
<p><b>Examination</b></p> <p><b>Autonomous Robotics Lab I</b> portfolio exam / length of examination: 60 minutes, graded</p> <p><b>Test Frequency:</b> when a course is offered</p>

<b>Module INF-3614: Autonomous Robotics Lab II</b> <i>Autonomous Robotics Lab II</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Contents:</b></p> <p>In the two-part course Autonomous Robotics Lab, students work together to develop an autonomous robot for use in domestic environments. The goal is to participate in RoboCup@Home each winter semester. The course focuses on software and mechatronic components.</p> <p>Autonomous Robotics Lab II focuses on the integration and testing of subcomponents and the overall system, as well as the final participation in RoboCup@Home.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of the course, students will be able to test existing functionality and integrate it into an overall cyberphysical system, as well as design and validate appropriate tests. Students will have knowledge of the use of the Robot Operating System (ROS) 2 and Docker, as well as the design and programming of autonomous robots. This includes, in particular, methods from:</p> <ul style="list-style-type: none"> <li>• Definition and implementation of unit tests</li> <li>• Derivation and implementation of test scenarios</li> <li>• Working and integration on real hardware</li> <li>• Dealing with uncertainties and resource limitations</li> <li>• Composition of heterogeneous software and hardware modules</li> </ul> <p>The software components are integrated on real robot hardware. All validation and integration tests are performed on real hardware. The final validation of the entire system takes place at RoboCup@Home.</p> <p><b>Key Qualifications</b></p> <ul style="list-style-type: none"> <li>• Acquisition of basic knowledge of autonomous robot systems</li> <li>• Independent work with primarily English-language technical literature</li> <li>• Analytical and methodological skills</li> <li>• Scientific methodology</li> <li>• Teamwork and communication skills</li> <li>• Determination and problem-solving skills</li> <li>• Time management and task prioritization</li> <li>• Creative thinking and abstract reasoning</li> <li>• Confident and precise presentation of own solutions</li> </ul> <p>The project is being carried out in cooperation with industrial companies. The project results will be presented publicly by the students at the RoboCup and then published.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h 150 h studying of course content through exercises / case studies (self-study) 90 h lecture (attendance)</p>		
<b>Conditions:</b> Module Autonomous Robotics Lab 1 (INF-3611) - recommended		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Part of the Module: Autonomous Robotics Lab II</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> German / English  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b>                  Work on course materials in small groups</p>
<p><b>Part of the Module: Part of the Module: Autonomous Robotics Lab II</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> German / English  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b>                  Work on course materials in small groups</p>

<p><b>Examination</b></p> <p><b>Autonomous Robotics Lab II</b>                  portfolio exam / length of examination: 60 minutes, graded</p> <p><b>Test Frequency:</b>                  when a course is offered</p>
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<b>Module INF-0066: Organic Computing II</b> <i>Organic Computing II</i>		5 ECTS/LP
Version 1.3.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Participants will be able to reproduce the essential concepts and methods of the research field of Organic Computing (OC).</p> <p>These include: Self-Organisation, Self-Adaptation, Robustness, Flexibility, Observer/Controller architectures (O/C), Self-X properties, Learning Classifier Systems (most notably, XCS), Genetic Algorithms (GA), Particle Swarm Optimisation, Influence Detection and Trust. They will also be able to justify the consideration of OC systems-based solutions and give examples for practical scenarios in which OC techniques should be applied.</p> <p>The students will be able to develop larger software systems using the O/C architecture as well as select suitable OC techniques for the architecture's components. They will be able to learn by themselves further OC techniques if solving a given problem requires it. Further, students will be able to solve practical problems using XCS, swarming and a GA. They will also be able to develop and evaluate OC system architectures and perform scientific evaluations related to OC systems.</p> <p><b>Key qualifications:</b> Ability to present and document results in a comprehensible way, ability to present ideas and concepts confidently and convincingly, knowledge of the way of thinking as well as the language of application-relevant disciplines, skill of working in teams.</p>		
<p><b>Remarks:</b> Lecture and exercise course in English Lecture slides in English Exams can be taken in either German or English Questions can be asked in either German or English</p>		
<p><b>Workload:</b> Total: 150 h 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Organic Computing II (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture "Organic Computing" teaches approaches to the organisation of complex networked systems that consist of a large number of autonomous subsystems. To this end, the requirements and goals of such systems are first defined and discussed. In addition, concepts from the field of system architectures and approaches from the field of nature-inspired algorithms are presented and evaluated. References to concrete application areas are given in all parts. The associated practice deepens the understanding of the approaches learned by applying them in an exemplary manner.

**Literature:**

- Slides
- Müller-Schloer und Tomforde: Organic Computing - Technical Systems for Survival in the Real World, Springer International Publishing, 2018, ISBN 978-3-319-68477-2
- Müller-Schloer et al.: Organic Computing - A Paradigm Shift for Complex Sys-tems, Birkhäuser Verlag, Basel, 2011, ISBN 978-3034801294
- Würtz (ed.): Organic Computing (Understanding Complex Systems), SpringerVerlag Berlin, 2008, ISBN 978-3540776567
- Mitchell: Machine Learning, The McGraw-Hill Companies, 1997, ISBN 978-0071154673
- Goldberg: Genetic Algorithms in Search, Optimization and Machine Learning, Addison-Wesley, 1989, ISBN 978-0201157673
- Michalewicz, Fogel: How to Solve it: Modern Heuristics, Springer Verlag Berlin, 2004, ISBN 978-3540224945
- Tomforde: Runtime Adaptation of Technical Systems, Südwestdeutscher Verlag für Hochschulschriften, 2012, ISBN 978-3838131337

**Assigned Courses:**

**Organic Computing II** (lecture)

*\*(in attendance) \**

**Part of the Module: Organic Computing II (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Organic Computing II** (exercise course)

*\*(in attendance) \**

**Examination**

**Organic Computing II (mündliche Prüfung)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

The exam can be taken every semester at the beginning and end of the lecture-free period.

<b>Module INF-0067: Peer-to-Peer and Cloud Computing</b> <i>Peer-to-Peer und Cloud Computing</i>		5 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Successful participation in this course results in professional competences in two sub-areas: Peer-to-Peer systems and Cloud Computing.</p> <p><b>Peer-to-Peer systems</b> Students can describe different peer-to-peer system architectures and their advantages as well as disadvantages. In particular, they are able to select a suitable architecture for a given use case and justify this decision. Furthermore, they can classify common decentralised search algorithms and heuristics and compare them with regard to their efficiency. They understand abstract network models and can use them to analyse peer-to-peer networks.</p> <p><b>Cloud Computing</b> Participants can distinguish the underlying technologies of cloud computing and analyse cloud computing architectures based on this knowledge. They know the importance of load balancing in the context of large cloud computing applications and can explain and weigh up the different approaches to this. Students know modern approaches to concurrent computations over large data sets and can apply them to simple problems. They are able to develop simple applications using platform-as-a-service frameworks.</p> <p><b>Key qualifications</b> Ability to think logically, analytically and conceptually; ability to expand existing knowledge independently; competence to recognise significant technical developments.</p>		
<p><b>Remarks:</b> Lecture slides in English Exams can be taken in either German or English</p>		
<p><b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Peer-to-Peer und Cloud Computing (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This module teaches approaches to organising complex abstracted IT infrastructures that can be dynamically adapted to changing conditions of use and provide services such as computing capacity, data storage, network capacities or software at different levels. For this purpose, the requirements, properties and goals of such systems are defined and discussed. In addition, concepts from the field of system architectures and approaches from the field of self-organising algorithms are presented and evaluated. References to concrete application areas are given in all parts.

**Literature:**

- current scientific paper
- Mahlmann und Schindelhauer: Peer-to-Peer Netzwerke - Algorithmen und Methoden, Springer 2007
- Antonopoulos und Gillam: Cloud Computing - Principles, Systems and Applications, Springer 2010

**Part of the Module: Peer-to-Peer und Cloud Computing (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Peer-to-Peer und Cloud Computing (mündliche Prüfung)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

The exam can be taken every semester at the beginning and at the end of the lecture-free period.

<b>Module INF-0069: Advanced Operating System Concepts</b> <i>Weiterführende Betriebssystemkonzepte</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> Die Veranstaltung vermittelt den Studierenden bei erfolgreicher Teilnahme fundierte fachliche Kenntnisse über moderne Betriebssysteme und die dahinterstehenden grundlegenden Konzepte. Sie können danach die Geschichte der Betriebssysteme wiedergeben und deren primäre Typen erläutern. Der theoretische Teil konzentriert sich auf die Vertiefung des Verständnisses von Mechanismen aus den Bereichen Multiprogramming, Interprozesskommunikation, Speicher-Management und Virtualisierung. Die Studierenden können die kennengelernten Ansätze hinsichtlich ihrer Eignung für einen bestimmten Einsatzzweck beurteilen. Der praktische Teil befasst sich mit dem Transfer und der Anwendung des im theoretischen Teil vermittelten Wissens. Sie benutzen Programme und Programmierschnittstellen aus dem Unix-Umfeld, um ein erarbeitetes Lösungskonzept mit dem Schwerpunkt Ein-/Ausgabe durch einen Programmcode zu realisieren.</p> <p><b>Schlüsselqualifikationen:</b> Qualitätsbewusstsein, Akribie; Auswahl und sichere Anwendung geeigneter Methoden; Fertigkeit zum logischen, analytischen und konzeptionellen Denken; Kenntnisse der Vor-/Nachteile von Entwurfsalternativen, Bewertung im jeweiligen Anwendungszusammenhang; Fachspezifische Vertiefungen; Umsetzen fachlicher Lösungskonzepte in Programme und Modelle.</p>		
<p><b>Workload:</b> Total: 240 h 30 h lecture (attendance) 60 h exercise course (attendance) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Weiterführende Betriebssystemkonzepte (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		

**Contents:**

Die Vorlesung beinhaltet u. a. folgende Themen:

- Grundlagen eines Betriebssystems
  - Aufgaben
  - Struktur und Aufbau
  - Historie
  - Shell
- Prozesse, Threads und Interrupts
  - Prozesse und Threads
  - HW-Interrupts
- Scheduling
  - Grundlagen des Scheduling
  - Echtzeit-Scheduling
- Speicher
  - Interaktion
  - Speicherkonzepte
  - Dateisysteme
- Virtualisierung

**Literature:**

- Folien
- Andrew S. Tanenbaum: "Moderne Betriebssysteme", Pearson Studium, ISBN:978-3-8273-7342-7

**Part of the Module: Weiterführende Betriebssystemkonzepte (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination**

**Weiterführende Betriebssystemkonzepte**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

**Description:**

Die Prüfung kann jedes Semester zu Beginn und Ende der vorlesungsfreien Zeit abgelegt werden.

<b>Module INF-0078: Database Programming (Oracle)</b> <i>Datenbankprogrammierung (Oracle)</i>		5 ECTS/LP
Version 1.2.0 (since SoSe14) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<b>Learning Outcomes / Competences:</b> After participating in the course, students are able to apply in-depth Oracle knowledge in real-life tasks. This requires extended knowledge in the areas of DB system architecture, DB design theory, administration, extended SQL, PL/SQL programming, tree structures, XML and OLAP. The students gain a subject-specific in-depth knowledge in the area of database systems and thus the skill to analyze and structure problems. In addition, students will be able to analyze, evaluate and solve these complex, practice-relevant tasks in the field of databases, especially using Oracle. They know the advantages and disadvantages of different ER modeling and can use logical and conceptual thinking to write a suitable solution for complex problems under practical constraints.		
<b>Workload:</b> Total: 150 h 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)		
<b>Conditions:</b> Fundamental knowledge on database systems recommended, e.g., from the lecture [INF-0073] Datenbanksysteme 1		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Database Programming (Oracle) (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00		
<b>Contents:</b> The lecture covers problem solving strategies with the help of an Oracle database. This includes Oracle architecture, access rights, transformation from ER to SQL, Oracle SQL, active content such as PL/SQL and Java in Oracle, XML support in Oracle, tree structures, tuning, backup and recovery.		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• R. Elmasri, S. Navathe: Fundamentals of Database Systems</li> <li>• S. Melton: Understanding the New SQL: A Complete Guide</li> <li>• Oracle 19g Online-Dokumentation</li> </ul>		
<b>Part of the Module: Datenbankprogrammierung (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		

**Examination**

**Database Programming (Oracle)**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0129: Software Engineering II</b> <i>Softwaretechnik II</i>		8 ECTS/LP
Version 2.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Fachbezogene Kompetenzen:</b></p> <p>Nach dem erfolgreichen Besuch des Moduls sind die Teilnehmer in der Lage, fortgeschrittene Verfahren der agilen Softwareentwicklung, des Requirements Engineerings, des Testens und des Refactorings von Softwaresystemen anzuwenden und miteinander zu verbinden. Sie können die Anwendbarkeit der verschiedenen Verfahren und Methoden situationsspezifisch beurteilen.</p> <p>Die Teilnehmer verstehen die Aufgaben des Requirements Engineering und sind in der Lage, wesentliche Methoden der Requirements-Erfassung und Dokumentation (Use-Cases, Satzschablonen, formale Modelle) anzuwenden und die Eignung der verschiedenen Dokumentationsformen im Projektkontext zu bewerten. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können so systematisch komplexe Kundenanforderungen analysieren und können diese formulieren und in geeigneten Modellen darstellen.</p> <p>Die Studierenden verstehen einen agilen Entwicklungsprozess und die Basisprinzipien agiler Vorgehensweisen. Sie können den agilen Entwicklungsprozess auf Projekte übertragen und seine Anwendbarkeit im Projektkontext beurteilen. Sie kennen agile Praktiken und deren Wechselwirkungen und können die Praktiken einsetzen. Sie verstehen die Aufgaben der beteiligten Rollen und die Bausteine des Entwicklungsprozesses.</p> <p>Die Studierenden verstehen die Aufgaben des Testens und die Teilschritte des Testprozesses. Sie kennen Verfahren zur Bestimmung von Testfällen und zur Bewertung der Adäquatheit von Testsuiten und können diese anwenden.</p> <p>Die Studierenden kennen die Prinzipien guten objektorientierten Designs und können durch Refactoring die Qualität des Designs eines Systems verbessern. Sie können Ideen und Konzepte sicher und überzeugend darstellen und haben die Fähigkeit zur Zusammenarbeit im Team.</p> <p>Die Studierenden erwerben insgesamt Kenntnisse in Methoden zur Entwicklung großer Softwaresysteme und der Konstruktion von Abstraktionen sowie die Fähigkeit zu deren Anwendung im Projektkontext. Sie können alternative Vorgehensweisen wissenschaftlich fundiert bewerten und für ein Projekt geeignete auswählen.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Abstraktionsfähigkeit</li> <li>• Moderieren fachlicher Sitzungen</li> <li>• Erlernen des eigenständigen Arbeitens mit Lehrbüchern und Arbeit in selbstorganisierten Teams</li> <li>• Kenntnisse von praxisrelevanten Aufgabenstellungen</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>Programmierkenntnisse in Java (empfohlen)</p> <p>Module Software Engineering (INF-0120) - recommended</p>		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Softwaretechnik II (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p><b>Agile Softwareentwicklung:</b></p> <ul style="list-style-type: none"> <li>• Entwicklungsmethoden (Scrum)</li> <li>• Agile Praktiken</li> <li>• Agile Werte, Prinzipien und Methoden</li> </ul> <p><b>Refactoring</b></p> <ul style="list-style-type: none"> <li>• Code Smells</li> <li>• Prinzipien des objektorientierten Designs</li> <li>• Wichtige Refactorings</li> </ul> <p><b>Testen</b></p> <ul style="list-style-type: none"> <li>• Testprozess und Ziele des Testens</li> <li>• Testarten</li> <li>• Methoden zur Testfallgewinnung</li> <li>• Adäquatheitskriterien beim Blackbox- und Whitebox-Testen</li> </ul> <p><b>Requirements Engineering</b></p> <ul style="list-style-type: none"> <li>• Aufgaben, Begriffe und Artefakte</li> <li>• RE-Prozess</li> <li>• Techniken zur Requirements-Elicitation, -Analyse und -Dokumentation</li> <li>• Qualitätskriterien für Software-Requirements</li> </ul>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Pohl, Rupp: Basiswissen Requirements Engineering, dpunkt Verlag 2009</li> <li>• U. Hammerschall, G. Benekean: Software Requirements, Pearson 2013</li> <li>• S. Robertson, J. Robertson: Mastering the Requirements Process, Addison-Wesley 2013</li> <li>• Bleek, Wolf: Agile Softwareentwicklung, dpunkt Verlag 2008</li> <li>• R. Pichler: Scrum, dpunkt.verlag 2008</li> <li>• Spillner, Linz: Basiswissen Softwaretest, dpunkt Verlag 2005</li> <li>• Fowler: Refactoring, Addison-Wesley 1999</li> <li>• Vorlesungsfolien mit schriftlichen Ergänzungen und Anmerkungen</li> </ul>
<p><b>Part of the Module: Softwaretechnik II (Übung)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> German  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 4,00</p>

**Examination**

**Softwaretechnik II**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0130: Formal Methods in Software Engineering</b> <i>Formale Methoden im Software Engineering</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Wolfgang Reif		
<b>Learning Outcomes / Competences:</b> <b>Fachbezogene Kompetenzen:</b> <p>Die Studierenden können mathematisch-formale Methoden für die Programmverifikation, speziell bei sicherheitskritischer Software einsetzen. Durch das Verständnis von Kalkülen trainieren sie die Fertigkeit zum logischen, konzeptuellen und analytischen Denken. Sie können Spezifikationen von Datenstrukturen entwerfen und deren Eigenschaften formal beweisen. Sie sind in der Lage, funktionale Eigenschaften von sequentiellen und nebenläufigen Programmen zu formulieren und dafür Beweise zu erstellen. Sie erwerben die Fertigkeit zur abstrakten, modularen Modellierung von Softwaresystemen und zur systematischen Entwicklung von korrekten Programmen aus diesen Modellen. Sie erwerben dadurch die Fertigkeit zur Analyse und Strukturierung komplexer Informatikproblemstellungen und können mit geeigneten Methoden wissenschaftlich aussagekräftige Bewertungen abgeben. Sie erwerben Fähigkeiten, um Beiträge zur Wissenschaft zu leisten.</p> <b>Schlüsselqualifikationen:</b> <ul style="list-style-type: none"> <li>• Training des logischen Denkens</li> <li>• Analytisch-methodische Kompetenz</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Fähigkeiten zur Modellbildung für Softwaresysteme</li> </ul>		
<b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Formale Methoden im Software Engineering (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Übergeordnetes Ziel ist die Produktion beweisbar korrekter Software. In der Vorlesung werden verschiedene klassische Methoden für die Programmverifikation im Kleinen behandelt. Darüber hinaus werde innovative Techniken für die formale Modellierung und Verifikation großer Systeme vermittelt. Als Werkzeug kommt das KIV-System zum Einsatz, das die formale Spezifikation und Verifikation von Systemen ermöglicht. Konkrete Inhalte sind: Algebraische Spezifikationen, interaktives Theorembeweisen, Hoare-Logik, Dynamische Logik, Temporallogik

**Literature:**

- Sperschneider, Antoniou: Logic: A Foundation for Computer Science, Addison Wesley 1991
- Loeckx, Ehrich, Wolf: Specification of Abstract Data Types, Wiley 1996
- Ausführliche Dokumentation
- Folienhandout

**Assigned Courses:**

**Formale Methoden im Software Engineering (lecture)**

*\*(in attendance) \**

**Part of the Module: Formale Methoden im Software Engineering (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Formale Methoden im Software Engineering (exercise course)**

*\*(in attendance) \**

**Examination**

**Formale Methoden im Software Engineering**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0133: Self-Organising, Adaptive Systems</b> <i>Selbstorganisierende, adaptive Systeme</i>		8 ECTS/LP
Version 3.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b> Die Studierenden haben vertiefte Fachkenntnisse über die Eigenschaften und den Aufbau selbst-organisierender Systeme aus der Biologie, Soziologie, Physik und anderen Bereichen und der systematischen Modellierung und Konstruktion adaptiver Systeme in der Informatik und können solche Systeme analysieren und selbst entwerfen. Sie kennen Vor- und Nachteile verschiedener Entwurfsalternativen und können sie im Kontext der Problemstellung bewerten. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können geeignete Methoden auswählen und anwenden und wissenschaftlich aussagekräftige Bewertungen abgeben. Die Studierenden sind in der Lage, adaptive Systeme adäquat zu modellieren und dokumentieren.</p> <p>Außerdem kennen die Studierenden praxisrelevante Fragestellungen.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Grundsätze guter wissenschaftlicher Praxis</li> </ul>		
<p><b>Workload:</b> Total: 240 h 30 h lecture (attendance) 60 h exercise course (attendance) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Selbstorganisierende, adaptive Systeme (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p> <p><b>Contents:</b> In der Vorlesung werden die Grundlagen verschiedener Selbst-Organisationsmechanismen sowie das Handwerkszeug, um diese in IT-Systemen einsetzen zu können, vermittelt. Im Verlauf der Veranstaltung werden verschiedene Beispiele für selbstorganisierende Systeme vorgestellt, untersucht und Anwendungen der erlernten Organisationsprinzipien auf Beispiele aus der Informatik erläutert. Schließlich werden Methoden betrachtet, mit deren Hilfe sich Selbst-Organisation und Adaptivität in die Entwicklung komplexer Computersysteme integrieren lassen. Konkrete Themen sind: Selbst-Organisation, Emergenz, Chaostheorie, zelluläre Automaten, Spieltheorie, Multi-Agentensysteme, Autonomic Computing, Organic Computing.</p>

**Literature:**

- Gleick: Chaos: Making a New Science, Penguin 2008
- Strogatz: Sync : The Emerging Science of Spontaneous Order, Hyperion 2003
- Miller, Page: Complex Adaptive Systems: An Introduction to Computational Models of Social Life, Princeton University Press 2007
- Dawkins: The Selfish Gene, Oxford University Press, 3rd Revised Edition
- Wolfram: A New Kind of Science, Wolfram Media Inc. 2002
- von Neumann, Morgenstern: Theory of Games and Economic Behavior, 2004
- Folienhandout

**Part of the Module: Selbstorganisierende, adaptive Systeme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Selbstorganisierende, adaptive Systeme**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0147: Processor Architecture</b> <i>Prozessorarchitektur</i>		5 ECTS/LP
Version 2.4.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer Dr. Martin Frieb		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students understand the principles of the structure of the following processors at an advanced, practical but scientific level: superscalar microprocessors, multi- and manycore processors, GPUs. They also learn current concepts of processor architecture and can assess and evaluate advantages/disadvantages of current and future processors based on their internal structure. They understand how different components of microprocessors work and how they interact. Thus, the students are able to classify the influence of different architecture extensions on the overall system. They will also be able to distinguish when it makes sense to use memory-coupled, message-coupled or data-parallel processors, and differentiate between techniques for energy-efficient or high-performance processors. In the practical exercise, students simulate different processor architectures and jump prediction techniques and evaluate their impact on runtime and energy consumption.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against a background of inadequacy and conflicting interests; skill in making scientifically meaningful assessments using appropriate methods; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b></p> <p>This course is bi-lingual: We provide english videos of the lecture, while the language of the live lecture is german. For the exercise, there are two courses: One in english and one in german.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>Basics of computer architecture (e.g. pipelining, memory hierarchy)</li> <li>Basics of assembly programming (e.g. RISC-V, DLX, MIPS, ARM, x86 assembly)</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>4,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Prozessorarchitektur (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

- CISC
- Simple and advanced Pipelines
- Superscalar & Out-of-Order Execution
- Multi-/Manycores
- Branch Prediction
- VLIW/EPIC
- Multithreading
- Vector Processors & GPUs

**Literature:**

- John L. Hennessy, David A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann, 7th edition, 2025
- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Heidelberg, 3rd edition, 2010

**Assigned Courses:**

**Prozessorarchitektur / Processor Architecture** (lecture)

*\*(in attendance) \**

**Part of the Module: Prozessorarchitektur (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercises for Processor Architecture (English)** (exercise course)

*\*(in attendance) \**

**Übung zu Prozessorarchitektur (Deutsch)** (exercise course)

*\*(in attendance) \**

**Examination**

**Processor Architecture**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0149: Practical Module Embedded Systems</b> <i>Praktikum Eingebettete Systeme</i>		5 ECTS/LP
Version 2.2.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Over the course of the semester, students develop a complete embedded system as a coherent semester assignment. A core task of the course is to analyse the characteristics and recognize the functionality of microcontrollers and peripherals based on data sheets and specifications. The students will have the opportunity to assemble the components needed for an assignment and to define suitable interfaces. Due to the required development and implementation on a microcontroller, the students apply the concepts learned directly in practice. The focus is on the interaction with sensors and actuators as well as on the communication with other parts of the system. To this end, they will identify and apply different types of flow control. During the lab, students learn to plan complex assignments, design solutions and test and evaluate their functionality. The exchange among the students aimed at during the course enables them to appropriately compare and discuss the results achieved.</p> <p>Students acquire competencies in the following areas at an advanced, practice-oriented, but scientific level: independent work with microcontrollers, data sheets and specifications, interfacing of analog and digital peripherals, design and modelling of embedded software with state charts and their implementation in code. Further focus is on the configuration of sequential interfaces as well as scheduling and task-based programming.</p> <p>Schlüsselqualifikationen:</p> <p>Ability to understand and document ideas, concepts and results;          Consciousness of quality, meticulousness;          Project-related work and time management;          selection and correct application of appropriate methods;          ability to expand existing knowledge independently;          Self-reflection</p>		
<p><b>Workload:</b></p> <p>Total: 150 h          90 h studying of course content through exercises / case studies (self-study)          60 h internship / practical course (attendance)</p>		
<b>Conditions:</b> Knowledge in C-Programming.		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: <i>Praktikum Eingebettete Systeme</i></b></p> <p><b>Mode of Instruction:</b> internship  <b>Language:</b> German / English  <b>Frequency:</b> irregular (usu. summer semester)  <b>Contact Hours:</b> 4,00</p>		

**Contents:**

The practical course "Embedded Systems" aims to learn the challenges of programming embedded systems. The central platform is a development board that offers a microcontroller as well as various sensors, actuators, displays and interfaces for further peripherals. The programming is done in C without the application of hardware abstraction layers and the created programs are supposed to read out different sensors and set corresponding actuators. In particular, the challenges of embedded systems, such as the timing of the software as well as working with data sheets, are to be learned. Towards the end of the course, the basic knowledge acquired at the beginning will be deepened and already existing sub-components will be assembled into a more complex embedded system.

**Literature:**

- Zhu, Yifeng: Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Third Edition, E-Man Press LLC, 2017
- White, Elecia: Making Embedded Systems, O'Reilly Media Inc., 2012
- Marwedel, Wehmeyer: Eingebettete Systeme, Springer Verlag, Heidelberg, 2007

**Examination**

**Praktikum Eingebettete Systeme**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0179: Introduction to Game Programming</b> <i>Einführung in die Spieleprogrammierung</i>		8 ECTS/LP
Version 1.2.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts for developing a game. They are able to implement their own gameplay concepts and to use suitable AI methods for decision-making as well as sequence control. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate AI components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Selection and confident application of appropriate methods, Interdisciplinary knowledge, Skill in analyzing and structuring complex computer science problems, Skill in developing and implementing solution strategies for complex problems, Understanding team processes, Skill in working in teams, Self-reflection; Acting responsibly in the face of inadequacy and conflicting interests, Quality awareness, Meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)</p>		
<b>Conditions:</b> Vacation task		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Foundations of Game Programming (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Game engines, AI character decision making, wayfinding and navigation, group behavior and dynamics, animations, physics, storytelling, input/output methodology, audio, game design, graphics and shader programming.		
<b>Literature:</b> Script		
<p><b>Assigned Courses:</b> <b>Einführung in die Spieleprogrammierung</b> (lecture) <i>*(in attendance) *</i></p>		

**Part of the Module: Foundations of Game Programming (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zur Einführung in die Spieleprogrammierung** (exercise course)

*\*(online/digital) \**

**Examination**

**Einführung in die Spieleprogrammierung**

portfolio exam, graded

**Test Frequency:**

when a course is offered

**Description:**

Exception summer term 2020: Portfolio exam

<b>Module INF-0182: Practical Module Multimodal Real Time Signal Processing</b> <i>Praktikum Multimodale Echtzeitsignalverarbeitung</i>		8 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students are familiar with the basic concepts of signal processing and machine learning. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. During the internship, they also learn to plan larger project tasks (development of software modules) in small teams, to solve them according to a self-developed project plan and to discuss the results appropriately in plenary sessions and present them as a team. The ability to evaluate suitable methods in a scientifically meaningful way, to develop the methods and algorithms independently and to implement them technically is also particularly encouraged.</p> <p><b>Key qualifications:</b> Advanced knowledge of signal processing and machine learning, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b> Programming experience Module Foundations of Multimedia I (INF-0087) - recommended Module Foundations of Multimedia II (INF-0166) - recommended</p>		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Practical Module Multimodal Real Time Signal Processing</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 6,00</p>		
<b>Contents:</b> The specific task from the wide field of multimodal real-time signal processing is designed every year.		
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.		
<b>Examination</b>		
<b>Practical Module Multimodal Real Time Signal Processing</b> practical exam, graded		
<b>Test Frequency:</b> when a course is offered		

<b>Module INF-0183: Practical Module Game Programming</b> <i>Praktikum Spieleprogrammierung</i>		8 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<b>Contents:</b> In this lab, several games are developed. It has a different focus every year.		
<b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of game development. They are able to plan larger project tasks in small teams, to solve them according to a self-developed project plan and to discuss and present the results appropriately in plenary sessions. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. During the internship, they learn to evaluate various components of a game in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results as well as logical, analytical and conceptual thinking are also particularly promoted in this context. <b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.		
<b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Module Introduction to Game Programming (INF-0179) - recommended		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Practical Module Game Programming</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00
<b>Contents:</b> A game is to be developed within the internship. The content focus of the internship is determined each year.
<b>Literature:</b> References will be announced at the beginning of the semester.

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**Examination**

**Practical Module Game Programming**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0207: Reinforcement Learning</b> <i>Reinforcement Learning</i>		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of reinforcement learning. They are able to translate technical solution concepts into programs and models and master the selection and safe application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills for confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Advanced mathematical-formal methodology, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Reinforcement Learning (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> Markov decision problem, Dynamic programming, Monte Carlo methods, TD learning, Eligibility traces, Hierarchical reinforcement learning, Planning and learning, Generalization.</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Script</li> <li>• Richard S. Sutton und Andrew G. Barto. Reinforcement Learning: An Introduction. MIT Press, 1998</li> </ul>

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**Part of the Module: Reinforcement Learning (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Reinforcement Learning**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0217: Practical Module Autonomous Driving</b> <i>Praktikum Autonomes Fahren</i>		10 ECTS/LP
Version 2.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Bernhard Bauer Prof. Dr. Lars Mikelsons		
<p><b>Learning Outcomes / Competences:</b></p> <p>After participating in the practical course on autonomous driving, students will be able to solve practical problems of high complexity in conceptual design, development, and safeguarding of highly automated/autonomous vehicles using current methods and tools of model-based development. The students acquire in-depth subject-specific and interdisciplinary knowledge and skills, for example, from hardware-related computer science, software engineering, and the underlying driving physics and mathematics. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine, present and document intermediate results and innovative ideas understandably.</p> <p>Key qualification: Ability to think logically, analytically, and conceptually; Independent work with English-language specialist literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Ability to work in teams and understand team processes; Project management skills.</p>		
<p><b>Remarks:</b></p> <p>The practical course is offered alternately by the two chairs mentioned above.</p>		
<p><b>Workload:</b></p> <p>Total: 300 h 150 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <p>Participation in one of the two seminars is recommended.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>10,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module:</b> <i>Praktikum Autonomes Fahren</i> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 10,00</p>		

**Contents:**

In this practical course, the participants learn how various selected partial aspects of autonomous driving can be implemented, simulated, and analyzed.

In addition, the participants will get to know, among other things, development tools frequently used in the automotive environment.

After an introductory course, the participants will implement autonomous driving functions in small groups with the help of the tools mentioned.

The developed results are finally demonstrated and evaluated.

**Examination**

**Practical Module Autonomous Driving**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0233: Industrial Robotics</b> <i>Industrierobotik</i>		8 ECTS/LP
Version 2.2.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage Industrieroboter zu programmieren, kennen das dafür erforderliche methodische Vorgehen und können die Eignung verschiedener Vorgehensweise bewerten. Sie können fachliche Lösungskonzepte in Roboterprogramme umsetzen und dabei Entwurfsalternativen bewerten und anwenden. Sie haben Kenntnisse von praxisrelevanten Aufgabenstellungen in der automatisierten Fertigung. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken.		
<b>Schlüsselqualifikationen:</b> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> </ul>		
<b>Remarks:</b> Dieses Modul ersetzt das Modul "INF-0132: Software in Mechatronik und Robotik". Sofern dieses bereits belegt wurde, ist eine erneute Belegung <b>nicht</b> möglich.		
<b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Industrierobotik (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00
<b>Contents:</b> Ziel der Veranstaltung ist es, an Beispielen die Programmierung und der Entwurf von Software für Industrieroboter, wie sie z.B. in der Automobilindustrie verwendet werden, zu erlernen. Dazu werden im ersten Teil der Vorlesung Grundlagen wie Kinematik und Bahnplanung mit Hilfe simulationsbasierter Programmieransätze behandelt. Im zweiten Teil der Vorlesung werden verschiedene, kleine Programmieraufgabenstellungen bearbeitet und auf einem KUKA Roboter evaluiert. Die Programmierung erfolgt mit der Roboterprogrammiersprache KRL.

**Literature:**

- L. Sciavicco, B. Siciliano: Modelling and Control of Robot Manipulators. Reihe: Advanced Textbooks in Control and Signal Processing. Springer 2000 (2nd Ed.)
- Handbücher von KUKA
- Folienhandout

**Assigned Courses:**

**Industrierobotik** (lecture)

*\*(in attendance) \**

**Part of the Module: Industrierobotik (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Industrierobotik** (exercise course)

*\*(hybrid/mixed) \**

**Examination**

**Industrierobotik**

portfolio exam / length of examination: 45 minutes

work period for assignment: 3 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0235: Software for Industry 4.0</b> <i>Software für Industrie 4.0</i>		5 ECTS/LP
Version 1.2.0 (since WS16/17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage die praktischen und methodischen Herausforderungen, die Industrie 4.0 für die Automatisierung und deren Softwareentwicklung bedeutet, zu verstehen. Sie werden sowohl in Techniken der klassischen Automatisierung als auch modernen Softwaretechnologien im Umfeld von Industrie 4.0 eingeführt und kennen so unterschiedliche anwendungsrelevante Disziplinen. Sie sind in der Lage Lösungskonzepte zu erstellen und dabei Entwurfsalternativen bewerten und anwenden.		
<b>Schlüsselqualifikationen:</b> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenzen</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> </ul>		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Software für Industrie 4.0 (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00		
<b>Contents:</b> Die Vorlesung behandelt aktuelle Themen im Kontext von Industrie 4.0. Dazu zählen folgende Inhalte: <ul style="list-style-type: none"> <li>• Einführung in die Automatisierung</li> <li>• Referenzarchitekturen für Industrie 4.0</li> <li>• Einführung in die (mobile Service) Robotik</li> <li>• OPC UA</li> <li>• AutomationML</li> <li>• Data Analytics für Industrie 4.0</li> </ul>		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0 - Abschlussbericht des Arbeitskreises Industrie 4.0; acaTech</li> </ul>		

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**Part of the Module: Software für Industrie 4.0 (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination**

**Software für Industrie 4.0**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0243: Process Mining</b> <i>Process Mining</i>		6 ECTS/LP
Version 1.2.0 (since SoSe17) Person responsible for module: Prof. Dr. Robert Lorenz		
<p><b>Learning Outcomes / Competences:</b> Participants understand the following essential concepts of computer science at an advanced scientific level, including their mathematical and formal foundations: event log, partial order, Petri net, concurrency, sequential and causal semantics of a concurrent system, synthesis of a concurrent system, business process, process mining, process discovery, conformance checking. They can model concurrent systems of medium complexity in a suitable modeling language, as well as generate, evaluate, and convert different models for analysis and simulation for a given concurrent system. They are familiar with the various process mining use cases with appropriate solution techniques and quality criteria for their evaluation. Participants will have advanced mathematical formal methodology for the analysis and formalization of complex process discovery problems. They will be able to confidently select suitable algorithms for their solution with regard to qualitative and quantitative criteria, apply them, and interpret and evaluate the results.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically, conceptually, and algorithmically; Independent work with textbooks and English-language specialist literature; Clear presentation of results; Quality awareness; Meticulousness; Principles of good scientific practice; Scientific methodology;</p>		
<p><b>Remarks:</b> The teaching materials are written in English (lecture notes and exercises). If foreign students with insufficient German language skills participate, the language of instruction will be English.</p>		
<p><b>Workload:</b> Total: 180 h 45 h lecture (attendance) 15 h exercise course (attendance) 23 h studying of course content using literature (self-study) 75 h studying of course content through exercises / case studies (self-study) 22 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b> none</p>		<p><b>Credit Requirements:</b> Passing the module examination</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Process Mining (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 3,00</p>
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**Contents:**

The lecture provides a comprehensive overview of the field of process mining research:

- Modeling techniques: Petri nets, workflow nets, process trees, direct follows graphs
- Discovering algorithms: Alpha-Algorithm, Inductive Miner, Direct Follows Miner, Synthesis based discovery techniques
- Conformance checking: fitness, precision, generalization, simplicity
- Tools: PROM, Celonis

**Literature:**

English-language lecture notes

Wil M. P. van der Aalst:

Process Mining - Data Science in Action, Second Edition. Springer 2016, ISBN 978-3-662-49850-7

Wil M. P. van der Aalst, Boudewijn F. van Dongen: Discovering Petri Nets from Event Logs. Trans. Petri Nets and Other Models of Concurrency 7: 372-422 (2013)

Robin Bergenthum, Jörg Desel, Robert Lorenz, Sebastian Mauser: Process Mining Based on Regions of Languages. BPM 2007: 375-383

Wil M. P. van der Aalst, Josep Carmona:

The Process Mining Handbook. Springer 2022, ISBN 978-3-031-08848-3

**Assigned Courses:**

**Process Mining** (lecture)

*\*(in attendance) \**

**Part of the Module: Process Mining (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 1,00

**Assigned Courses:**

**Übung zu Process Mining** (exercise course)

*\*(in attendance) \**

**Examination**

**Process Mining (Klausur)**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0248: Collaborative Robotics</b> <i>Kollaborative Robotik</i>		8 ECTS/LP
Version 1.1.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b> Die Studierenden sind in der Lage kollaborative Roboter zu programmieren und verstehen die regulatorischen Randbedingungen (vgl. ISO/TS 15066:2016). Sie verstehen die grundlegenden Konzepte und Methoden der kollaborativen Robotik. Sie können dementsprechend fachliche Lösungskonzepte umsetzen und Entwurfsalternativen bewerten und anwenden. Sie haben die Fertigkeit zum analytischen und konzeptionellen Denken und können grundlegende Bewertungen der Risiken eines kollaborativen Robotersystems durchführen. Die Studierenden können abwägen, für welche praxisrelevanten Problemstellungen kollaborative Roboter eingesetzt werden können.</p> <p><b>Schlüsselqualifikationen:</b></p> <ul style="list-style-type: none"> <li>• Analytisch-methodische Kompetenz</li> <li>• Abwägen von Lösungsansätzen</li> <li>• Erwerb von Abstraktionsfähigkeiten</li> <li>• Erwerb von Grundlagen für die Sicherheitsbewertung</li> </ul>		
<p><b>Remarks:</b> <b>Voraussetzungen (empfohlen):</b> Software für Industrie 4.0 oder Industrierobotik oder Grundlagen der Robotik</p>		
<p><b>Workload:</b> Total: 240 h</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Kollaborative Robotik (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 4,00</p>		

**Contents:**

Die Digitalisierung dringt mittlerweile in viele Bereiche des täglichen Lebens vor. Von Industriemaschinen und Robotersystemen (*Smart Factory, Industrie 4.0*) bis hin zu intelligenten Hausgeräten oder Heizungsanlagen (*Smart Home*) findet eine immer stärkere Vernetzung dieser Geräte im Internet der Dinge statt. Hierbei spricht man von cyber-physischen Systemen, die einerseits durch ein komplexes Zusammenspiel von vernetzen eingebetteten Systemen entstehen und andererseits geprägt sein werden von einer vollkommen neuen Art der Mensch-Technik-Interaktion in den Anwendungen.

Eine besondere Rolle unter den cyber-physischen Systemen nehmen Assistenz- oder Serviceroboter ein, da sie durch einen geteilten Arbeitsraum in eine direkte, auch physische Interaktion mit dem Menschen treten können. Diese robotischen Systeme können den Menschen in seiner täglichen Arbeit unterstützen bzw. entlasten. Das gilt sowohl im häuslichen Umfeld als auch in der Fabrik. Im Kontext von Industrie 4.0 haben robotische Co-Worker (CoBots) vereinzelt bereits Eingang in die Produktion gefunden. Diese kollaborativen Einsatzszenarien werden jedoch in Zukunft noch weiter an Bedeutung gewinnen. Durch die in 2016 veröffentlichte Norm ISO/TS 15066:2016 zur Mensch-Roboter-Kollaboration stehen dem Einsatz innovativer Robotersysteme neue Möglichkeiten offen.

Während die grundlegende Hardware, d.h. die Roboter, mobilen Plattformen, Greifer und Sensoren, bereitgestellt wird, liegt der Schwerpunkt der Veranstaltung auf der Entwicklung von Software für kollaborative (mobile) Manipulatoren. Durch die intelligente Vernetzung von Aktuatorik und Sensorik, neuartige Algorithmen für die Sensorauswertung und kreative Konzepte zur (physischen) Interaktion mit dem Menschen entstehen innovative, kollaborative Robotersysteme im praktischen Teil der Veranstaltung.

Infolgedessen liegt der thematische Fokus der Veranstaltung auf

- der Umsetzung multi-modaler Benutzerschnittstellen,
- der Gestaltung neuartiger, auch physischer Interaktionsmöglichkeiten,
- der Realisierung intelligenter Verhaltensweisen durch Techniken der Künstlichen Intelligenz bzw. des Machine Learnings und
- der Entwicklung kognitiver Fähigkeiten des Robotersystems.

Diese Kernelemente bieten die Grundlage, um eine praktische Aufgabenstellung prototypisch umzusetzen. Die Programmierung erfolgt dabei in objektorientierten Programmiersprachen. So können kollaborative Roboter bspw. in Java mit der Robotics API programmiert werden, einem am ISSE in Kooperation mit KUKA entwickelten Roboterframework. Alternativ oder ergänzend kann das Robot Operating System (ROS) verwendet werden, das in den Programmiersprachen C++ und Python programmiert werden kann.

**Part of the Module: Kollaborative Robotik (Vorlesung)**

**Mode of Instruction:** lecture

**Language:** German

**Frequency:** irregular

**Contact Hours:** 2,00

**Literature:**

- ISO/TS 15066:2016. 2016-02-15. Robots and robotic devices - Collaborative robots
- DIN EN ISO 13849-1:2016-06. 06.2016. Sicherheit von Maschinen - Sicherheitsbezogene Teile von Steuerungen - Teil 1: Allgemeine Gestaltungsleitsätze (ISO 13849-1:2015); Deutsche Fassung EN ISO 13849-1:2015
- DIN EN ISO 10218-1:2012. 01.2012. Industrieroboter - Sicherheitsanforderungen - Teil 1: Roboter (ISO 10218-1:2011); Deutsche Fassung EN ISO 10218-1:2011

**Examination**

**Kollaborative Robotik**

practical exam / length of examination: 60 minutes

work period for assignment: 3 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0250: Practical Module Reinforcement Learning</b> <i>Praktikum Reinforcement Learning</i>		8 ECTS/LP
Version 1.3.0 (since SoSe17) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of reinforcement learning. They are able to plan larger project tasks in small teams, to solve them according to a self-developed project plan and to discuss and present the results appropriately in plenary sessions. You are able to translate technical solution concepts into programs and models and are proficient in the selection and confident application of appropriate methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. During the internship, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking are also particularly promoted in this context.</p> <p><b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 150 h studying of course content through exercises / case studies (self-study) 90 h internship / practical course (attendance)</p>		
<b>Conditions:</b> Programming experience		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Practical Module Reinforcement Learning****Mode of Instruction:** internship**Language:** German**Frequency:** irregular**Contact Hours:** 6,00**Contents:**

The specific task from the field of "reinforcement learning" is designed anew each semester.

**Examination****Practical Module Reinforcement Learning**

practical exam, graded

**Test Frequency:**

when a course is offered

**Description:**

Exception summer term 2020: practical exam

<b>Module INF-0277: Analysing Massive Data Sets</b> <i>Analyzing Massive Data Sets</i>		8 ECTS/LP
Version 1.2.0 (since SoSe18) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<p><b>Learning Outcomes / Competences:</b> After attending the course, students will be able to understand and evaluate the concepts and methods, procedures, techniques, and technologies for analyzing massively large data sets. Possible content includes:</p> <ul style="list-style-type: none"> <li>• Fundamentals of information retrieval</li> <li>• Similarity search and clustering</li> <li>• Analysis of data streams and temporal data</li> <li>• Web graphs: Link analysis and social networks</li> <li>• Dynamic networks and information diffusion</li> <li>• Recommender systems and online advertising</li> <li>• Computational methods for massive data sets</li> </ul> <p>Students will also be able to implement technical solution concepts for analyzing large data sets in programs. <b>Key Skills:</b> Ability to think logically, analytically and conceptually, weigh up approaches to solutions, acquire abstraction skills; subject-specific in-depth knowledge; implement subject-specific solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives and evaluation in the respective application context; selection and confident application of suitable methods; ability to make scientifically meaningful evaluations using suitable methods; ability to solve problems under practical boundary conditions; competence in recognizing significant technical developments;</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 60 h lecture (attendance) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b> Module Database Systems (INF-0073) - recommended Module Discrete structures for computer science (INF-0109) - recommended Module Computer Science 3 (INF-0111) - recommended</p>		
<b>Frequency:</b> Sommersemester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Analyzing Massive Data Sets (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 4,00</p>		
<p><b>Contents:</b> The lecture covers basic concepts for the analysis of massively large data sets such as information extraction, similarity search, clustering, link and network analysis as well as their implementation.</p>		

**Literature:**

- Mining of Massive Datasets. J. Leskovec, A. Rajaraman, J.D. Ullman. Cambridge University Press, 2014
- D. Easley, J. Kleinberg. Networks, Crowds, and Markets: Reasoning About a Highly Connected World. Cambridge University Press, 2010.
- R. Baeza-Yates, B. Ribeiro-Neto: Modern Information Retrieval

Weitere Literatur wird in der Vorlesung bekannt gegeben

**Assigned Courses:**

**Analyzing Massive Data Sets** (lecture)

*\*(in attendance) \**

**Part of the Module: Analyzing Massive Data Sets (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Analyzing Massive Data Sets** (exercise course)

*\*(in attendance) \**

**Examination**

**Analyzing Massive Data Sets**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0293: Advanced Deep Learning</b> <i>Advanced Deep Learning</i>		8 ECTS/LP
Version 1.1.0 (since WS18/19) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After participating in the practical module, students have detailed and up-to-date knowledge in the field of machine learning, can identify significant technical developments and can implement a complete pipeline for multimodal data processing with deep neural networks. They can precisely describe and discuss problems and results in the field and apply learned concepts and methods to similar problems in machine learning. In addition, the students analyse advanced concepts, methods, procedures, techniques and technologies from the field of machine learning to apply them in research projects, transfer them to current industry-related tasks and actively participate in them. The students learn to transfer scientifically challenging topics in the field of machine learning to other research questions and, building on this, to work out a complex project in group work. They also have the teamwork and communication skills to discuss problems in the field, to discuss, describe and present questions and interim results. In addition, students can conduct detailed experiments and assess, compare and check results for plausibility.</p> <p><b>Key qualifications:</b> Advanced mathematical-formal methodology; Translating subject-specific solution concepts into programs and models; Methods for developing larger software systems, construction of abstractions and architectures; Interdisciplinary knowledge; Systematic further development of design methods; Skill of confident and convincing presentation of ideas and concepts; Understanding of team processes; Skill of working in teams; Ability to lead teams; Familiarity with procedures and processes in the application environment of computer science; Skill of solving problems under practical boundary conditions; Self-reflection; Responsible action against the background of inadequacy and conflicting interests; Ability to expand existing knowledge independently; Quality awareness, meticulousness</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 20 h lecture (attendance) 40 h exercise course (attendance)</p>		
<p><b>Conditions:</b> Fundamental knowledge in computer vision (basic studies lectures "Multimedia Grundlagen 1", "Grundlagen der Signalverarbeitung und des Maschinellen Lernens", "Multimedia Grundlagen 2" as well as master's lectures "Multimedia 2" and "Machine Learning and Computer Vision")</p>		<p><b>Credit Requirements:</b> Passing the portfolio examination</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Advanced Deep Learning (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Deep Learning in general
- Deep Convolutional Neural Networks
- Transfer Learning
- Recurrent Neural Networks / LSTM Networks
- Natural Language Processing
- Multimodal Fusion (Vision+Language)
- Application: Image Captioning

**Part of the Module: Advanced Deep Learning (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Advanced Deep Learning**

portfolio exam, The final grade is made up of assessed exercise sheets and an assessed team project., graded

**Test Frequency:**

when a course is offered

**Description:**

Die Endnote setzt sich aus bewerteten Übungsblättern und einem bewerteten Teamprojekt zusammen.

<b>Module INF-0307: Model-Based Development and Analysis of Software Systems</b> <i>Modellbasierte Entwicklung und Analyse von Software Systemen</i>		6 ECTS/LP
Version 1.1.0 (since SoSe19) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Model-based development and analysis of software systems deals with increasing efficiency in software development through automation and reuse. In this course, participants learn to apply and compare methods for model-driven development of software systems. In doing so, they develop in-depth, subject-specific solution concepts for MDSD. They will be able to evaluate current technologies and standards for MDSD and analyse their applicability in practical tasks. Participants will develop skills for analysing and structuring complex IT problems when generating infrastructure code, subsystems, configurations or entire applications from models. In doing so, they will develop logical, analytical and conceptual thinking skills and will be able to systematically develop and evaluate solutions to problems.</p> <p>Key qualifications: Interdisciplinary knowledge; ability to connect different subject areas; teamwork and communication skills; ability to independently expand existing knowledge; quality awareness; familiarity with the procedures and processes in the application environment of computer science; knowledge and understanding of formal quantitative fundamentals; ability to present and document results in a comprehensible manner.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>23 h studying of course content using literature (self-study)</p> <p>22 h studying of course content using provided materials (self-study)</p> <p>30 h exercise course (attendance)</p> <p>45 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Knowledge of object-oriented programming</li> <li>• Fundamental knowledge of modeling languages (e.g., UML)</li> <li>• Fundamental knowledge of software architectures and design patterns</li> <li>• Frühere Veranstaltung "Modellgetriebene Softwareentwicklung" darf <b>nicht</b> belegt worden sein wegen Überschneidungen.</li> <li>• The previous course 'Model-Driven Software Development' must not have been taken due to overlaps.</li> </ul>		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 5,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Model-Based Development and Analysis of Software Systems (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 3,00</p>		

**Contents:**

Model-based development and analysis of software systems deals with increasing efficiency in software development through automation and reuse. Infrastructure code, subsystems, configurations or entire applications are generated from models.

**Literature:**

- Slides
- Pohl et al. Software Product Line Engineering: Foundations, Principles, and Techniques
- Kleppe et al: MDA explained
- Hitz et al: UML@Work
- weitere Literatur in der Vorlesung zu speziellen Themen

**Part of the Module: Model-Based Development and Analysis of Software Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination**

**Model-Based Development and Analysis of Software Systems**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0308: Software-Intensive Systems</b> <i>Software-intensive Systeme</i>		6 ECTS/LP
Version 1.2.0 (since SoSe19) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b> Students are able to design (K3), evaluate (K6), and document software architectures. For this purpose, they can transfer domain-specific solution concepts into models and are familiar with methods for developing such abstractions and architectures. They are able to describe the advantages and disadvantages of design alternatives (K4) and to evaluate them in the respective application context (K6). Problems can be independently identified (K4), and solutions can be systematically designed (K5) and implemented (K3). Furthermore, students have developed skills for analyzing and structuring problem domains within enterprise architectures and are familiar with the concepts and procedures for creating such architectures. Students are able to identify practice-relevant questions in enterprise architectures (K1). They can select appropriate methods for architecture design and evaluation and apply them confidently. Students are familiar with modeling languages and patterns for creating software and enterprise architectures. They have the competence to recognize significant technological developments.</p> <p><b>Key competencies:</b> Ability to integrate knowledge from different disciplines; teamwork and communication skills; ability to independently extend existing knowledge; quality awareness; ability to clearly present and document results; practical experience and professional qualification.</p>		
<p><b>Workload:</b> Total: 180 h 22 h studying of course content using provided materials (self-study) 23 h studying of course content using literature (self-study) 45 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Knowledge of object-oriented programming</li> <li>• Fundamental knowledge of modeling languages (e.g., UML)</li> <li>• Fundamental knowledge of software architectures and design patterns</li> <li>• The previous course 'Software-intensive Systems' must not have been taken due to overlaps.</li> </ul>		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 5,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Software-intensive Systeme (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> Sommersemester <b>Contact Hours:</b> 3,00</p>
<p><b>Contents:</b> The lecture content includes patterns, modelling techniques and the evaluation of software architectures. Furthermore, the area of enterprise architecture management is addressed.</p>

**Literature:**

- Bass et al: Software Architecture in Practice
- Clements et al: Documenting Software Architectures
- Clements et al: Evaluation of Software Architectures
- Kopetz: Real-Time Systems

**Part of the Module: Software-intensive Systeme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** Sommersemester

**Contact Hours:** 2,00

**Examination**

**Software-intensive Systeme**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0309: Real-Time Systems</b> <i>Echtzeitsysteme</i>		8 ECTS/LP
Version 1.11.0 (since WS19/20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture imparts basic and advanced knowledge of real-time systems as they occur in almost all embedded systems, but especially in the areas of automotive, aerospace and robotics. The theoretical foundations will be based on the current state of research and will enable students to further engage with the topic of embedded real-time systems at a scientific level.</p> <p>The lecture will provide students with the ability to distinguish and classify different embedded systems based on their real-time requirements. Students will learn to apply, compare, and critically analyze current methods for validation of timing behavior with respect to possible certification of timing behavior. This includes the optimization and selection of real-time schedules and their verification. The lecture will also cover different processor types, and will go into more detail about the specifics of single-core and multi-core processors in the real-time domain. Students will be able to classify processors based on their suitability for real-time systems and to investigate the impact of design decisions on real-time behavior and real-time behavior analysis.</p> <p>The course material will be exemplified by case studies from the automotive and aerospace fields and applied by the students using a simple real-time system.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against a background of inadequacy and conflicting interests.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>60 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Echtzeitsysteme (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

- WCET Analysis
- Scheduling Analysis
- Programming of real-time systems
- Processors for real-time systems
- Real-time operating systems
- Certification of real-time systems

**Literature:**

- Sanjoy Baruah, Marko Bertogna, Giorgio Buttazzo, Multiprocessor Scheduling for Real-Time Systems, Springer, 2015.
- Giorgio Buttazzo, Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications, Springer, 2011.
- Heinz Wörn, Uwe Brinkschulte, Echtzeitsysteme, Springer Verlag, Berlin/Heidelberg, 2005
- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Verlag, Heidelberg, dritte Auflage 2010

**Part of the Module: Echtzeitsysteme (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Echtzeitsysteme**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

this semester

<b>Module INF-0316: Machine Learning and Computer Vision</b> <i>Machine Learning and Computer Vision</i>		8 ECTS/LP
Version 1.0.0 (since SoSe19) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students possess advanced knowledge of machine learning (decision trees, neural networks and deep neural networks, hypothesis evaluation, instance-based learning, Bayesian learning, learning theory), data reduction (e.g. principal component analysis), advanced image processing and machine vision and are able to apply them. They can analyse, understand and programmatically implement scientifically complex procedures in the field of multimedia data processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of digital signal processing and multimedia data processing.</p> <p><b>Key qualifications:</b> advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.</p>		
<p><b>Workload:</b> Total: 240 h 30 h exercise course (attendance) 60 h lecture (attendance) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each summer semester (except for summer term 2026)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Machine Learning and Computer Vision (Lecture)</b>  <b>Mode of Instruction:</b> lecture  <b>Language:</b> German  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b>  The lecture gives a good overview of all aspects of machine learning and machine extraction of information from multimedia data (e.g. "Google Image Search", "Google Goggles"). The learned concepts will be practised, analysed, and evaluated in the exercises using successful examples from practice. At the end of the semester, advanced topics such as object detection and object recognition of faces and people will be covered. The contents of the lecture include: Machine Learning (Decision Tree Learning, Artificial Neural Networks, Bayesian Learning, Discrete Adaboost), Data Reduction (Quantization (K-Means Clustering, Affinity Propagation), Dimensionality Reduction Techniques (PCA, NMF, Random Projection, MDS)) and Image Processing &amp; Computer Vision (Salient Feature Points and Feature Descriptors, Object Detection (Face/Car/People Detection), Object Recognition (Face Recognition), Image Search with pLSA).</p>

**Literature:**

Literature references will be announced at the beginning of the semester.

**Assigned Courses:**

**Machine Learning and Computer Vision** (lecture)

*\*(in attendance) \**

**Part of the Module: Machine Learning and Computer Vision (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Machine Learning and Computer Vision** (exercise course)

*\*(in attendance) \**

**Examination**

**Machine Learning and Computer Vision**

written exam / length of examination: 120 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0318: Practical Module on Simulation of Autonomous Vehicles</b> <i>Praktikum Simulation von autonomen Fahrzeugen (Vertiefung)</i>		8 ECTS/LP
Version 1.0.0 (since WS19/20) Person responsible for module: Prof. Dr. Lars Mikelsons		
<b>Learning Outcomes / Competences:</b> Subject-related competencies: After participating in the internship, students understand problems of higher complexity in the field of simulation of autonomous vehicles and have deeper technical knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in small groups and are able to apply innovative methods in solving problems. This enables them to connect to international research and implement existing concepts. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate objectives, and critically evaluate, classify, combine and present intermediate results and innovative ideas.  Key Competencies: Skill in logical, analytical, and conceptual thinking; Validation of simulation results and software modules; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in collaborating in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;		
<b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Good programming skills Helpful: Python, C++, ROS, Game Engines		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Practice Model on Simulation of Autonomous Vehicles (Advanced)</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00 <b>ECTS Credits:</b> 8.0		
<b>Contents:</b> In the practical course, students work in small groups on application-oriented tasks for the simulation of autonomous vehicles. They are allowed to implement and validate individual software modules of a virtual vehicle themselves.		

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**Examination**

**Practice Model on Simulation of Autonomous Vehicles**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0335: Safety-Critical Systems</b> <i>Safety-Critical Systems</i>		5 ECTS/LP
Version 1.2.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students will learn about fault tolerance requirements in embedded systems and classify them using the underlying regulations and standards (e.g. ISO 26262) for designing safety-relevant systems. They are able to describe the causes and effects of hardware faults and are able to analyze and evaluate different redundancy techniques.</p> <p>The course also focuses on applying the stochastic principles of fault calculus, analyzing and modeling computing systems with reliability block diagrams and fault trees, and differentiating different types of redundancy and using them in various hardware and software techniques for fault detection.</p> <p>Techniques for error correction, fault diagnosis, and reconfiguration are also introduced and explored. Students learn to classify and compare different concepts of fault-tolerant computing systems from theory and practice, such as lockstep execution, process redundancy, ECC memory implementations, or control flow checking.</p> <p>In the practical exercises, students apply the methods of modeling and fault computation to various tasks, work out their solutions, and compare on a qualitative level various fault tolerance concepts from research and practice.</p> <p><b>Key qualifications:</b> Analytical-methodical competence in the analysis of fault-tolerant computational systems, consideration of solution approaches, comprehensible presentation of solutions to exercise problems, ability to extend existing knowledge independently, self-reflection.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Safety-Critical Systems (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture considers methods for maintaining functional safety in computing systems, as well as their design and analysis. First, different types of faults are characterized and the importance of fault models is emphasized. Then, different hardware and software methods for detecting and tolerating faults are presented. The measures discussed refer not only to structural, but also to temporal and informational redundancy (fault tolerant codes). After a brief review of probability theory and combinatorics, various analysis methods such as classical probability theory, reliability block diagrams, Markov chains, FMEA, and fault trees are presented, differences highlighted, and explained with practical examples. Various fault injection methods necessary for evaluating fault tolerant systems are briefly discussed.

**Literature:**

- D. Sorin: Fault Tolerant Computer Architecture, Morgan and Claypool, 2009
- S. Mukherjee: Architecture Design for Soft Errors, Morgan Kaufmann, 2008
- I. Koren, C.M. Krishna: Fault-Tolerant Systems, Morgan Kaufmann, 2007

**Part of the Module: Safety-Critical Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Examination****Safety-Critical Systems**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0367: Advanced Machine Learning and Computer Vision</b> <i>Advanced Machine Learning and Computer Vision</i>		5 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students have in-depth advanced knowledge of machine learning (support vector machines and deep neural networks and their basic building blocks) and machine vision (deep neural network architectures and systems) and can apply these. They can analyse, understand and programmatically implement scientifically complex procedures in the field of image, text, video and signal processing, as well as to appropriately apply the principles learned to new problems. They develop skills in logical, analytical and conceptual thinking in the field of machine learning and vision.</p> <p><b>Key qualifications:</b> advanced mathematical-formal logic; critical reading and analysis of scientific publications; implementation of technical solution concepts; interdisciplinary knowledge; development and implementation of solution strategies of complex problems; systematic further development of design methods; skills in solving problems under practical boundary conditions</p>		
<p><b>Workload:</b> Total: 150 h 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b> "Knowledge of Machine Learning and Computer Vision" (Master's lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")</p>		<p><b>Credit Requirements:</b> Passing the module examination</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b> from 2.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Advanced Machine Learning and Computer Vision (Lecture)</b>  <b>Mode of Instruction:</b> lecture  <b>Language:</b> German / English  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> The lecture gives an in-depth insight into all aspects of machine learning and machine vision. The concepts learned will be practiced, analyzed and evaluated in the exercises using successful real-world examples. The contents of the lecture include: support vector machines, basic building blocks of deep neural networks (layer structures, normalization, attention mechanisms), as well as current reference architectures and systems for image, text, video processing and their combination with further sensor signals.</p>
<p><b>Literature:</b> Will be announced at the beginning of the semester.</p>

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**Part of the Module: Advanced Machine Learning and Computer Vision (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination**

**Advanced Machine Learning and Computer Vision (Examination)**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0368: Embedded Hardware</b> <i>Embedded Hardware</i>		5 ECTS/LP
Version 1.2.0 (since WS20/21) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides basic and advanced knowledge of hardware components (e.g. GPIO, hardware timer, ...) as they are found in almost all embedded systems. Furthermore, the functional principles of different sensors and actuators are presented. A special focus will be on their use to interact with the physical world and on particularities of their application. The theoretical foundations will be based on the current state of research and will allow students to further engage with the topic of embedded hardware at a scientific level.</p> <p>The lecture will provide students with the ability to distinguish and classify different embedded systems based on their hardware requirements. Students will learn to apply current component programming methods, compare them, and critically analyze them for efficient use. This includes selecting and evaluating hardware components relevant to the system, as well as developing a configuration of components optimized for an existing problem. The lecture will also cover various sensors and actuators, and will go into more detail about the conversion between an analog, physical quantity and a digital, electrical quantity. Here, students will be able to classify physical quantities based on their properties and make a decision about the sensors, actuators, and hardware components needed for the conversion.</p> <p>The subject matter is exemplified by means of case studies, e.g. from the automotive field, and applied by the students using a simple embedded system.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, consideration of approaches to solutions, presentation of solutions to exercise problems; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; quality awareness, meticulousness; self-reflection; responsible action against the background of inadequacy and conflicting interests.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Embedded Hardware (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Modeling of sensors and actuators
- Basics in electronics
- Hardware components of embedded processors and SoC
- Serial interfaces
- Sensors and input devices
- Actuators and output devices

**Literature:**

- Yifeng Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, E-Man Press LLC, 2017
- Edward Ashford Lee, Sanjit Arunkumar Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, MIT Press, 2017
- Elecia White, Making Embedded Systems, O'Reilly Media, 2012
- John Catsoulis, Designing Embedded Hardware, O'Reilly Media, 2005
- Rüdiger R. Asche, Embedded Controller: Grundlagen und praktische Umsetzung für industrielle Anwendungen, Springer, 2016
- Hermann Winner, Stephan Hakuli, Felix Lotz, Christina Singer Hrsg., Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 2015
- Bernhard Grimm, Gregor Häberle, Heinz Häberle, u.a., Fachkunde Industrieelektronik und Informationstechnik, Europa Lehrmittel, 2003

**Part of the Module: Embedded Hardware (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Embedded Hardware**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0371: Approximation Algorithms</b> <i>Approximation Algorithms</i>		5 ECTS/LP
Version 1.3.0 (since WS20/21) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b> Developing an understanding of central topics in the field of approximation algorithms; acquiring powerful mathematical tools to analyze algorithms; improve the ability to abstract and systematically solve optimization problems. <b>Key Skills:</b> Ability to build intuitive understanding of mathematical formalisms; ability to identify core properties of optimization problems; deep understanding of powerful mathematical tools		
<b>Remarks:</b> <b>You can take this course only when you did not visit the course <i>INF-0420: Approximationsalgorithmen!</i></b>		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Basic knowledge of Algorithms and Data Structures (e.g., "INF-0111: Informatik 3") and Theoretical Computer Science (e.g., "INF-0110: Einführung in die Theoretische Informatik").		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Approximation Algorithms (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00
<b>Contents:</b> Given an NP-hard optimization problem, how well can it be approximated in polynomial time? It is exciting and challenging to understand the approximability of fundamental optimization problems. This course mainly focuses on upper bounds, i.e., designing efficient approximation algorithms.  In this course, we will study several classes of problems, such as packing problems, network design, and graph problems. We will cover central algorithmic techniques for designing approximation algorithms, including greedy algorithms, dynamic programming, linear and semi-definite programming, and randomization.
<b>Literature:</b> <ul style="list-style-type: none"> <li>• David P. Williamson and David B. Shmoys, The Design of Approximation Algorithms, Cambridge University Press.</li> <li>• Vijay V. Vazirani, Approximation Algorithms, Springer.</li> </ul>

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**Part of the Module: Approximation Algorithms (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 2,00

**Examination**

**Approximation Algorithms**

portfolio exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0379: Practical Module Simulation of Cyber-Physical Systems</b> <i>Praktikum Simulation cyber-physischer Systeme</i>		6 ECTS/LP
Version 1.0.0 (since SoSe21) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b> After successful participation in this module, students will be able to apply advanced methods of simulation to use virtual prototypes for model-based development of mechatronic systems. They know methods for different application areas along the development process and interpret their result.</p> <p><b>Methodological competencies:</b> Students are able to evaluate different simulation methods for different application areas. They are also able to select and independently apply suitable simulation methods depending on the simulation purpose.</p> <p><b>Interdisciplinary competencies:</b> Students are able to solve certain engineering problems with the help of information technology. They can use abstractions of physical systems and apply them in combination with information technology methods for the development of mechatronic systems.</p> <p><b>Key Competencies:</b> Advanced skill in answering engineering questions, particularly in the area of mechatronic systems design, using virtual prototypes; selection and application of advanced simulation methods; assessment and analysis of mathematical models.</p>		
<p><b>Workload:</b> Total: 180 h 90 h internship / practical course (attendance) 90 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b> Attendance of the course Mechatronics and/or object-oriented methods of modeling and simulation.</p>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b> from 4.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Praktical Module Simulation of Cyber-Physical Systems</b>  <b>Mode of Instruction:</b> internship  <b>Lecturers:</b> Prof. Dr. Lars Mikelsons  <b>Language:</b> German / English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 6,00</p>		

**Contents:**

Nowadays, the development of mechatronic systems is generally model-based. In doing so, the application of simulation in practice often encounters the following challenges:

- How do I improve a physical model when measurements become available?
- How do I know how much I can trust my model?
- How do I combine simulation of physical systems with virtual control units?
- How can I even use simulation to investigate the safety of the real system?

In this lab, students will learn methods for answering these (and other) questions and apply what they learn through hands-on exercises. Experts from industrial practice are brought in for some parts of the course.

**Examination**

**Praktical Module Simulation of Cyber-Physical Systems**

portfolio exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0381: Embedded Systems - Advanced Course</b> <i>Embedded Systems - Vertiefung</i>		5 ECTS/LP
Version 1.3.0 (since SoSe21) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides in-depth knowledge on changing focus topics in embedded systems, which are used in nearly all areas of industry—such as automotive, aerospace, and robotics—as well as in everyday life. The focus topics are selected from the field of developing and analyzing safe, reliable, and high-performance embedded systems. In particular, current research questions are addressed, and discussions are held on how embedded systems might be developed and analyzed in the future.</p> <p>Students will, on the one hand, be enabled to identify and justify the specific requirements of embedded systems. On the other hand, they will learn to apply various development techniques and analysis methods for embedded systems to examples, and to evaluate and classify them with respect to reliability and practicality. Furthermore, the lecture imparts the ability to independently analyze scientific theses related to the focus topics, formulate their own theses, evaluate them, and, if necessary, refute them. The focus topics will be aligned with the current state of research and will enable students to further engage with the subject of embedded systems on a scientific level.</p> <p><b>Key qualifications:</b> Analytical-methodical competence, scientific methodology; principles of good scientific practice; skill in presenting and documenting results in a comprehensible manner; independent work with English-language specialist literature; ability to independently expand existing knowledge; analytical-methodological competence; skill in clear and confident oral presentation of (practical or theoretical) ideas, concepts, and results.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>60 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>none</p>		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Embedded Systems - Advanced Course (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <ul style="list-style-type: none"> <li>• Development and analysis of safe, reliable, and high-performance embedded systems</li> <li>• Non-functional properties of embedded systems</li> <li>• Current research questions and topics in the field of embedded systems</li> </ul>		
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Selected literature and current scientific articles on embedded systems (varies each semester)</li> </ul>		
<b>Assigned Courses:</b>		

**Embedded Systems - Advanced Course** (lecture)

*\*(in attendance) \**

**Part of the Module: Embedded Systems - Vertiefung (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercise for Embedded Systems - Advanced Course** (exercise course)

*\*(in attendance) \**

**Examination**

**Embedded Systems - Advanced Course**

oral exam / length of examination: 20 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0383: Algorithms for Big Data</b> <i>Algorithmen für Big Data</i>		5 ECTS/LP
Version 1.1.0 (since SoSe21) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b> Development and understanding of central competences in algorithm design for situations, where there are large amounts of data such that not all of them can be accessed without restrictions; acquisition of knowledge of mathematical tools to analyze algorithms; improvement of competences in abstract thinking and analyzing problems in a systematic manner.  <b>Key Qualifications:</b> Ability to develop an intuitive understanding of mathematical formalisms; ability to identify the core properties of algorithmic problems; deep understanding of useful mathematical tools		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)		
<b>Conditions:</b> Basic knowledge in algorithms and data structures (for example Informatik 3 (INF-0111)) and in probability theory (for example Stochastik für Informatiker (MTH-6040)).		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Algorithms for Big Data (lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00	
<b>Contents:</b> In modern data processing, we increasingly have the problem that there are large quantities of data which can only be stored on cheap and slow mass storage media. Algorithmically, this poses the problem that at each point in time, we can only access a snapshot of the data, for example in a sequential manner. In the course, we study algorithms that despite such limitations provably yield high quality results.	
<b>Literature:</b> Wissenschaftliche Papiere, Surveys, Skripte	
<b>Assigned Courses:</b> <b>Algorithmen für Big Data</b> (lecture) *(in attendance) *	

**Part of the Module: Algorithms for Big Data (exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Algorithmen für Big Data** (exercise course)

*\*(in attendance) \**

**Examination**

**Algorithms for Big Data**

portfolio exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0408: Extremal Combinatorics</b> <i>Extremal Combinatorics</i>		5 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Tobias Mömke		
<b>Learning Outcomes / Competences:</b>		
<b>Knowledge</b> Developing an understanding of central topics in the field of combinatorics; acquiring powerful mathematical tools to analyze performance of algorithms; improve the ability to abstract and systematically solve counting problems.		
<b>Methodical Competences</b> The students are able to develop and write mathematical proofs in the context of advance combinatoric problems. They are able to understand complex reasoning and judge the correctness of mathematical arguments. The students are able to develop novel solution approaches, as solutions to relevant questions are usually not unique		
<b>Key Skills</b> Ability to build intuitive understanding of mathematical formalisms; ability to identify core properties of optimization problems; deep understanding of powerful mathematical tools; Skills of mathematical thinking		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance)		
<b>Conditions:</b> Basic knowledge in mathematics, in particular linear algebra is necessary. Basic knowledge in graph theory is recommended.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Extremal Combinatorics (Vorlesung)</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English / alle Sprachen		
<b>Frequency:</b> irregular		
<b>Contact Hours:</b> 2,00		
<b>Contents:</b> How many people do you need to invite for your party, in order to have 3 strangers or a group of 3 friends? If 10 people have keys to a safe, how many locks are necessary to make sure any 5 of them can open it? What is the dictator paradox, and should you be worried about it? This course provides an introduction to extremal combinatorics, which helps us to find answers to the questions above.		
<b>Literature:</b>		

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**Part of the Module: Extremal Combinatorics (Übung)**

**Mode of Instruction:** exercise course

**Language:** English / alle Sprachen

**Frequency:** irregular

**Contact Hours:** 2,00

**Examination**

**Extremal Combinatorics**

oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0409: Cyber Security</b> <i>Cyber Security</i>		6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.</p> <p>To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for</p> <p>They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.</p> <p>Key qualification: Competence to network different subject areas; team and ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>23 h studying of course content using literature (self-study)</p> <p>22 h studying of course content using provided materials (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>45 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Fundamental knowledge of software development and software engineering</li> <li>• Fundamental knowledge of software architectures and software development processes</li> <li>• Basic knowledge of IT systems, operating systems, and computer networks</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester SoSe 25 danach WiSe 26-27</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 5,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Cyber Security (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 3,00</p>
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**Contents:**

The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.

**Literature:**

- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

**Part of the Module: Cyber Security (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Examination**

**Cyber Security**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0410: Gesture-Based Communication in Human-Computer Interaction</b> <i>Gesture-Based Communication in Human-Computer Interaction</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students understand the essential concepts of gesture-based communication in human-computer interaction. They are able to translate technical solution concepts into programs and models and master the selection and application of suitable methods. They have the knowledge of the way of thinking and the language of application-relevant disciplines. Within the framework of the lecture, they learn to evaluate learning components in a scientifically meaningful way using suitable methods, to develop the methods and algorithms independently and to implement them technically. Particularly promoted in this framework are also the skills for confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as logical, analytical and conceptual thinking.</p> <p><b>Key qualifications:</b> Advanced mathematical formal methodology, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in collaborating in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Gesture-Based Communication in Human-Computer Interaction (Lecture)</b>  <b>Mode of Instruction:</b> lecture  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b>  HCI methods and principles, Interaction design, Nonverbal communication, Gestures, Gesture recognition systems, Collaboration, Applied computer vision, Ubiquitous computing</p>
<p><b>Part of the Module: Gesture-Based Communication in Human-Computer Interaction (Exercise Course)</b>  <b>Mode of Instruction:</b> exercise course  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 4,00</p>

**Examination**

**Gesture-Based Communication in Human-Computer Interaction**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0418: Practical Module Conversational AI: Virtual Assistants and Chatbots</b> <i>Praktikum Conversational AI: Virtual Assistants and Chatbots</i>		5 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> Students are familiar with methods and techniques of interaction design and engineering for health care applications. After successful participation, they will have the necessary knowledge to analyze application scenarios according to the guidelines of the user-centered design process and to design software solutions tailored to the target group. They are able to translate current interaction paradigms and design guidelines into models and programs for novel interaction devices, as well as to independently familiarize themselves with the necessary technologies. Furthermore, they are able to apply practice-relevant evaluation methods to assess the quality of the created software prototype. They are able to plan larger project tasks in small teams, solve them according to a self-developed project plan and discuss the results appropriately in plenary sessions and present them as a team.</p> <p><b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the mindset and language of application-relevant disciplines; understanding of team processes; skill in collaborating in teams; skill in leading teams; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 150 h 90 h studying of course content through exercises / case studies (self-study) 60 h internship / practical course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Practical Module Interaction Design and Engineering for Health Care Applications</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4,00</p>		
<b>Contents:</b> The specific assignment for student projects is designed each year.		
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.		
<b>Examination</b>		
<p><b>Practical Module Interaction Design and Engineering for Health Care Applications</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>		

<b>Module INF-0425: Cyber Security 2</b> <i>Cyber Security 2</i>		6 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students can create (K3), evaluate (K6), and document security aspects in the software development process and software architectures.</p> <p>To this end, they can transfer technical solution concepts into development processes and IT architectures and know methods for developing secure software. They can describe the advantages and disadvantages of security alternatives (K4) and evaluate them in the respective application context (K6). Problems can be identified independently (K4) and solutions systematically designed (K5) and implemented (K3). Furthermore, they have developed skills for analyzing and structuring the problems of security architectures and know the concepts and procedures for creating such architectures. Students can name practice-relevant issues in security architectures and secure software development processes (K1). They can select suitable methods for</p> <p>They can select and safely apply suitable methods for creating and evaluating security architectures. The students know concepts and technologies for developing secure software and security architectures. They have the competence to recognize significant technical developments.</p> <p>Key qualification: Competence to network different subject areas; team and ability to communicate; ability to expand existing knowledge independently; quality awareness; ability to present and document results understandably; practical experience and professional aptitude.</p>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>30 h exercise course (attendance)</p> <p>45 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>23 h studying of course content using literature (self-study)</p> <p>22 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Solid knowledge of software development and software engineering</li> <li>• Good knowledge of software and IT architectures</li> <li>• Knowledge of secure software development processes</li> <li>• Basic knowledge of operating systems, computer networks, and IT security mechanisms</li> </ul>		
<p><b>Frequency:</b> each summer semester erst wieder ab SoSe 26</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 5,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Cyber Security 2 (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 3,00</p>
<p><b>Contents:</b></p> <p>The lecture content includes security standards, secure software development lifecycles, as well as security architectures, and their evaluation in respective technology contexts. and the evaluation of security architectures.</p>

**Literature:**

- Slides
- A. Deane, A. Kraus: The Official (ISC)2 CISSP CBK Reference
- Further literature in the lecture on specific topics

**Assigned Courses:**

**Cyber Security 2** (lecture)

*\*(in attendance) \**

**Part of the Module: Cyber Security 2 (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Cyber Security 2** (exercise course)

*\*(in attendance) \**

**Examination**

**Cyber Security 2**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0427: Deep Ubiquitous and Wearable Computing for Healthcare</b> <i>Deep Ubiquitous and Wearable Computing for Healthcare</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> Students are familiar with methods and techniques of interaction design and engineering for health care applications. After successful participation, they will have the necessary knowledge to analyze application scenarios according to the guidelines of the user-centered design process and to design software solutions tailored to the target group. They are able to translate current interaction paradigms and design guidelines into models and programs for novel interaction devices, as well as to independently familiarize themselves with the necessary technologies. Furthermore, they are able to apply practice-relevant evaluation methods to assess the quality of the created software prototype. They are able to plan larger project tasks in small teams, solve them according to a self-developed project plan and discuss the results appropriately in plenary sessions and present them as a team.</p> <p><b>Key qualifications:</b> Skill in confident and persuasive presentation of ideas and concepts; knowledge of the mindset and language of application-relevant disciplines; understanding of team processes; skill in collaborating in teams; skill in leading teams; skill in presenting and documenting results in a comprehensible manner; ability to expand existing knowledge independently; ability to contribute to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Practical Module Interaction Design and Engineering for Health Care Applications</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> The specific assignment for student projects is designed each year.		
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.		

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**Part of the Module: Deep Ubiquitous and Wearable Computing for Healthcare (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Practical Module Interaction Design and Engineering for Health Care Applications**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0428: Practical Module Programming Parallel Embedded Systems</b> <i>Praktikum Programming Parallel Embedded Systems</i>		5 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students analyse the particular requirements of embedded systems and optimise the software they develop regarding the available resources and mandatory time limits. They create parallel applications for embedded systems in an industry-typical programming language. The emerging problems of implementing multithreaded applications are identified and suitable solutions for those are developed. Different data structures for use in parallel applications are classified, their implementations are reviewed, and the performance is evaluated. Debugging and code-analysis techniques are applied, and different optimisation possibilities are investigated.</p> <p>The students apply the skills they learned in projects, building parallel applications independently. Further, the performance of the developed software is evaluated, and analysed regarding the project requirements.</p> <p><b>Key qualifications:</b> Analytical and methodological competence; selection and confident use of appropriate methods; ability to expand existing knowledge independently; skill in presenting and documenting ideas, concepts and results in a comprehensible manner; self-reflection</p>		
<p><b>Workload:</b></p> <p>Total: 150 h 90 h studying of course content through exercises / case studies (self-study) 60 h internship / practical course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: <i>Praktikum Programming Parallel Embedded Systems</i></b></p> <p><b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. winter semester) <b>Contact Hours:</b> 4,00</p>		
<p><b>Contents:</b></p> <p>In the practical module, essential techniques to develop software projects in an industry-typical programming language are investigated, as well as methods for code-analysis, and for testing and debugging. Special focus is on programming parallel and concurrent applications with tasks and threads for single- and multi-core processors, and on programming with GPGPUs. Platform-independent programming is demonstrated on different systems, from 8 bit microcontrollers to 64 bit workstations, while the effects of the instruction set architecture on the performance of the software are analysed, and the resulting potential performance optimisations are evaluated. After the introduction into the essential features of the programming language, the typically used tools, as well as relevant parallel data structures, the students implement a parallel application in a larger project.</p>		

**Examination**

**Praktikum Programming Parallel Embedded Systems**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0432: Isabelle-Lab</b> <i>Isabelle-Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Kirstin Peters		
<p><b>Contents:</b></p> <p>The general idea of interactive theorem proving is introduced and the tool Isabelle/HOL is discussed. Several common features of Isabelle/HOL are studied: e.g. basic concepts such as data structures and functions, modelling mechanisms such as locales, proof techniques such as structural induction, and the proof language Isar.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Knowledge:</b> Students will get to know the key concepts, definitions, and techniques of interactive theorem proving with Isabelle/HOL. They will get insights and practical knowledge about the design of models in Isabelle/HOL such as the conception of data structures and functions or the abstraction of concepts into a locale. They will learn strategies to tackle complex and technically very detailed proofs. They will learn about automated reasoning mechanisms as well as interactive proof tactics; their respective advantages and typical areas of application. Finally, students learn about the guarantees provided by machine checked proofs and the additional complexity that comes with such projects.</p> <p><b>Skills:</b> Students will be familiar with the basic concepts of modelling and proving in Isabelle/HOL. Students will be able to formally and correctly model applications and concepts in Isabelle/HOL. They are able to select appropriate proof methods and carry out complex proofs with the assistance of Isabelle/HOL. They understand the hints provided by the proof assistance, can analyse the current state of a proof and its proof obligations, and can carry out the next relevant steps. They understand under which circumstances the automatic proof methods are useful and how to apply them. Moreover, they are able to plan and carry out a project and meet the time restrictions that come with such a project. Finally, they will practice logical and conceptual thinking as well as the abstraction and formalisation of concepts in a stringent mathematical framework.</p> <p><b>Competences:</b> Students are prepared to work on verification projects. Students are able to plan and carry out the modelling as well as the proof obligations of such a project in an interactive theorem prover. They understand the nature of the correctness guarantees provided by machine checked proofs, but also the additional complexity that is necessary to carry out such proofs. Furthermore, they know how to characterise and judge on the quality and suitability of existing models and theories in Isabelle/HOL. More abstractly, they are able to reason more concretely about the correctness of a formalisation and proofs.</p> <p><b>Key skills:</b> Formal methods; Knowledge of advantages and disadvantages of different design alternatives in modelling; Ability to carry out very detailed proofs; Ability to work on and organise projects; Ability to work autonomously; Quality awareness; Scientific working.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Isabelle-Lab (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00
<b>Contents:</b> We discuss the basic design of Isabelle and how to work with this interactive theorem prover. In particular we study: <ul style="list-style-type: none"><li>• higher-order logic (HOL)</li><li>• isabelle syntax and semantics</li><li>• proof strategies</li><li>• induction and induction principles</li><li>• formalisation of theories in Isabelle/HOL</li><li>• proof support (proof tactics and external assistance)</li><li>• proof language Isar</li></ul>
<b>Literature:</b> <a href="https://isabelle.in.tum.de/documentation.html">https://isabelle.in.tum.de/documentation.html</a>
<b>Part of the Module: Isabelle-Lab (Übung)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4,00
<b>Examination</b> <b>Isabelle-Lab</b> practical exam, graded <b>Test Frequency:</b> when a course is offered

<b>Module INF-0440: Quantum Algorithms</b> <i>Quantum Algorithms</i>		5 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann		
<b>Contents:</b> Foundations of Quantum Information Processing: <ul style="list-style-type: none"> <li>• qubits and their representation</li> <li>• BraKet notation and necessary structures from linear algebra</li> <li>• operations on qubits: circuits and gates</li> </ul> Quantum Algorithms <ul style="list-style-type: none"> <li>• quantum search and amplitude amplification</li> <li>• quantum fourier transform and it's applications</li> <li>• quantum simulation</li> <li>• variational quantum algorithms</li> <li>• differentiable quantum algorithmic procedures</li> <li>• quantum heuristics</li> <li>• usecases from current day research</li> </ul>		
<b>Learning Outcomes / Competences:</b> Students acquire basic knowledge of quantum algorithms and are able to explain fundamental principles and describe their use in algorithmic structures. They can describe established algorithmic structures from the field of quantum algorithms, such as search, Fourier transform, and phase estimation, and determine and compare potential areas of application. After attending the course, they will be able to construct quantum algorithmic approaches and translate them into discrete operations on qubit systems. Students will have a sound basic knowledge of fundamental quantum algorithmic structures and variational heuristics. They will be able to identify, analyze, and evaluate quantum algorithmic elements in current literature.		
<b>Workload:</b> Total: 150 h 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 30 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> Linear Algebra (basics)		<b>Credit Requirements:</b> Passing the exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Quantum Algorithms (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Foundations of Quantum Information Processing:

- qubits and their representation
- BraKet notation and necessary structures from linear algebra
- operations on qubits: circuits and gates

Quantum Algorithms

- quantum search and amplitude amplification
- quantum fourier transform and it's applications
- quantum simulation
- variational quantum algorithms
- differentiable quantum algorithmic procedures
- quantum heuristics
- usecases from current day research

**Literature:**

**Basics of Quantum Information/Quantum Computation:**

- Michal Nielsen; Isaac Chuang: Quantum Computation and Quantum Information

**Basics of quantum mechanics:**

- Richard P. Feynman; Robert B. Leighton; Matthew Sands: Feynman-Vorlesungen über Physik: Band III, Quantenmechanik
- original scripts are online: <https://www.feynmanlectures.caltech.edu/info/>

**Overview over variational quantum algorithms:**

- <https://doi.org/10.1103/RevModPhys.94.015004>
- <https://doi.org/10.1038/s42254-021-00348-9>

**More on quantum algorithms:**

- <http://theory.caltech.edu/~preskill/ph229/> (chapter 5 provides a good summary of the well-known "traditional" quantum algorithms)

**Assigned Courses:**

**Quantum Algorithms** (lecture)

*\*(in attendance) \**

**Part of the Module: Quantum Algorithms (Übung)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Quantum Algorithms** (lecture)

*\*(in attendance) \**

**Examination**

**Quantum Algorithms**

oral exam / length of examination: 25 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0456: Content Creation for Virtual Environments</b> <i>Content Creation for Virtual Environments</i>		8 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful completion of this module, students will understand essential concepts and techniques for making and integrating 2D/3D graphics and audio for virtual environments. They have the knowledge of the mindset and language of application-relevant disciplines. Within the framework of the lecture, they learn to create content by hand and generatively with procedural methods and algorithms, taking into account design principles, to integrate the content into applications, to develop algorithms independently and to implement them technically. The skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as creative, aesthetic, musical, logical, analytical and conceptual thinking are also particularly promoted within this framework.</p> <p><b>Key Qualifications:</b> Aesthetic, design, artistic, and musical fundamentals, design of virtual worlds, selection and confident application of appropriate methods, interdisciplinary knowledge, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Content Creation for Virtual Environments (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<p><b>Part of the Module: Content Creation for Virtual Environments (Exercise Course)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4,00</p>		

**Examination**

**Content Creation for Virtual Environments**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0462: Embedded Hardware Lab</b> <i>Embedded Hardware Lab</i>		8 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>Over the course of the semester, students develop a complete embedded system as a coherent semester assignment. A core task of the course is to analyse the characteristics and recognize the functionality of microcontrollers and peripherals based on data sheets and specifications. The students will have the opportunity to assemble the components needed for an assignment and to define suitable interfaces. Due to the required development and implementation on a microcontroller, the students apply the concepts learned directly in practice. The focus is on the interaction with sensors and actuators as well as on the communication with other parts of the system. To this end, they will identify and apply different types of flow control. During the lab, students learn to plan complex assignments, design solutions and test and evaluate their functionality. The exchange among the students aimed at during the course enables them to appropriately compare and discuss the results achieved.</p> <p>Students acquire competencies in the following areas at an advanced, practice-oriented, but scientific level: independent work with microcontrollers, data sheets and specifications, interfacing of analog and digital peripherals, design and modelling of embedded software with state charts and their implementation in code. Further focus is on the configuration of sequential interfaces as well as scheduling and task-based programming.</p> <p><b>Key Qualifikations:</b> Ability to understand and document ideas, concepts and results; Consciousness of quality, meticulousness; Project-related work and time management; selection and correct application of appropriate methods; ability to expand existing knowledge independently; Self-reflection</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p>		
<p><b>Conditions:</b></p> <p>Module Foundations of Technical Computer Science (INF-0138) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Embedded Hardware Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> irregular</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The practical course "Embedded Hardware Lab" aims to learn the challenges of programming embedded systems. The central platform is a development board that offers a microcontroller as well as various sensors, actuators, displays and interfaces for further peripherals. The programming is done in C without the application of hardware abstraction layers and the created programs are supposed to read out different sensors and set corresponding actuators. In particular, the challenges of embedded systems, such as the timing of the software as well as working with data sheets, are to be learned. Towards the end of the course, the basic knowledge acquired at the beginning will be deepened and already existing sub-components will be assembled into a more complex embedded system.

**Literature:**

- Zhu, Yifeng: Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Third Edition, E-Man Press LLC, 2017
- White, Elecia: Making Embedded Systems, O'Reilly Media Inc., 2012
- Marwedel, Wehmeyer: Eingebettete Systeme, Springer Verlag, Heidelberg, 2007

**Part of the Module: Embedded Hardware Lab (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination****Embedded Hardware Lab**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0463: Embodied Characters and Interactive Virtual Worlds Lab</b> <i>Embodied Characters and Interactive Virtual Worlds Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> As part of the practical module, students implement interactive multimedia applications in the areas of 2D/3D/Virtual Reality/Serious Games/Simulations/Robotics. Essential concepts and techniques of embodied characters and virtual worlds include planning, making and integrating 2D/3D graphics, animations, user interfaces, storytelling and audio for virtual environments as well as conceptualizing and implementing user interaction. After successful participation, students will have the knowledge of the mindset and language of application-relevant disciplines. During the internship, they learn to create content by hand and generatively with procedural methods and algorithms, taking into account design and musical principles, to integrate the content into applications, to develop algorithms independently and to implement them technically. Particularly encouraged in this context are also the skills of confident and convincing presentation of ideas and concepts, comprehensible presentation and documentation of results, as well as creative, aesthetic, musical, logical, analytical and conceptual thinking.</p> <p><b>Key Qualifications:</b> Aesthetic, design, artistic and musical fundamentals, design of embodied characters and virtual worlds; skill in confident and convincing presentation of ideas and concepts; knowledge of the thinking and language of application-relevant disciplines; understanding of team processes; skill in working in teams; ability to lead teams; skill in comprehensible presentation and documentation of results; ability to expand existing knowledge independently; ability to make contributions to science; competence in recognizing significant technical developments; quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 90 h internship / practical course (attendance) 150 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Programming experience</li> <li>• INF-0456 Content Creation for Virtual Environments (recommended)</li> <li>• INF-0179 Einführung in die Spieleprogrammierung (optional)</li> <li>• INF-0183 Praktikum Spieleprogrammierung (optional)</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Practical Module Embodied Characters and Interactive Virtual Worlds</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 6,00</p>		
<p><b>Contents:</b> The specific task from the field of "Embodied Characters and Interactive Virtual Worlds" is designed anew each semester.</p>		
<p><b>Literature:</b> Ändert sich jedes Jahr und wird daher in der Veranstaltung bekannt gegeben</p>		

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**Examination**

**Practical Module Embodied Characters and Interactive Virtual Worlds**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0464: Conversational Artificial Intelligence</b> <i>Conversational Artificial Intelligence</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> In the course of this lecture, the student seeks a general understanding of multimodal spoken dialogue systems technology. He acquires some basic knowledge in the field. He understands general problems of speech synthesis, speech recognition, semantic analysis and dialogue modelling. The presentation of current technologies, some selected solutions, applications and products will foster this knowledge. The student understands the interdisciplinary character of multimodal spoken dialogue systems technology. By way of analysing scientific papers, he synthesizes specific aspects of the research field.</p> <p><b>Key Qualifications:</b> Selection and confident application of appropriate methods, interdisciplinary knowledge, skill in analyzing and structuring complex computer science problems, skill in developing and implementing solution strategies for complex problems, understanding of team processes, skill in working in teams, self-reflection; acting responsibly in the face of inadequacy and conflicting interests, quality awareness, meticulousness.</p>		
<p><b>Workload:</b> Total: 240 h 45 h exercise course (attendance) 45 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Conversational Artificial Intelligence (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 3,00</p>
<p><b>Literature:</b> wird in der Veranstaltung bekannt gegeben</p>
<p><b>Part of the Module: Conversational Artificial Intelligence (Exercise Course)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 3,00</p>

**Examination**

**Conversational Artificial Intelligence**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0465: Machine Learning for Healthcare</b> <i>Machine Learning for Healthcare</i>		8 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this course, students will have a grasp of the fundamentals of machine learning for healthcare. This course aims to give students a comprehensive insight into the application of machine learning for healthcare, encompassing numerous health data modalities (such as EHR, imaging, speech, mobile, and wearables) to enhance clinical workflows as machine learning methodologies and tools. We will be delving into a broad range of topics, including statistical machine learning, deep learning, transfer learning, fairness, interpretability, privacy-preserving ML, ethics, graphical models, and time series analysis.</p> <p><b>Key Qualifications:</b> Mathematical-formal basics; competence in networking different subject areas; knowledge of practice-relevant tasks; skill in analyzing and structuring computer science problems; skill in developing and implementing solution strategies; quantitative aspects of computer science; skill in logical, analytical and conceptual thinking; methods for developing larger software systems, construction of abstractions and architectures; skill in working in teams; skill in presenting and documenting results in an understandable way.</p>		
<p><b>Workload:</b> Total: 240 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Machine Learning for Healthcare (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<p><b>Part of the Module: Machine Learning for Healthcare (Exercise)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 4,00</p>		
<p><b>Examination</b> <b>Machine Learning for Healthcare</b> portfolio exam, graded <b>Test Frequency:</b> when a course is offered</p>		

<b>Module INF-0466: Biophotonics</b> <i>Biophotonics</i>		5 ECTS/LP
Version 1.3.0 (since WS23/24) Person responsible for module: Prof. Dr. Sebastian Zaunseder		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b></p> <p>After successful participation, students have knowledge and competences with regard to biophotonic methods for diagnostic applications. Students have basic knowledge from the field of photonics and know basic principles of light-tissue interaction. They are familiar with the functional principles of selected biophotonic methods for diagnostics, are able to work with them or with data from them and to interpret results. Students can also contribute to the (further) development of corresponding methods.</p> <p><b>Methodological competencies:</b></p> <p>Students are able to deal independently with the functionality and possible applications of biophotonic processes, to prepare biophotonic measurement data using common script languages such as Python, and to document and interpret the application of methods for data preparation appropriately. Students also have basic competencies in the area of modeling/simulation of biophotonic processes.</p> <p><b>Interdisciplinary Competencies:</b></p> <p>Students are able to apply the acquired knowledge in any area of study that deals with diagnostically relevant data. In addition, the module teaches essential problem-solving skills, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.</p> <p><b>Key skills:</b></p> <p>Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> basic math skills; basic programming skills		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Biophotonics (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The lecture deals with the fundamentals, implementation and application of biophotonic methods. The following contents are covered:

- Fundamentals of photonics
- Basics of light-tissue interaction
- Selected biophotonic methods in medical diagnostics (e.g. optical coherence tomography, laser speckle imaging, pulse oximetry)
- Introduction to possibilities for modeling and simulation in the context of biophotonics

**Literature:**

- Bigio, I. J., & Fantini, S. (2016). Quantitative Biomedical Optics. Cambridge University Press. <https://doi.org/10.1017/CBO9781139029797>
- Keiser, G. (2016). Biophotonics. Springer Singapore. <https://doi.org/10.1007/978-981-10-0945-7>
- Boudoux, C (2017). Fundamentals of Biomedical Optics From light interactions with cells to complex imaging systems. Blurb

**Part of the Module: Biophotonics (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Contents:**

The exercise teaches practical skills in the context of biophotonic methods. The focus is on computational aspects of biophotonic methods and solving concrete problems related to diagnostically applicable biophotonic methods.

The following contents are covered:

- Familiarization with and preparation of biophotonic measurement methods and their application
- Handling of biophotonic measurement data
- Modeling and simulation in the context of biophotonic methods

**Examination**

**Biophotonics**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0472: Management of Communication Networks</b> <i>Management von Kommunikationsnetzen</i>	5 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Michael Seufert	
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides students with knowledge and skills in the field of management of communication networks. The module covers various aspects of the efficient and secure operation of communication networks and prepares students to successfully plan, implement, and manage complex network infrastructures. Students gain a solid understanding of the fundamentals of network management, including the different management levels, protocols, and tools. They understand the significance of network management for the effective utilization of communication networks.</p> <p>The module provides students with comprehensive knowledge and skills to effectively manage network elements, deploy management systems, configure devices, and perform troubleshooting. Additionally, topics such as measurements in communication networks, active and passive network monitoring, Quality of Service (QoS)/Quality of Experience (QoE), automation of network management, virtualization and softwarization of communication networks, network security, and network neutrality are addressed.</p> <p>Students develop a deeper understanding of the relationships between theoretical concepts in network management and their practical application. They can analyze complex management challenges and develop solution strategies. Students can interpret performance data from communication networks, identify potential bottlenecks, and apply diagnostic procedures to analyze and resolve network issues.</p> <p>Students will be able to assess the effectiveness of network management solutions and analyze their impact on the performance and security of communication networks. They will be able to compare and evaluate different approaches and technologies in order to make informed decisions and provide recommendations for improvements.</p> <p>Students will be empowered to develop new approaches and concepts in the field of network management. They will be able to design innovative solutions that go beyond traditional methods and address the current challenges of network management. They will be capable of researching new management strategies and techniques and applying them in practice.</p> <p>Students will be able to assess the impact of network management on organizational goals and business processes. They will be able to quantify the added value of effective network management for businesses and society, and apply appropriate evaluation methods to analyze the costs, risks, and benefits of network management.</p> <p>The exercises in Management of Communication Networks complement the lecture and provide students with the opportunity to apply their acquired knowledge in practical scenarios within real or simulated environments. The exercises include practical tasks, case studies, and projects that allow students to further develop their skills in network management and strengthen their problem-solving capabilities.</p> <p><b>Key qualifications:</b> subject-specific specialization; knowledge of the approaches and terminology of application-relevant disciplines; understanding of the application domain as well as the advantages and disadvantages of alternative technologies and their evaluation in the respective context; competence in identifying significant technological developments; ability to select and confidently apply appropriate concepts and methods; capacity to implement discipline-specific solution strategies; proficiency in solving problems under practice-oriented conditions; ability to present and document results clearly; competence in effective teamwork.</p>	
<p><b>Remarks:</b></p> All materials are in English. The voice track will be in German or English depending on the audience.	
<p><b>Workload:</b></p> Total: 150 h 30 h lecture (attendance) 30 h exercise course (attendance) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using provided materials (self-study)	

<b>Conditions:</b> <ul style="list-style-type: none"> <li>Basics of communication systems and networking</li> <li>Familiarity with ISO/OSI layers 1–4</li> <li>Knowledge of IP, routing, TCP/UDP and protocols for popular Internet applications (web browsing, video streaming)</li> <li>Basics of network performance and network security</li> </ul>		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Management of Communication Networks (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00	
<b>Contents:</b> <ul style="list-style-type: none"> <li>Definitions and Models for Network Management</li> <li>Network Elements and Management Systems</li> <li>Configuration of Network Elements and Troubleshooting</li> <li>Active and Passive Network Measurements</li> <li>Quality of Service (QoS)</li> <li>Data Models for and Automation of Network Management</li> <li>Virtualization and Softwarization of Communication Networks</li> <li>Network Security</li> <li>Quality of Experience (QoE)</li> <li>Network Neutrality</li> </ul>	
<b>Literature:</b> <ul style="list-style-type: none"> <li>Clemm A.: Network Management Fundamentals, Cisco Press, 2006</li> <li>Claise B., Wolter R.: Network Management: Accounting and Performance Strategies, Cisco Press, 2007</li> <li>Edelman J, Lowe S. S., Oswald M.: Network Programmability and Automation, O'Reilly, 2018</li> <li>Capobianco J. W.: Automate Your Network, 2019</li> <li>Garrett J.: Data Analytics for IT Networks, Cisco Press, 2019</li> <li>Claise B., Clarke J., Lindblad J.: Network Programmability with YANG, Addison-Wesley, 2019</li> <li>Chou E.: Mastering Python Networking, Packt, 2020</li> <li>Kurose J.W., Ross K.W.: Computer Networking - A Top-Down Approach, 7th edition, Pearson, 2016</li> <li>Göransson P., Black C., Culver T.: Software Defined Networks: A Comprehensive Approach, 2nd edition, Morgan Kaufmann, 2017</li> </ul>	
<b>Assigned Courses:</b> <b>Management von Kommunikationsnetzen (lecture)</b> <i>*(in attendance) *</i>	
<b>Part of the Module: Management of Communication Networks (Exercise)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00	
<b>Assigned Courses:</b>	

**Übung zu Management von Kommunikationsnetzen** (exercise course)

*\*(in attendance) \**

**Examination**

**Management of Communication Networks**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0476: Computer Vision for Intelligent Systems</b> <i>Computer Vision für Intelligente Systeme</i>		5 ECTS/LP
Version 1.1.0 (since WS23/24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b> Students will understand the following methodological foundations of computer vision for intelligent systems at an in-depth scientific level and will be able to implement appropriate algorithms for advanced problems: Image formation, two-view geometry, deep learning basics for images and point clouds, image motion estimation and optical flow, keypoints and point correspondences, factor graphs and probabilistic state estimation, visual odometry and visual simultaneous localization and mapping, 3D object detection, 3D mapping. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring machine vision problems for intelligent systems and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b> Total: 150 h 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Advantageous: Basic knowledge in Deep Learning</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. winter semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Computer Vision for Intelligent Systems (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2,00</p>		

**Contents:**

This lecture teaches basic methods and algorithms for computer vision for intelligent systems. The lecture covers the following topics:

- Image formation, geometric primitives and transformations.
- Two-view geometry
- Basics of deep learning for images and point clouds
- Motion estimation in images and optical flow
- Keypoints, descriptors and point correspondences
- Camera motion estimation from images
- Factor graphs and probabilistic state estimation
- Visual simultaneous localization and mapping
- 3D object detection
- 3D mapping

**Literature:**

Lecture slides will be provided. Additional literature will be provided in lecture and exercises.

Recommended textbooks:

- Yi Ma, Stefano Soatto, Jana Kos Košecká, S. Shankar Sastry. An Invitation to 3-D Vision
- R. Szeliski. Computer vision: algorithms and applications
- K. Murphy. Probabilistic Machine Learning: An Introduction. MIT Press, 2022
- C. Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Part of the Module: Computer Vision for Intelligent Systems (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Contact Hours:** 2,00

**Examination**

**Computer Vision for Intelligent Systems**

written exam / length of examination: 90 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0499: Foundation Models in Deep Learning</b> <i>Foundation Models in Deep Learning</i>		5 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Rainer Lienhart		
<b>Learning Outcomes / Competences:</b> After successful participation in this module, participants understand basics and in-depth issues and algorithms of robotics (e.g. recursive state estimation, Gaussian and non-parametric filters, Kalman filters, motion and localisation, perception, mapping, SLAM) from a probabilistic point of view and can apply learned concepts to complex, practice-relevant tasks. Students can analyse and evaluate problems in this context. Participation in this module promotes skills in logical, analytical and conceptual thinking in the field of probabilistic robotics. Students can select suitable methods from the concepts learned in a targeted manner, apply them confidently and transfer them to new problems, including those from other disciplines. The module imparts competencies for recognising current research and significant technological developments in this field.		
<b>Key qualifications:</b> advanced mathematical-formal logic; implementation of subject-specific solution concepts; interdisciplinary knowledge; development and implementation of solution strategies for complex problems; systematic further development of design methods; ability to solve problems under practical boundary conditions.		
<b>Workload:</b> Total: 150 h 30 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)		
<b>Conditions:</b> Knowledge in machine learning and machine vision (Master lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each summer semester except summer term 2026	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Probabilistic Robotics (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each summer semester except summer term 2026 <b>Contact Hours:</b> 2,00		

**Contents:**

1. Introduction to Probabilistic Robotics
2. Recursive State Estimation
3. Gaussian Filters
4. Nonparametric Filters
5. Robot Motion
6. Robot Perception
7. Mobile Robot Localization: Markov and Gaussian
8. Mobile Robot Localization: Grid and MonteCarlo
9. Occupancy Grid Mapping
10. SLAM

**Literature:**

References will be announced at the beginning of the semester.

**Part of the Module: Probabilistic Robotics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester except summer term 2026

**Contact Hours:** 2,00

**Examination**

**Probabilistic Robotics (Examination)**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

each semester

**Description:**

The examination can be taken every semester during the examination period.

<b>Module INF-0504: Medical Monitoring and Advanced Sensor Data Processing</b> <i>Medical Monitoring and Advanced Sensor Data Processing</i>		8 ECTS/LP
Version 1.3.0 (since SoSe24) Person responsible for module: Prof. Dr. Sebastian Zaunseder Aublin, Pierre, Dr.		
<p><b>Learning Outcomes / Competences:</b></p> <p><b>Subject-related competences:</b></p> <p>After successful participation, students have knowledge and competences with regard to the field of medical monitoring. Students have basic knowledge on the background of medical monitoring and common technical solutions for clinical and out-of-hospital use. They are familiar with the functional principles of various methods relevant to medical monitoring and their interpretation. Students can also contribute to the (further) development of monitoring applications.</p> <p><b>Methodological competencies:</b></p> <p>Students are able to deal independently with solutions to medical monitoring. In particular, they are able to process medical data using common script languages such as Python, to document their solutions and to interpret processing results appropriately. In addition, Students have basic competencies in the handling of monitoring data and devices for monitoring.</p> <p><b>Interdisciplinary Competencies:</b></p> <p>Students are able to apply the acquired knowledge in any area of study that deals with (medical) data. In addition, the module teaches essential problem-solving skills, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.</p> <p><b>Key skills:</b></p> <p>Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>60 h studying of course content using provided materials (self-study)</p> <p>60 h exercise course (attendance)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>basic math skills; basic programming skills; basic knowledge on handling digital signals</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<p><b>Part of the Module: Medical monitoring and advanced sensor data processing (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>The lecture deals with the fundamentals, implementations and applications of medical monitoring. The following topics, all of them elaborate with respect and in close connection to medical monitoring, are covered:</p> <ul style="list-style-type: none"> <li>• Fundamentals of medical monitoring (basic ideas, history, current solutions, trends)</li> <li>• Fundamentals of sensor data fusion</li> <li>• Preprocessing approaches (e.g. denoising by conventional filters, Kalman filters and autoencoders)</li> <li>• Dimension reduction and source separation (e.g. principal component analysis and independent component analysis)</li> <li>• Feature extraction by functional transforms (e.g. time-frequency transforms)</li> <li>• Basic detection/classification approaches</li> </ul>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• S. Bernhard, A. Brensing, and K.-H. Witte, <i>Biosignalverarbeitung</i>. De Gruyter, 2019. doi: 10.1515/9783110442434.</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Medical Monitoring and Advanced Sensor Data Processing</b> (lecture)  <i>*(in attendance) *</i></p>
<p><b>Part of the Module: Medical Monitoring and Advanced Sensor Data Processing (Exercise)</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> English  <b>Frequency:</b> each summer semester  <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b></p> <p>The exercise teaches practical skills with relevance to the field of medical monitoring. The focus is handling and processing data from/for monitoring applications. The following contents are covered:</p> <ul style="list-style-type: none"> <li>• Familiarization with techniques of data acquisition and handling data</li> <li>• Denoising of data of variable origin</li> <li>• Application of feature extraction and dimension reduction techniques</li> <li>• Prediction/detection of (patho)physiological states</li> <li>• Techniques for visualization and interpretation of sensor data</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Exercise to Medical Monitoring and Advanced Sensor Data Processing</b> (exercise course)  <i>*(hybrid/mixed) *</i></p>
<p><b>Examination</b></p> <p><b>Medical Monitoring and Advanced Sensor Data Processing</b>  portfolio exam, graded</p> <p><b>Test Frequency:</b>  when a course is offered</p>

<b>Module INF-0506: Search Engines and Neural Information Retrieval</b> <i>Search Engines and Neural Information Retrieval</i>		8 ECTS/LP
Version 1.3.0 (since SoSe24) Person responsible for module: Prof. Dr. Annemarie Friedrich		
<p><b>Learning Outcomes / Competences:</b></p> <p>Neural Information Retrieval leverages the power of neural networks to enhance the representation, understanding, and retrieval of information, addressing many of the challenges posed by the complexity and variability of natural language. With the recent development in the area of large language models (or more generally, foundation models), novel approaches to interactive information retrieval are developing.</p> <p>After taking part in the course, students are able to explain the concepts and methods, procedures, techniques and technologies related to neural information retrieval. In particular, the course covers:</p> <ul style="list-style-type: none"> <li>• Basics of traditional information retrieval methods</li> <li>• Vector-based document and query representations (topic modeling and neural representations)</li> <li>• Ranking with embeddings</li> <li>• Question answering, entity search, and knowledge graphs</li> <li>• Multimodal retrieval</li> <li>• Interactive information retrieval and personalization</li> </ul> <p>Students will be able to recognise important technical developments in the field of information retrieval. They can apply machine learning procedures, such as feature extraction, embedding learning, and pattern recognition, to information retrieval problems. They will be able to perform literature research in the area of information retrieval, and identify gaps in the state-of-the-art. They know how to make scientifically meaningful evaluations of proposed systems. They will further learn how to document and present results and complex ideas in a reasonable and meaningful way. Participants will also deepen their programming skills in Python.</p> <p><b>Key skills:</b> Formal methods; Knowledge of advantages and disadvantages of different design alternatives; Ability to work in teams; Knowledge of workflows and processes; Ability to find solutions for practical problems; Ability to work autonomously; Quality awareness; Scientific working; Literature research.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> Recommended: linear algebra, basic probability theory, Python programming.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Search Engines and Neural Information Retrieval (Lecture)</b></p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

This first part of this interactive course will cover the basics of traditional search engine technology, topic modeling, query expansion, collaborative filtering, neural networks, word and document embeddings, transformers, text classification, ranking and learning to rank, question answering, and evaluation designs. The second part of the course will dive into the recent literature on neural information retrieval including (for example) multi-modal search, interactive retrieval systems, entity search, personalization, and retrieval-augmented generative artificial intelligence. We will also discuss aspects related to responsible information retrieval such as bias and transparency.

The course design is complementary to INF-0277 Analyzing Massive Datasets, which focuses on compute frameworks and algorithms for processing big data.

**Literature:**

- Bhaskar Mitra; Nick Craswell, *An Introduction to Neural Information Retrieval*, 2018. doi: 10.1561/15000000061.
- Tonello, Nicola. "Lecture Notes on Neural Information Retrieval." *ArXiv abs/2207.13443* (2022): <https://arxiv.org/abs/2207.13443>
- Dan Jurafsky and James H. Martin. *Speech and Language Processing*. 3rd edition draft available here: <https://web.stanford.edu/~jurafsky/slp3/>
- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, *Introduction to Information Retrieval*, Cambridge University Press. 2008. <https://nlp.stanford.edu/IR-book/information-retrieval-book.html>

**Part of the Module: Search Engines and Neural Information Retrieval (Exercise)**

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination****Search Engines and Neural Information Retrieval**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0508: Probabilistic Machine Learning</b> <i>Probabilistic Machine Learning</i>		8 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students will understand the following methodological foundations of probabilistic machine learning at an in-depth scientific level and will be able to implement appropriate algorithms for advanced problems: Univariate and multivariate distributions, probabilistic graphical models, maximum likelihood and a-posteriori estimation, Bayesian inference and learning, information theory, expectation maximization, linear and logistic regression, probabilistic deep neural networks, Gaussian and Neural processes, probabilistic dimensionality reduction, deep generative models, and probabilistic state-space models. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring probabilistic machine learning problems and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant scientific and technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Basic knowledge of probability theory</li> <li>• Recommended: Basic knowledge in deep learning</li> </ul>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Probabilistic Machine Learning (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> irregular (usu. summer semester)</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

This lecture teaches basic methods and algorithms for probabilistic machine learning. The lecture includes the following topics:

1. Univariate and multivariate distributions
2. Probabilistic graphical models
3. Maximum likelihood and a-posteriori estimation
4. Bayesian statistics and posterior predictive distribution
5. Bias-Variance tradeoff
6. Information theory
7. Linear and logistic regression
8. Variational inference
9. Expectation maximization and Gaussian mixture models
10. Probabilistic deep neural networks (deep ensembles, variational Bayesian neural networks, Laplace approximation)
11. Probabilistic dimensionality reduction (principal component analysis, variational autoencoders)
12. Deep generative models (probabilistic diffusion models)
13. Gaussian and Neural processes
14. Probabilistic state-space models

**Literature:**

Lecture slides will be provided. Additional references to literature will be provided in lecture and exercises.

Recommended textbooks:

- C. Bishop. Pattern Recognition and Machine Learning. Springer, 2006
- K. Murphy. Machine Learning: A Probabilistic Perspective. MIT Press, 2012
- K. Murphy. Probabilistic Machine Learning: An Introduction. MIT Press, 2022
- K. Murphy. Probabilistic Machine Learning: Advanced Topics. MIT Press, 2023
- C. Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Assigned Courses:**

**Probabilistic Machine Learning / Machine Learning** (lecture)

*\*(in attendance) \**

**Part of the Module: Probabilistic Machine Learning (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 2,00

**Assigned Courses:**

**Exercises for Probabilistic Machine Learning / Machine Learning** (exercise course)

*\*(in attendance) \**

**Examination**

**Probabilistic Machine Learning**

written exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0509: Embodied Artificial Intelligence</b> <i>Embodied Artificial Intelligence</i>		8 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b> Students will understand fundamental and contemporary methods of embodied artificial intelligence (robot learning, reinforcement learning, visual scene perception, foundation models for robotics) at a scientific level and will gain practical experience by implementing appropriate algorithms for advanced problems in team projects. Participants understand the advantages and disadvantages of different methods and can analyze and select them for applications and apply them to new problems. Students have developed skills for analyzing and structuring problems in embodied artificial intelligence and know concepts and approaches for implementing algorithms for these problems. In addition, they have the competence to recognize significant scientific and technical developments.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; selection and confident application of appropriate methods; independent work with textbooks; implementation of technical solution concepts in programs and models; knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context; ability to make scientifically meaningful assessments using appropriate methods. Comprehensible presentation of results; ability to work in teams.</p>		
<p><b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Basic programming knowledge in Python</li> <li>• Basic knowledge in Deep Learning</li> </ul>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> irregular (usu. summer semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Embodied Artificial Intelligence (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00</p>		

**Contents:**

Embodied artificial intelligence is about intelligent robots which learn to solve tasks that require perception and interaction with the environment through the agent's embodiment (sensors and actuators). More specifically, the course will cover state-of-the-art methods for robot learning and perception.

The course consists of a lecture part, which teaches theoretical basics and contemporary methods in embodied artificial intelligence, and an exercise part, which deepens the contents of the lecture in the exercises in practical team projects. The course includes the following topics:

1. Introduction
2. Robot kinematics
3. Deep learning basics
4. Transformer and diffusion models
5. Model-free reinforcement learning
6. Model-based reinforcement learning
7. Imitation learning
8. Vision-language-action models
9. Object perception
10. Localization and mapping

**Literature:**

Lecture slides will be provided. Additional references to literature will be provided in the lecture.

Recommended textbooks:

- Sutton and Barto. Reinforcement Learning. Second Edition. MIT Press 2018
- Bishop. Deep Learning - Foundations and Concepts. Springer, 2023

**Assigned Courses:**

**Embodied Artificial Intelligence** (lecture)

*\*(in attendance) \**

**Part of the Module: Embodied Artificial Intelligence (Exercises)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular (usu. summer semester)

**Contact Hours:** 4,00

**Assigned Courses:**

**Exercises for Embodied Artificial Intelligence** (exercise course)

*\*(in attendance) \**

**Examination**

**Embodied Artificial Intelligence**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0511: Processor Design Lab</b> <i>Processor Design Lab</i>		8 ECTS/LP
Version 1.1.0 (since SoSe24) Person responsible for module: Prof. Dr. Sebastian Altmeyer Dr. Martin Frieb		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students acquire competencies in the following areas at an advanced, practical but scientific level: design process for digital circuits, circuit logic and gates, physical principles of electronic components, description of hardware with a hardware description language.</p> <p>First, students learn how to link logic gates and build a half-adder and a full-adder. They understand the digital circuit design process and apply it directly in a practical way by designing their own RISC-V processor. They model and implement it independently using the hardware description language VHDL. They learn the advantages and disadvantages of schematic and textual hardware description and can decide when it makes sense to use which variant. Furthermore, they combine synchronous and asynchronous processes to achieve a good interaction of the components of their self-built microprocessor. Finally, students evaluate the efficiency of their implementation based on the clock frequency achieved and the hardware effort required. In a final project phase, they learn to plan a complex task, to solve it according to a self-developed sound project plan and to discuss and present the results appropriately in a plenary session.</p> <p><b>Key qualifications:</b> Skill in presenting and documenting ideas, concepts and results in a comprehensible manner; quality awareness, meticulousness; project-bound work and time management; selection and confident use of appropriate methods; ability to expand existing knowledge independently; self-reflection.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>15 h studying of course content using literature (self-study)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>30 h lecture (attendance)</p> <p>60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <ul style="list-style-type: none"> <li>• Grundlagen der Rechnerarchitektur (Pipelining, Zweierkomplement, Speicherhierarchie, z.B. "Systemnahe Informatik" an der Uni Augsburg)</li> <li>• Grundkenntnisse in Assemblerprogrammierung (z.B. RISC-V-, DLX-, MIPS-, ARM-, x86-Assembler)</li> </ul> <p>Module Processor Architecture (INF-0147) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Processor Design Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p>
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**Contents:**

The course "Processor Design Lab" presents methods of logical design of digital circuits, starting with the abstract description in a hardware description language (like VHDL) up to the physical implementation on transistor level. In the practical part of the course, hardware design is illustrated using the example of a five-stage processor pipeline. The result is an executable processor developed in VHDL for an FPGA prototype board.

**Literature:**

- Uwe Brinkschulte, Theo Ungerer, Mikrocontroller und Mikroprozessoren, Springer Verlag, Heidelberg, dritte Auflage 2010
- John L. Hennessy, David A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann, 5. Auflage, 2011

**Part of the Module: Processor Design Lab (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Examination**

**Processor Design Lab**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3011: Conformance Checking</b> <i>Conformance Checking</i>		6 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Robert Lorenz Patrizia Schalk		
<b>Learning Outcomes / Competences:</b> After successful participation, participants will have mastered the formal basics of using process models (using Petrinets as an example) to represent and analyze real business processes and will have a good overview of the measures of fitness, precision, generalization, and simplicity for evaluating the quality of such process models. They will be familiar with various algorithms for the automated calculation of these measures, as well as their strengths and weaknesses. They will learn to critically question process models and algorithms for their evaluation and to analyze them using formal and scientific methods. Key qualifications: Ability to think logically, analytically, conceptually, and algorithmically; Independent work with textbooks and English-language specialist literature; Clear presentation of results; Quality awareness; Meticulousness; Principles of good scientific practice; Scientific methodology;		
<b>Remarks:</b> The teaching materials are written in English (lecture notes and exercises). If foreign students with insufficient German language skills participate, the language of instruction will be English.		
<b>Workload:</b> Total: 180 h 22 h studying of course content using provided materials (self-study) 75 h studying of course content through exercises / case studies (self-study) 23 h studying of course content using literature (self-study) 15 h exercise course (attendance) 45 h lecture (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>  <b>Part of the Module: Conformance Checking (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. winter semester) <b>Contact Hours:</b> 3,00
<b>Contents:</b> The event provides a comprehensive overview of the subfield of conformance checking in the research area of process mining: <ul style="list-style-type: none"> <li>- Modeling techniques: workflow nets, partial languages</li> <li>- Event logs</li> <li>- Fitness metrics and their limitations</li> <li>- Precision metrics and their limitations</li> <li>- Generalization metrics and their limitations</li> <li>- Simplicity metrics and their limitations</li> </ul>

**Literature:**

- English-language lecture notes
- Josep Carmona, Boudewijn van Dongen, Andreas Solti and Matthias Weidlich:
- Conformance Checking - Relating Processes and Models, Springer 2018, ISBN 978-3-319-99413-0
- Anja F. Syring, Niek Tax, Wil M. P. van der Aalst:
- Evaluating Conformance Measures in Process Mining using Conformance Propositions (Extended version), <https://arxiv.org/abs/1909.02393>

**Part of the Module: Conformance Checking (Übung)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 1,00

**Examination**

**Conformance Checking**

written exam / length of examination: 60 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3013: Generative Artificial Intelligence for Human-Computer Interaction Lab</b> <i>Generative Artificial Intelligence for Human-Computer Interaction Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<b>Learning Outcomes / Competences:</b> Students will be familiar with methods and techniques of Generative AI for developing interactive systems. After successful participation, they will have the necessary knowledge to develop and evaluate generative models that can be used in various HCI application scenarios. They will be able to translate current artificial intelligence and machine learning methods into models and programs for novel interactive applications and independently work with the necessary technologies. Furthermore, they can apply practical evaluation methods to assess the quality of the created generative models. They will be capable of planning larger project tasks in small teams, solving them according to a self-developed project plan, and appropriately discussing and presenting the results as a team in the plenary.  <b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.		
<b>Workload:</b> Total: 240 h 15 h studying of course content using literature (self-study) 15 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance) 120 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Generative AI for Human-Computer Interaction Lab (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		
<b>Contents:</b> The specific tasks for student projects are redesigned each year.		
<b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.		

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**Part of the Module: Generative AI for Human-Computer Interaction Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular

**Contact Hours:** 4,00

**Examination**

**Generative Artificial Intelligence for Human-Computer Interaction Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3015: Interactive Machine Learning Lab</b> <i>Interactive Machine Learning Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After successful participation in this module, students are familiar with basic concepts of interactive machine learning. They are able to translate domain-specific solution concepts into models and master the selection and safe application of suitable methods. In addition, they will gain an insight into current work in the research area. Furthermore, competencies in the areas of teamwork and communication skills as well as self-organization are taught through the processing of project tasks and their independent project planning. In the context of these project tasks, knowledge of the mindset and language of the research field is fostered through the discussion and presentation of project results.</p> <p><b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b> Cannot be taken if "INF-0296: Praktikum Interactive Machine Learning" has already been taken. Cannot be taken at the same time as "Interactive Machine Learning for Healthcare Lab".</p>		
<p><b>Workload:</b> Total: 240 h 120 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 15 h studying of course content using literature (self-study) 60 h exercise course (attendance)</p>		
<b>Conditions:</b> Programming experience		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Interactive Machine Learning Lab (Lecture)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b> The specific tasks for student projects are redesigned each year.</p>
<p><b>Literature:</b> Literature references will be announced at the beginning of the semester depending on the topic.</p>

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**Part of the Module: Interactive Machine Learning Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Interactive Machine Learning Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3017: Interactive Machine Learning for Healthcare Lab</b> <i>Interactive Machine Learning for Healthcare Lab</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>In contrast to the "Interactive Machine Learning Lab" event, the focus is on applications in the healthcare sector. After successful participation in this module, students are familiar with basic concepts of interactive machine learning. They are able to translate domain-specific solution concepts into models and master the selection and safe application of suitable methods. In addition, they will gain an insight into current work in the research area. Furthermore, competencies in the areas of teamwork and communication skills as well as self-organization are taught through the processing of project tasks and their independent project planning. In the context of these project tasks, knowledge of the mindset and language of the research field is fostered through the discussion and presentation of project results.</p> <p><b>Key qualifications:</b> Conversion of technical solution concepts into programs and models; subject-specific consolidation; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Remarks:</b></p> <p>Cannot be taken if "INF-0296: Praktikum Interactive Machine Learning" has already been taken.</p> <p>Cannot be taken at the same time as "Interactive Machine Learning Lab".</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>60 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>Programming experience</p>		<p><b>Credit Requirements:</b></p> <p>Bestehen der Modulprüfung</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Interactive Machine Learning for Healthcare Lab (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>The specific tasks for student projects are redesigned each year.</p>		
<p><b>Literature:</b></p> <p>Literature references will be announced at the beginning of the semester depending on the topic.</p>		

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**Part of the Module: Interactive Machine Learning for Healthcare Lab (Exercise Course)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination**

**Interactive Machine Learning for Healthcare Lab**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3027: Algorithmic Game Theory</b> <i>Algorithmic Game Theory</i>		8 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b></p> <p>The goal of the lecture is to use suitably chosen examples to give a broad overview over the field of Algorithmic Game Theory. For this, we will encounter classical results from Game Theory along with recent results from Algorithmic Game Theory.</p> <p>The students will learn how to model and analyse the interaction of strategic agents in various settings. They will be able to understand and explain different game-theoretic concepts as well as their application in different domains. They will also be able to compute equilibrium solutions for many game variants and they will be able to understand and apply several practical algorithms for solving allocation problems. For this we will formally analyze the efficiency and other properties of the employed algorithms. Moreover, the students will learn how to evaluate the impact of selfishness in optimization problems and how to prove quality guarantees for game-theoretic settings.</p> <p><b>Key skills:</b> Advanced mathematical-formal methodology, subject-specific specializations, quantitative aspects of computer science, ability to analyze and structure complex computer science problems, ability to develop and implement solution strategies for complex problems, knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context, Ability to think logically, analytically and conceptually, selection and reliable application of suitable methods, ability to work in teams, knowledge of practical tasks, ability to present and document results in a comprehensible manner, ability to expand existing knowledge independently, quality awareness, meticulousness</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <p>No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in complexity theory from the Bachelor studies will be assumed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Algorithmic Game Theory (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

Algorithmic Game Theory is a young and thriving research area in the intersection of Mathematics, Algorithmics and Economics. Motivated by the rise of the Internet and its related new kinds of problems, Algorithmic Game Theory was established within the last two decades to tackle classical problems from Game Theory with an algorithmic perspective.

Among others we will discuss the following questions:

- How can we solve assignment problems (e.g. assigning talks/projects to students) such that all participants are happy with their assignment?
- Are there auctions in which all bidders want to bid honestly?
- How does the perfect voting system look like?
- Does every game have an equilibrium, that is, an outcome in which all players are happy?
- Is it easy to find an equilibrium for a specific game?
- How good/bad are equilibria reached via egoistic behavior compared to the best centrally enforced solution?

Answers to the above questions have been awarded with 7 "Nobel Prizes" in Economics (most recently, the 2020 Economics Nobel Prize!) and some of the most prestigious awards in Mathematics and Computer Science.

**Literature:**

- Nisan et al.: Algorithmic Game Theory, Cambridge University Press
- Shoham and Leyton-Brown: Multitagent Systems, Cambridge University Press
- Roughgarden: 20 Lectures on Algorithmic Game Theory, Cambridge University Press
- Easley and Kleinberg: Networks, Crowds and Markets, Cambridge University Press
- Brandt et al.: Handbook of Computational Social Choice, Cambridge University Press

**Part of the Module: Algorithmic Game Theory (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination****Algorithmic Game Theory**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3035: Autonomous and Self-Learning Systems</b> <i>Autonomous and Self-learning Systems</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Jörg Hähner		
<b>Contents:</b> Es werden Grundlagen des Reinforcement Learnings vermittelt und in zentrale Methoden wie Temporal Difference Learning eingeführt. Aufbauend darauf werden Ansätze aus dem Deep Reinforcement Learning behandelt. Es folgen policy-basierte Verfahren wie Actor-Critic-Methoden sowie weiterführende Themen wie Multi-Objective Reinforcement Learning zur Optimierung mehrerer Ziele und Multi-Agent Reinforcement Learning zur Modellierung von Interaktionen zwischen mehreren Agenten.		
<b>Learning Outcomes / Competences:</b> Nach erfolgreicher Teilnahme an diesem Modul verfügen die Studierenden über ein fundiertes Verständnis der grundlegenden und fortgeschrittenen Konzepte des Reinforcement Learnings, einschließlich Deep Reinforcement Learning, Multi-Agenten Reinforcement Learning und Multi-Objective Reinforcement Learning. Sie sind in der Lage, komplexe Problemstellungen in mathematische und algorithmische Modelle zu übersetzen, geeignete Methoden auszuwählen und diese sicher anzuwenden. Die Studierenden beherrschen die Implementierung, Simulation und Evaluierung moderner RL-Algorithmen und können diese auf realitätsnahe Szenarien anwenden. Sie erlernen, komplexe Modelle wissenschaftlich zu bewerten, zu dokumentieren und die Ergebnisse klar zu kommunizieren. Die Veranstaltung fördert insbesondere das logische und analytische Denken, die Fähigkeit zur Zusammenarbeit sowie die kreative Problemlösung. Ergänzend erwerben die Studierenden Kompetenzen im Umgang mit aktuellen Forschungsergebnissen und praktischen Tools zur Umsetzung von RL-Methoden.		
<b>Remarks:</b> Wenn <i>INF-0291: Praktikum Selbstlernende Systeme</i> bereits absolviert wurde, ist eine Belegung des Moduls nicht möglich.		
<b>Workload:</b> Total: 240 h 60 h exercise course (attendance) 30 h lecture (attendance) 15 h studying of course content using provided materials (self-study) 120 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study)		
<b>Conditions:</b> Programmiererfahrung, Teamfähigkeit		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Autonomous and Self-learning Systems (Vorlesung)</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		

**Contents:**

Die Vorlesung vermittelt die Grundlagen des Reinforcement Learnings und führt in zentrale Methoden wie Temporal Difference Learning ein. Aufbauend darauf werden Ansätze aus dem Deep Reinforcement Learning behandelt. Es folgen policy-basierte Verfahren wie Actor-Critic-Methoden sowie weiterführende Themen wie Multi-Objective Reinforcement Learning zur Optimierung mehrerer Ziele und Multi-Agent Reinforcement Learning zur Modellierung von Interaktionen zwischen mehreren Agenten.

**Literature:**

- Skript
- Sutton, Richard S. "Reinforcement learning: An introduction." A Bradford Book (2018).
- Hayes, Conor F., et al. "A practical guide to multi-objective reinforcement learning and planning." Autonomous Agents and Multi-Agent Systems 36.1 (2022): 26.
- Albrecht, Stefano V., et al. "Multi-agent reinforcement learning: Foundations and modern approaches." MIT Press, 2024.

**Assigned Courses:**

**Autonomous and Self-learning Systems** (lecture)

*\*(in attendance) \**

**Part of the Module: Autonomous and Self-learning Systems (Übung)**

**Mode of Instruction:** exercise course

**Language:** German

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Assigned Courses:**

**Übung zu Autonomous and Self-learning Systems** (exercise course)

*\*(in attendance) \**

**Examination**

**Autonomous and Self-learning Systems**

portfolio exam / length of examination: 30 minutes, graded

**Test Frequency:**

only in the summer semester

**Description:**

Die Prüfung kann jedes Sommersemester abgelegt werden.

<b>Module INF-3037: Graph Algorithms</b> <i>Graph Algorithms</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b></p> <p>The goal of the lecture is to use suitably chosen examples to give a broad overview over the field of Graph Algorithms. The students will learn how to design and analyse graph algorithms for various settings . They will be able to understand and explain different graph-theoretic concepts as well as their application in different domains. They will also be able to understand and apply several practical algorithms for computing shortest paths, flows, matchings, cuts, and embeddings. For this we will formally analyze the efficiency and other properties of the employed algorithms. Moreover, the students will learn how to evaluate the impact of graph properties on complexity of graph problems.</p> <p><b>Key skills:</b> Advanced mathematical-formal methodology, subject-specific specializations, quantitative aspects of computer science, ability to analyze and structure complex computer science problems, ability to develop and implement solution strategies for complex problems, knowledge of the advantages/disadvantages of design alternatives, evaluation in the respective application context, Ability to think logically, analytically and conceptually, selection and reliable application of suitable methods, ability to work in teams, knowledge of practical tasks, ability to present and document results in a comprehensible manner, ability to expand existing knowledge independently, quality awareness, meticulousness</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>30 h exercise course (attendance)</p> <p>60 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in complexity theory from the Bachelor studies will be assumed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Graph Algorithms (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 4,00</p>		

**Contents:**

Graphs play a central role in the world of algorithms. For example, navigation devices use an algorithm to compute shortest paths on a graph to answer a route query. Many planning and assignment problems can also be easily modeled as problems on graphs. In principle, it is true that a great many problems can be thought of as graph problems, so designing efficient algorithms for such problems is an important subfield of theoretical computer science.

In this lecture we will enter the world of graph algorithms. On the one hand, we will learn about important algorithmic problem classes on graphs and efficient algorithms to solve them. Among other things, we will look at finding shortest paths, flows, cuts, separators, and matchings in graphs. Algorithms for these problems have a wide variety of applications, making them an important and useful tool for any algorithmicist. On the other hand, we will also study how constraints on the graphs at hand affect the complexity of the problems and their algorithmic solution. For example, many algorithmic problems are more efficiently solvable on trees and planar graphs (i.e., graphs that can be embedded in the plane without intersection) than on general graphs. We will also explore some properties of graphs that we can exploit specifically for designing efficient algorithms. For example, trees and planar graphs have small separators (sets of nodes whose removal causes the graphs to decompose into multiple context components), which helps design efficient divide & conquer algorithms.

The goal of the lecture is the development and training of a structured approach to algorithmic problems on graphs. In doing so, we will jointly develop efficient graph algorithms with appropriate data structures, prove their correctness, and analyze their resource requirements (runtime and memory). In addition, the lecture will highlight special graph classes and other important concepts in graph theory and their impact on the world of algorithms.

**Part of the Module: Graph Algorithms (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 2,00

**Examination****Graph Algorithms**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3039: Human-Robot Interaction</b> <i>Human-Robot Interaction</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>In this course, the students will learn the core concepts regarding the field of human-robot interaction as well as the latest developments drawing examples from recent literature. After successful participation in this course, the students will gain the skills to design, and evaluate solutions to real-world Human-Robot Interaction (HRI) challenges across diverse scenarios. Within the framework of this lecture, the students will learn where does HRI fit into the increasingly technological world of HCI, the history of social robotics, physical versus social HRI, various dimensions of interactions such as proxemics, verbal, and non-verbal interaction modes and how these modalities interplay. They will further learn about the autonomy spectrum and the various technical methods for perception and generation of human and robot behaviors in HRI. They will also acquire the knowledge about design principles of effective HRI and how a complete HRI design cycle looks like. The students will apply these concepts in real world problems situated in, for example, educational, healthcare, in-home, public, entertainment scenarios through case studies and exercises.</p> <p><b>Schlüsselqualifikationen:</b> Technical foundation with basics of cognitive systems/AI/ML; interdisciplinary awareness on computer science, multimodal human behavior analysis, psychology, ethics and society, design thinking; practical skills such as analytical thinking and ability to both work independently and in teams; attitudes such as curiosity to create impactful and creative HCI solutions; interest in communicating research ideas and latest technological developments; interdisciplinary knowledge; ability to make scientifically meaningful evaluations using suitable methods; knowledge of the mindset and language of application-relevant disciplines; ability to work in teams; knowledge of practice-relevant tasks; familiarity with procedures and processes in the application environment of computer science; ability to present and document results in a comprehensible manner; ability to expand existing knowledge independently; competence in recognizing significant technical developments.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Human-Robot Interaction (Lecture)</b></p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

- Social and physical HRI
- Dimensions of interaction (spacial, verbal, non-verbal)
- Autonomy in interaction
- Technical methods for perception and generation
- Cognitive models of HRI such as mental models, engagement, trust, transparency
- Design principles for effective HRI
- Evaluation in HRI
- HRI design cycle
- Prevalent software and hardware

**Literature:**

- Bartneck, Christoph, Tony Belpaeme, Friederike Eysel, Takayuki Kanda, Merel Keijsers, and Selma Šabanovi#. Human-robot interaction: An introduction. Cambridge University Press, 2020
- Thomaz, Andrea, Guy Hoffman, and Maya Cakmak. "Computational human-robot interaction." Foundations and Trends in Robotics 4, no. 2-3 (2016): 105-223.
- Cynthia Brezeal: Social robots: beyond tools to partners

**Part of the Module: Human-Robot Interaction (Exercise Course)**

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 4,00

**Examination**

**Human-Robot Interaction**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3041: Digital Forensics</b> <i>Digital Forensics</i>	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Frank Breitingner Dr. Janine Schneider	
<b>Contents:</b> The lecture is aimed at computer science students and teaches both theoretical knowledge and practical methods for conducting digital investigations efficiently and systematically. In order to participate in the exercise, students are required to have a laptop with sufficient free storage space (min. ~30 GB) and internet. A tablet or smartphone is not sufficient. If no laptop is available, the exercise must be completed independently on a suitable computer outside the exercise sessions.	
<b>Learning Outcomes / Competences:</b> Objectives: <ol style="list-style-type: none"> <li>1. Remembering <ul style="list-style-type: none"> <li>- Define what digital forensics is and what types exist.</li> <li>- Describe which digital traces may arise in different systems.</li> <li>- Reproduce the legal framework (e.g. §202a-d StGB).</li> </ul> </li> <li>2. Understanding <ul style="list-style-type: none"> <li>- Explain why digital forensics is important for law enforcement and IT security.</li> <li>- Illustrate how HDDs, SSDs, USB sticks and cloud storage differ technologically.</li> <li>- Summarize how the forensic process works and what documentation is required.</li> </ul> </li> <li>3. Applying <ul style="list-style-type: none"> <li>- Perform a forensic data acquisition (e.g. imaging of a drive).</li> <li>- Identify relevant digital traces in a given scenario.</li> <li>- Apply forensic tools to analyze data carriers.</li> </ul> </li> <li>4. Analyzing <ul style="list-style-type: none"> <li>- Distinguish between different types of digital traces and their relevance to an investigation.</li> <li>- Evaluate the significance of timestamps in a file system.</li> <li>- Break down an investigation into individual forensic questions.</li> </ul> </li> <li>5. Evaluating <ul style="list-style-type: none"> <li>- Critically assess which investigation methods are appropriate in a particular case.</li> <li>- Assess the forensic probative value of certain data sources.</li> <li>- Discuss the challenges of current and future forensic methods.</li> </ul> </li> <li>6. Creating <ul style="list-style-type: none"> <li>- Formulate a forensic report for a fictitious case.</li> </ul> </li> </ol>	
<b>Remarks:</b> The lecture and exercise will be given in EN. In case all participants are German speaking, this may change.	
<b>Workload:</b> Total: 240 h 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance) 60 h exercise course (attendance)	
<b>Conditions:</b> none	<b>Credit Requirements:</b> Passing the Module Exam

<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

### Parts of the Module

#### Part of the Module: Digital Forensics (Lecture)

**Mode of Instruction:** lecture

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 2,00

#### Contents:

Digital forensics deals with the identification, securing and analysis of digital evidence for use in legal proceedings. The starting point in each case is the suspicion of a computer crime or an offense that has been committed with the help of digital devices. The lecture provides a sound introduction to the basic concepts, methods and legal framework of digital forensics.

After a brief introduction to forensics and its importance, the focus will be on technical aspects: What types of digital traces are there, how are they created and how can they be classified? Which storage media and file systems are relevant and how can data be forensically secured?

A central component of the lecture is the technical analysis of digital evidence. In addition to methods for analyzing file systems, timestamps and other metadata are also considered in detail.

Furthermore, the legal framework relevant to digital forensics is considered. The role of the expert witness is also explained, particularly with regard to court-proof documentation and communication of forensic findings.

#### Assigned Courses:

**Digital Forensics** (lecture)

*\*(in attendance) \**

#### Part of the Module: Digital Forensics (Exercise)

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each summer semester

**Contact Hours:** 4,00

#### Contents:

In the exercise, the topics of the lecture are practiced in the context of case studies

#### Assigned Courses:

**Digital Forensics (Exercise)** (exercise course)

*\*(in attendance) \**

### Examination

#### Digital Forensics

written exam / length of examination: 90 minutes, graded

#### Test Frequency:

when a course is offered

<b>Module INF-3047: Design and Development of Embedded Systems</b> <i>Design and Development of Embedded Systems</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>The course provides fundamental, practice-oriented knowledge for the development and analysis of embedded systems, which are used in almost all areas of industrial application—such as automotive engineering, aerospace, and robotics—as well as increasingly in everyday life.</p> <p>As part of the course, students will design and implement their own embedded system and systematically measure and evaluate the resulting system. This includes identifying relevant system requirements and precisely defining the desired functionality. Through this process, students are enabled to select and apply appropriate development methods in a targeted manner. In addition, they acquire the competence to analyze, compare, and select suitable system components based on well-founded criteria. In doing so, the complete development process of an embedded system is exemplified and conveyed both theoretically and practically.</p> <p><b>Key qualifications:</b> Analytical and methodological competence; evaluation of alternative solution approaches; presentation of solutions to exercise problems; ability to independently expand existing knowledge; quality awareness and attention to detail; self-reflection.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>15 h preparation of presentations (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Design and Development of Embedded Systems (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>

**Literature:**

- Embedded System Design Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things, Peter Marwedel
- Making Embedded Systems: Design Patterns for Great Software, Elicia White
- Prototype to Product: A Practical Guide for Getting to Market, Alan Cohen
- Introduction to Embedded Systems— A Cyber-Physical Systems Approach, Edward A. Lee and Sanjit A. Seshia
- Hard Real-Time Computing Systems - Predictable Scheduling Algorithms and Applications, Giorgio Buttazzo
- Test-Driven Development for Embedded C, James W. Grenning

**Part of the Module: Design and Development of Embedded Systems (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 4,00

**Examination**

**Design and Development of Embedded Systems**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3049: Trustworthy Artificial Intelligence</b> <i>Trustworthy Artificial Intelligence</i>		5 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Bernhard Bauer Dr. Fabian Stieler		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students acquire knowledge of central concepts and principles of trustworthy AI, including ethical, legal and social framework conditions as well as technical requirements. They will understand how trustworthy AI systems can be designed, evaluated and documented and will be able to apply these theoretical principles to practical issues.</p> <p>The course presents methods and approaches that can ensure transparency, explainability, fairness, security, robustness and data protection in AI systems. These include, for example, methods of interpretable machine learning. Students learn to identify typical challenges such as bias, security risks and data protection issues and to develop suitable solutions. This also includes cybersecurity in the context of AI systems, whereby students become familiar with specific attack scenarios and develop suitable protection mechanisms conceptually.</p> <p>In addition, students gain in-depth insights into software engineering for AI systems. Key concepts such as machine learning operations (MLOps), AI lifecycle management and principles such as reproducibility, automation and scalability are taught. Other focal points include aspects of operating AI systems in production environments, including infrastructure, monitoring and concept drift.</p> <p>Furthermore, students are taught organizational and technical measures to ensure accountability, traceability and governance. They learn about relevant standards and procedures in the areas of auditing, certification and risk management of AI systems as well as approaches to the sustainable and responsible development of AI systems.</p> <p>Key qualifications: Understanding of interdisciplinary relationships between technology, ethics and law; teamwork and communication skills; independent acquisition of knowledge; quality awareness; ability to document AI systems in a comprehensible manner; sensitization to practical professional requirements.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h lecture (attendance)</p> <p>30 h exercise course (attendance)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p>		
<b>Conditions:</b> Basic knowledge of machine learning is an advantage.		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Trustworthy Artificial Intelligence (Vorlesung)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

The course teaches the basics of trustworthy AI systems, including ethical and legal frameworks, as well as technical concepts for implementing transparency, fairness and interpretability in AI systems, MLOps practices, cybersecurity in the context of AI systems, and governance, accountability and sustainability.

**Literature:**

- Slides
- Further literature in the lecture on specific topics

**Part of the Module: Trustworthy AI Engineering (Exercise)**

**Mode of Instruction:** exercise course

**Language:** German / English

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Examination**

**Trustworthy Artificial Intelligence**

oral exam / length of examination: 30 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3051: Network and System Security</b> <i>Network and System Security</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Frank Breitingger		
<b>Learning Outcomes / Competences:</b> A course focusing on forensics on Linux, applications, and networks as well as current trends utilization instructions, demonstrations, and lab exercises. After this course, students will <ul style="list-style-type: none"> <li>• <b>Explain</b> key network and application protocols and how they influence system and network security.</li> <li>• <b>Differentiate</b> between encryption, anonymization, and their implications for secure communications and monitoring.</li> <li>• <b>Collect and interpret</b> host-based and network-based traces to support threat detection and security assessments.</li> <li>• <b>Configure</b> tools like the ELK Stack to visualize security data and detect suspicious activity in real time.</li> <li>• <b>Evaluate</b> network and system behaviors to identify intrusions, including advanced techniques like data exfiltration and tunneling.</li> </ul>		
<b>Remarks:</b> The lecture and exercise will be given in EN. In case all participants are German speaking, this may change.		
<b>Workload:</b> Total: 240 h 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 30 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Understanding of Networkin (IPs, subnets) as well as basic protocols (DNS, HTTP)</li> <li>• Basic understanding in Linux and the terminal</li> </ul>		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

**Parts of the Module****Part of the Module: Network and System Security (Lecture)****Mode of Instruction:** lecture**Language:** English**Frequency:** each winter semester**Contact Hours:** 2,00

**Contents:**

This course provides an in-depth study of modern network and system security concepts, focusing on the detection, analysis, and mitigation of threats across host and network environments. Students will explore core protocols and their interactions, examine the security challenges in contemporary systems, and gain hands-on experience with tools and techniques used in real-world security operations.

Topics include network and application-layer protocols, encryption and anonymization techniques, intrusion detection, data exfiltration, and tunneling. The course emphasizes both theoretical understanding and practical skills through demonstrations and labs, including the use of the ELK Stack (Elasticsearch, Logstash, Kibana) for visualizing and analyzing security events.

Students will develop the ability to assess system behavior, collect and interpret trace data, and respond effectively to security incidents. The course prepares students for roles in security operations, incident response, and infrastructure defense.

**Part of the Module: Network and System Security (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Contents:**

In the exercise, the topics of the lecture are practiced in the context of case studies

**Examination**

**Network and System Security**

portfolio exam / length of examination: 120 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3053: Evolutionary Computation</b> <i>Evolutionary Computation</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successfully completing this module, students will have a sound understanding of basic and advanced concepts in the field of Evolutionary Computation. In particular, they will be familiar with common techniques and how these can be applied to a variety of black-box optimisation problems. Students have learnt to apply this basic knowledge in several specific use cases, especially in the field of Evolutionary Machine Learning.</p> <p>They are able to identify and formulate optimisation problems and solve them without mathematical approaches by applying the most suitable techniques. In addition, students will be able to design experiments to evaluate various techniques and analyse them in a comprehensible manner.</p> <p>Students have in-depth knowledge of the application of these techniques to generate explainable Machine Learning models and are aware of the importance of transparent AI models.</p> <p>In addition to the theoretical aspects, students are able to put various Evolutionary Computation techniques into practice by implementing, evaluating and presenting them. They learn how to present experimental results in a stakeholder-specific (e.g. scientific) way and how to analyse, evaluate and present them statistically.</p> <p>In addition, students acquire skills in dealing with current research results and practical tools from the field of Evolutionary Computation.</p> <p>In particular, the course promotes logical and analytical thinking, the ability to work together and creative problem solving.</p>		
<p><b>Remarks:</b></p> <p>Lecture and exercise course in English</p> <p>Lecture slides in English</p> <p>Exams can be taken in either German or English</p> <p>Questions can be asked in either German or English</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>60 h exercise course (attendance)</p> <p>30 h lecture (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <p>none</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Evolutionary Computation (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English / German</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

In this course, students learn about the various areas of the field of Evolutionary Computation. These are divided on the one hand into the multitude of different optimisation algorithms (ES, GA, PSO, ACO, NSGA-II, ...), whereby various basic concepts of optimisation (e.g. single- vs multi-objective) are also introduced, and on the other hand into downstream/advanced techniques, such as: Genetic Programming, Learning Classifier Systems and Neuroevolution (in particular Neural Architecture Search) from the field of Evolutionary Machine Learning; automated algorithm design and hyperheuristics; benchmarking; and behaviour and landscape analysis.

**Literature:**

- Skript
- Patrick Siarry. 2017. Metaheuristics. Springer Cham. <https://doi.org/10.1007/978-3-319-45403-0>
- Sean Luke. 2013. Essentials of Metaheuristics. Lulu. ISBN: 978-1-300-54962-8. Available at <http://cs.gmu.edu/~sean/book/metaheuristics/>
- William B. Langdon, Riccardo Poli. 2002. Foundations of Genetic Programming. Springer Berlin, Heidelberg. <https://doi.org/10.1007/978-3-662-04726-2>
- Ryan J. Urbanowicz, Will N. Browne. 2017. Introduction to Learning Classifier Systems. Springer Berlin, Heidelberg. <https://doi.org/10.1007/978-3-662-55007-6>

**Part of the Module: Evolutionary Computation (Exercise)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Frequency:** each winter semester

**Contact Hours:** 4,00

**Examination****Evolutionary Computation**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3055: Analytical Performance Evaluation of Communication Networks</b> <i>Analytische Leistungsbewertung von Kommunikationsnetzen</i>	5 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Michael Seufert	
<p><b>Learning Outcomes / Competences:</b></p> <p>The lecture provides students with knowledge and skills in the analytical performance evaluation of communication networks. The module focuses on quantitative methods for modeling, analyzing, and dimensioning communication systems, with an emphasis on queueing theory and network calculus, and prepares students to rigorously assess the performance of modern networked infrastructures.</p> <p>Students gain a solid understanding of the fundamentals of performance modeling, including traffic models, service models, and key performance indicators such as waiting times, blocking probability, throughput, and utilization. They understand the significance of analytical performance evaluation for the design, optimization, and operation of communication networks.</p> <p>The module provides students with comprehensive knowledge and skills to formulate and analyze queueing models, e.g., single and multi-server queues, and to apply network calculus for end-to-end delay and backlog bounds. Further topics include traffic characterization, scheduling and resource allocation, dimensioning of links and buffers, performance aspects of Quality of Service (QoS)/Quality of Experience (QoE), as well as model validation. Students develop a deeper understanding of the relationships between theoretical concepts in performance analysis and their practical application in real communication networks. They can analyze complex performance problems, select appropriate modeling techniques, and develop solution strategies. Students can interpret performance data, identify potential bottlenecks, and apply analytical and numerical methods to evaluate and improve network performance.</p> <p>Students will be able to assess the effectiveness of different designs, protocols, and resource management strategies of networked systems with respect to performance and reliability. They will be able to compare and evaluate alternative architectures and mechanisms based on analytical models and performance bounds, in order to make informed design decisions and provide recommendations for improvements.</p> <p>Students will be empowered to develop new analytical approaches and concepts for the performance evaluation of emerging communication technologies. They will be able to adapt existing and to design innovative models that go beyond standard queueing setups and network calculus techniques. They will be capable of researching advanced performance evaluation methods and applying them to novel scenarios.</p> <p>Students will be able to assess the impact of network performance on organizational goals, service-level agreements, and user experience. They will be able to quantify the added value of performance-aware design of networked systems, and apply appropriate evaluation methods to analyze the costs, risks, and benefits of different design and provisioning options.</p> <p>The exercises in Analytical Performance Evaluation of Communication Networks complement the lecture and provide students with the opportunity to apply their acquired knowledge to analytical problem sets, numerical experiments, and case studies in networking contexts. The exercises include derivations, model-based evaluations, and small projects that allow students to further develop their skills in queueing theory and network calculus, and to strengthen their analytical and problem-solving capabilities.</p> <p><b>Key qualifications:</b> subject-specific specialization; knowledge of the concepts, methods, and terminology of queueing theory, network calculus, and related application-oriented disciplines; understanding of the application domain as well as the advantages and disadvantages of alternative system designs and their modeling and evaluation in the respective context; competence in identifying significant technological and methodological developments; ability to select and confidently apply appropriate concepts and methods; capacity to implement discipline-specific solution strategies; proficiency in solving problems under practice-oriented conditions; ability to present and document results clearly; competence in effective teamwork.</p>	
<p><b>Remarks:</b></p> All materials are in English. The voice track will be in German or English depending on the audience.	

<b>Workload:</b> Total: 150 h 15 h studying of course content using provided materials (self-study) 60 h studying of course content through exercises / case studies (self-study) 15 h studying of course content using literature (self-study) 30 h exercise course (attendance) 30 h lecture (attendance)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Basics of communication systems and networking</li> <li>• Familiarity with ISO/OSI layers 1–4</li> <li>• Knowledge of IP, routing, TCP/UDP and protocols for popular Internet applications (web browsing, video streaming)</li> <li>• Basics of network performance and network security</li> </ul>		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>		
<b>Part of the Module: Analytical Performance Evaluation of Communication Networks (Lecture)</b> <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to Performance Modeling and Queueing Models for Communication Networks</li> <li>• Description of Traffic, Arrivals, and Service in Networks using Elementary Random Processes</li> <li>• Analysis of Markovian Systems (Loss Systems, Delay Systems, Processor Sharing Systems)</li> <li>• Outlook to Advanced Queueing Models and Applications</li> <li>• Introduction to Network Calculus to Analyze Real-time Networks</li> <li>• Modeling of Traffic and Resources using Arrival and Service Curves</li> <li>• Analysis of Worst-case Performance Bounds (Delay, Backlog)</li> <li>• Outlook to Advanced Network Calculus and Applications</li> </ul>		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Tran-Gia P., Hoßfeld T.: Performance Modeling and Analysis of Communication Networks – A Lecture Note, Würzburg University Press, 2021 (online:<a href="https://doi.org/10.25972/WUP-978-3-95826-153-2">https://doi.org/10.25972/WUP-978-3-95826-153-2</a>, 2021)</li> <li>• Tran-Gia P.: Einführung in die Leistungsbewertung und Verkehrstheorie, Oldenbourg Wissenschaftsverlag, 2009</li> <li>• Shortle J.F., Thompson J.M., Gross D., Harris C.M.: Fundamentals of Queueing Theory, Wiley, 2018</li> <li>• Giambene G.: Queueing Theory and Telecommunications – Networks and Applications, Springer, 2021</li> <li>• Le Boudec J.-Y., Thiran P.: Network Calculus – A Theory of Deterministic Queueing Systems for the Internet, Springer, 2001 (online:<a href="https://leboudec.github.io/netcal/">https://leboudec.github.io/netcal/</a>, 2022)</li> <li>• Boulliard A., Boyer M., Le Corronc E.: Deterministic Network Calculus: From Theory to Practical Implementation, Wiley, 2018</li> <li>• Van Bemten A, Kellerer W.: Network Calculus: A Comprehensive Guide, TUM Technical Report, 2016</li> <li>• Jiang Y., Liu Y.: Stochastic Network Calculus, Springer 2006</li> </ul>		
<b>Assigned Courses:</b> <b>Analytische Leistungsbewertung von Kommunikationsnetzen (lecture)</b> *(in attendance) *		

**Part of the Module: Analytical Performance Evaluation of Communication Networks (Exercise)**

**Language:** English / German

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Übung zu Analytische Leistungsbewertung von Kommunikationsnetzen** (exercise course)

*\*(in attendance) \**

**Examination**

**Analytical Performance Evaluation of Communication Networks**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3059: Project Seminar Responsible Artificial Intelligence: Design, Evaluation and Challenges (Master)</b> <i>Projektseminar zu Verantwortungswürdige Künstliche Intelligenz: Gestaltung, Bewertung und Herausforderungen (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, the students can independently work out and analyse advanced problems, concepts, methods, procedures, techniques, and technologies from the field of digital ethics and evaluate them in relation to the individual seminar topic.</p> <p>Participants possess scientific methodology, communication skills, and the ability to present a special topic clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively.</p> <p>Furthermore, they learn to recognise logical structures of thinking and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a talk that is clear and easy to follow. Additionally, the students know how to focus on essential messages and convey them in a comprehensible way, even with complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to confidently deal with common presentation media and use them interactively. They manage to gear a talk to a specific target group, apply various moderation techniques, and keep their audience engaged even over a longer period.</p> <p><b>Key qualifications:</b> Presentation techniques; literature research; principles of good scientific practice; evaluating solution approaches, procedures, techniques, and technologies from different points of view.</p>		
<p><b>Remarks:</b></p> <p>Sofern Ihre PO vorschreibt, dass Sie ein Seminar belegen müssen, kann dieses Modul <b>nicht</b> dafür verwendet werden, da das Projektseminar nicht als Seminar zählt!</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of presentations (self-study)</p>		
<p><b>Conditions:</b> none</p>		<p><b>Credit Requirements:</b> Passing the module examination</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 2,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Seminar Digital Ethics (Master)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>The topics of the seminar change over time, in order to reflect up-to-date developments</p>		
<p><b>Literature:</b></p> <p>Literature depends on the chosen topic</p>		

**Assigned Courses:**

**Projektseminar zu Verantwortungswürdige Künstliche Intelligenz: Gestaltung, Bewertung und Herausforderungen (Bachelor / Master)** (project seminar)

*\*(in attendance) \**

**Examination**

**Seminar Digital Ethics (Master)**

Combined written and oral exam / length of examination: 45 minutes, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3065: Machine Learning for Time Series</b> <i>Machine Learning for Time Series</i>		8 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successful participation in this course, students will have a thorough understanding of time series analysis, bridging classical statistical methods and modern machine learning. This course provides a comprehensive foundation in modelling temporal data, covering autoregression and dependence structures, preprocessing and feature engineering, spectral methods, state space models, latent space representations, and probabilistic forecasting. Students will learn how fundamental concepts from classical statistics underpin modern neural architectures such as RNNs, LSTMs, Transformers, and Variational Autoencoders, and will gain hands-on experience implementing and evaluating these methods on real-world datasets.</p> <p><b>Key Qualifications:</b> Mathematical-formal foundations in probability and statistical modelling; competence in connecting classical statistical theory with modern machine learning paradigms; knowledge of practice-relevant forecasting tasks; analytical and conceptual thinking for selecting appropriate modelling approaches for temporal data; practical experience developing and implementing time series models in Python/PyTorch and evaluating probabilistic forecasts using proper scoring rules; ability to critically assess model assumptions and justify architectural choices based on data properties; competence in designing end-to-end time series modelling pipelines and constructing probabilistic forecasting systems that account for uncertainty.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h exercise course (attendance)</p> <p>120 h studying of course content through exercises / case studies (self-study)</p> <p>60 h lecture (attendance)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>15 h studying of course content using literature (self-study)</p>		
<p><b>Conditions:</b></p> <p>Basic familiarity with machine learning concepts and Python programming is beneficial.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>6,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Machine Learning for Time Series (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b></p> <p>Time series data is everywhere, from energy consumption and climate measurements to financial markets, medical signals, and speech. The ability to model and forecast temporal data is a highly relevant skill in modern machine learning, underpinning applications across science, industry, and policy. This course bridges the gap between classical statistical foundations and modern neural architectures, equipping students with the theoretical and practical tools to tackle the unique challenges that temporal data presents.</p>

**Literature:**

Bibliography will be given in the lecture

**Part of the Module: Machine Learning for Time Series (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** each summer semester

**Contact Hours:** 2,00

**Assigned Courses:**

**Machine Learning for Time Series (Tutorial)** (exercise course)

*\*(in attendance) \**

**Examination**

**Machine Learning for Time Series**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3067: Deep Learning for Weather Forecasting</b> <i>Deep Learning for Weather Forecasting</i>		5 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of this course, students are able to independently analyse and evaluate the design choices underlying modern deep learning architectures for weather forecasting. They can explain how different architectural paradigms, including attention mechanisms, neural operators, and score-based generative models, are motivated by the structure of atmospheric data and the requirements of operational forecasting. They are able to critically compare models in terms of their assumptions, inductive biases, computational trade-offs, and forecast quality, and to implement and evaluate a deep learning approach for a weather forecasting task. They furthermore understand the relationship between data-driven and physics-based modelling and can assess the promises and limitations of current weather foundation models.</p> <p><b>Key Qualifications:</b> Systematic understanding of modern deep learning architectures and their application to spatiotemporal prediction problems; knowledge of the landscape of operational weather forecasting and the role of data-driven methods; competence in connecting architectural design choices with the physical structure of the atmosphere; practical experience implementing and evaluating deep learning models for weather prediction in Python/PyTorch; ability to critically assess model assumptions, inductive biases, and evaluation protocols; analytical thinking for situating individual contributions within a rapidly evolving research field.</p>		
<p><b>Workload:</b></p> <p>Total: 150 h</p> <p>30 h lecture (attendance)</p> <p>60 h studying of course content through exercises / case studies (self-study)</p> <p>15 h studying of course content using literature (self-study)</p> <p>15 h studying of course content using provided materials (self-study)</p> <p>30 h exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>Students should have a solid foundation in deep learning and some practical experience with PyTorch is beneficial. No prior knowledge of numerical weather prediction or atmospheric science needed.</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>4,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Deep Learning for Weather Forecasting (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> irregular</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

This course provides an advanced treatment of modern deep learning architectures for numerical weather prediction, tracing the rapid shift from classical physics-based models towards data-driven and hybrid approaches. Starting from the foundations of atmospheric modelling and the structure of weather data, students progressively engage with the family of architectures that have come to define the current state of the art, including transformer-based models, graph neural networks, neural operators, diffusion models, and hybrid physics-ML systems. The course places particular emphasis on global medium-range forecasting and situates each model within the broader landscape of operational weather prediction.

**Literature:**

Bibliography will be given in the lecture

**Assigned Courses:**

**Deep Learning for Weather Forecasting (Lecture)** (lecture)

*\*(in attendance) \**

**Part of the Module: Deep Learning for Weather Forecasting (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** irregular

**Contact Hours:** 2,00

**Assigned Courses:**

**Deep Learning for Weather Forecasting (Tutorial)** (exercise course)

*\*(in attendance) \**

**Examination**

**Deep Learning for Weather Forecasting**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3611: Autonomous Robotics Lab 1</b> <i>Autonomous Robotics Lab I</i>		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Contents:</b></p> <p>In the two-part course Autonomous Robotics Lab, students work together to develop an autonomous robot for use in domestic environments. The goal is to participate in RoboCup@Home each winter semester. The course focuses on software and mechatronic components.</p> <p>Autonomous Robotics Lab I focuses on requirements analysis, system design, and the subsequent implementation of autonomy functions.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of the course, students will be able to derive requirements for autonomous robots within specific framework conditions, select and model a system and modular architecture based on these requirements, and finally implement key functionalities of autonomous robots. Students will have knowledge of the use of the Robot Operating System (ROS) 2 and Docker, as well as the design and programming of autonomous robots. This includes, in particular, methods from:</p> <ul style="list-style-type: none"> <li>• Computer vision</li> <li>• Localization</li> <li>• Navigation, trajectory and path planning</li> <li>• Manipulation</li> <li>• Semantic understanding of domestic tasks</li> <li>• Task planning</li> <li>• Human-robot interaction</li> </ul> <p>The results of the course will be tested and validated using simulations and, if necessary, the real system.</p>		
<p><b>Key Qualifications</b></p> <ul style="list-style-type: none"> <li>• Acquisition of basic knowledge of autonomous robot systems</li> <li>• Independent work with primarily English-language technical literature</li> <li>• Analytical and methodological skills</li> <li>• Scientific methodology</li> <li>• Teamwork and communication skills</li> <li>• Determination and problem-solving skills</li> <li>• Time management and task prioritization</li> <li>• Creative thinking and abstract reasoning</li> <li>• Confident and precise presentation of own solutions</li> </ul> <p>The project is being carried out in cooperation with industrial companies. The project results will be presented publicly by the students at the RoboCup and then published.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h 150 h exercise course (attendance) 90 h lecture (attendance)</p>		
<b>Conditions:</b> keine		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Part of Module: Autonomous Robotics Lab I</b></p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2,00</p> <p><b>ECTS Credits:</b> 8.0</p>
<p><b>Contents:</b></p> <p>Work on course materials in small groups</p>
<p><b>Assigned Courses:</b></p> <p><b>Autonomous Robotics Lab I</b> (lecture)</p> <p><i>*(in attendance) *</i></p>
<p><b>Part of the Module: Part of Module: Autonomous Robotics Lab I</b></p> <p><b>Language:</b> German / English</p> <p><b>Contact Hours:</b> 4,00</p>
<p><b>Assigned Courses:</b></p> <p><b>Übung zu Autonomous Robotics Lab I</b> (exercise course)</p> <p><i>*(in attendance) *</i></p>
<p><b>Examination</b></p> <p><b>Autonomous Robotics Lab I</b></p> <p>portfolio exam / length of examination: 60 minutes, graded</p> <p><b>Test Frequency:</b></p> <p>when a course is offered</p>

<b>Module INF-3614: Autonomous Robotics Lab II</b> <i>Autonomous Robotics Lab II</i>		8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Lars Mikelsons		
<p><b>Contents:</b></p> <p>In the two-part course Autonomous Robotics Lab, students work together to develop an autonomous robot for use in domestic environments. The goal is to participate in RoboCup@Home each winter semester. The course focuses on software and mechatronic components.</p> <p>Autonomous Robotics Lab II focuses on the integration and testing of subcomponents and the overall system, as well as the final participation in RoboCup@Home.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of the course, students will be able to test existing functionality and integrate it into an overall cyberphysical system, as well as design and validate appropriate tests. Students will have knowledge of the use of the Robot Operating System (ROS) 2 and Docker, as well as the design and programming of autonomous robots. This includes, in particular, methods from:</p> <ul style="list-style-type: none"> <li>• Definition and implementation of unit tests</li> <li>• Derivation and implementation of test scenarios</li> <li>• Working and integration on real hardware</li> <li>• Dealing with uncertainties and resource limitations</li> <li>• Composition of heterogeneous software and hardware modules</li> </ul> <p>The software components are integrated on real robot hardware. All validation and integration tests are performed on real hardware. The final validation of the entire system takes place at RoboCup@Home.</p> <p><b>Key Qualifications</b></p> <ul style="list-style-type: none"> <li>• Acquisition of basic knowledge of autonomous robot systems</li> <li>• Independent work with primarily English-language technical literature</li> <li>• Analytical and methodological skills</li> <li>• Scientific methodology</li> <li>• Teamwork and communication skills</li> <li>• Determination and problem-solving skills</li> <li>• Time management and task prioritization</li> <li>• Creative thinking and abstract reasoning</li> <li>• Confident and precise presentation of own solutions</li> </ul> <p>The project is being carried out in cooperation with industrial companies. The project results will be presented publicly by the students at the RoboCup and then published.</p>		
<p><b>Workload:</b></p> <p>Total: 240 h 150 h studying of course content through exercises / case studies (self-study) 90 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>Module Autonomous Robotics Lab 1 (INF-3611) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module exam</p>
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>

<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program
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<b>Parts of the Module</b>
<p><b>Part of the Module: Part of the Module: Autonomous Robotics Lab II</b></p> <p><b>Mode of Instruction:</b> lecture  <b>Language:</b> German / English  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b>                  Work on course materials in small groups</p>
<p><b>Part of the Module: Part of the Module: Autonomous Robotics Lab II</b></p> <p><b>Mode of Instruction:</b> exercise course  <b>Language:</b> German / English  <b>Frequency:</b> each winter semester  <b>Contact Hours:</b> 4,00</p>
<p><b>Contents:</b>                  Work on course materials in small groups</p>

<p><b>Examination</b></p> <p><b>Autonomous Robotics Lab II</b>                  portfolio exam / length of examination: 60 minutes, graded</p> <p><b>Test Frequency:</b>                  when a course is offered</p>
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<b>Module INF-3835: ConceptHack "Development of Methods for Medical Data Analysis"</b> <i>ConceptHack "Development of Methods for Medical Data Analysis"</i>		5 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Sebastian Zaunseder Sahl, Fabienne		
<b>Contents:</b> The module ConceptHack "Development of Methods for Medical Data Analysis" combines conceptual knowledge and practical skills doing actual development. The module provides an introduction to the legal and regulatory framework for the development of medical software and introduces tools, which help to comply with the existing rules. It further covers the application of acquired knowledge as well as the development of practical skills within a hackathon dedicated to a current problem from the field of medical diagnostics.		
<b>Learning Outcomes / Competences:</b>		
<b>Subject-related competences:</b> After successful participation, students possess knowledge and practical competences regarding the development of software and algorithms to process medical images and signals. Students have basic knowledge on the development process and have experience using respective tools, e.g. for documentation and testing. They are familiar with the functional principles of selected methods to process images or signals and their evaluation.		
<b>Methodological competencies:</b> Students are able to deal independently with methods to handle medical data for diagnostics or prognostics. In particular, they are able to process medical data using common script languages such as Python, to document own solutions and to describe as well as interpret processing results appropriately.		
<b>Interdisciplinary Competencies:</b> Students are able to apply the acquired knowledge in any area of study that deals with (medical) data processing. In addition, the module teaches essential problem-solving skills in an interdisciplinary area, whereby an abstract way of thinking as well as a structured approach to problem solving are learned.		
<b>Key skills:</b> Ability to think logically, analytically and conceptually; ability to present and document results in a comprehensible manner; ability to communicate orally and in writing in a way that is appropriate to the situation and specific to the target group; ability to work together in teams; ability to solve problems under practical boundary conditions; ability to expand existing knowledge independently; quality awareness.		
<b>Workload:</b> Total: 150 h 30 h lecture (attendance) 30 h exercise course (attendance) 60 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> basic mathematic knowledge; basic programming skills; basic knowledge/ experience in data processing		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<p><b>Parts of the Module</b></p>
<p><b>Part of the Module: ConceptHack “Development of Methods for Medical Data Analysis” (Lecture)</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>The lecture covers fundamental concepts regarding the development and documentation of medical software and algorithms. It further introduces the domain-specific background of a focus topic, which is chosen on a yearly basis. Both aspects are essential for the exercise that covers a practical data processing task (image and/or signal processing) related to the focus topic. The exercise is accomplished as a hackathon (i.e. as block course) in the lecture-free period (details see below).</p> <p>The part on the development and documentation of medical software and algorithms covers overviews on</p> <ul style="list-style-type: none"> <li>• Medical devices and software</li> <li>• Regulatory aspects in the development of medical software and algorithms</li> <li>• Basics on project management in the development of medical software</li> <li>• Relevant methods and tools to be used within the development of medical software (e.g. version control and unit testing)</li> </ul> <p>The lectures on the domain specific background convey the medical and algorithmic knowledge to successfully work on a practical data processing task related to the focus topic. Focus topics have a close relation to diagnostics or prognostics and address current challenges related to processing medical images and/or signals. They vary per year and are defined together with medical and/or industrial partners. Examples are, e.g., processing biophotonic data as video data, hyperspectral or photoplethysmographic data to assess tissue and hemodynamics, prediction of sleep phases from multimodal data and processing heavily distorted data from recorded by wearables.</p>
<p><b>Part of the Module: ConceptHack “Development of Methods for Medical Data Analysis” (Exercise)</b></p> <p><b>Mode of Instruction:</b> exercise course</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each winter semester</p> <p><b>Contact Hours:</b> 2,00</p>
<p><b>Contents:</b></p> <p>Throughout the semester, students will attend lectures designed to convey general knowledge on the development of medical software and algorithms and to prepare them for the exercise. The exercise covers the application of gained knowledge by solving an individually assigned data processing task (medical images and/or signals) related to a focus topic from the field of diagnostic sensing (see above for more details).</p> <p>The exercise will be held as a week-long hackathon in the lecture-free period. If participant numbers permit (and according to participants’ interests), the hackathon will be held in Sion, located in the Swiss Alps. In this case, a fee will be charged to cover travel, food, and accommodation expenses. The total cost remains within a reasonable range (approximately 100 Euro for the entire week).</p> <p>The hackathon itself covers</p> <ul style="list-style-type: none"> <li>• the presentation of the individual tasks by the participants themselves including the presentation of their working plan</li> <li>• working on the own task and its documentation</li> <li>• a final presentation on the own task (within the hackathon or immediately after it)</li> </ul>

**Examination**

**ConceptHack “Development of Methods for Medical Data Analysis”**

portfolio exam, graded

**Test Frequency:**

when a course is offered

<b>Module MTH-2650: Homotopy Type Theory</b> <i>Homotopietypentheorie</i>		9 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
<b>Contents:</b> Initially, mathematical work within an intuitionistic type theory is taught. A special focus is placed on the concept of equality. Equality in elementary types is characterised. Homotopy theory concepts, the axiom of univalence and examples of higher inductive types are introduced. Higher inductive types are introduced. This homotopy-theoretic extension of the type theory is used to calculate selected homotopy groups and to develop abstract variants of classical results of algebraic topology.		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Mathematical reasoning and proving in a dependent type theory. This knowledge is a basis for the use of most computer-assisted proof systems.</li> <li>• Fundamental understanding of issues and techniques in abstract homotopy theory. The ideas gained are transferable to other approaches such as higher category theory.</li> <li>• Application of univalence and higher inductive types to homotopy theory problems. A study of advanced topics homotopy type theory becomes possible.</li> </ul>		
<b>Workload:</b> Total: 270 h		
<b>Conditions:</b> Experience with abstract mathematics, such as that gained in the context of introductory modules in the fields of topology and algebra. Elementary knowledge of these areas is helpful, but not required.		<b>Credit Requirements:</b> Pass the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> 1. - 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Homotopietypetheorie</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German / English <b>Frequency:</b> Wintersemester <b>Contact Hours:</b> 4,00	
<b>Part of the Module: Übungen zur Homotopietypentheorie</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German / English <b>Contact Hours:</b> 2,00	

<b>Examination</b> <b>Modulprüfung</b> portfolio exam, graded <b>Test Frequency:</b> not this semester
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<b>Module PHM-0291: Quantum Computing</b> <i>Quantum Computing</i>		6 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Markus Heyl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Qbits, quantum gates and quantum circuits</li> <li>• Physical realizations</li> <li>• Quantum noise</li> <li>• Quantum error correction</li> <li>• Quantum algorithms</li> <li>• Digital quantum simulation</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students acquire basic understanding of the principles of quantum computers and their applications.</li> <li>• They have the skills to construct concrete quantum circuits and algorithms.</li> <li>• They have the competence to identify the advantages of quantum information processing as well as to follow the modern developments in the field.</li> <li>• Integrated acquisition of key qualifications: Abstraction skills through the translation of physics problems onto quantum computing language, familiarization with English professional language.</li> </ul>		
<b>Workload:</b> Total: 180 h 40 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 40 h studying of course content using provided materials (self-study) 20 h exam preparation (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basic knowledge of quantum mechanics such as acquired in lectures PHM-0017 Theoretische Physik II, INF-0437 Grundlagen der Quanteninformationsverarbeitung, or INF-0440 Quantum Algorithms.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> every 4th semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Quantum Computing</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2,00		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Part of the Module: Quantum Computing (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English / German

**Contact Hours:** 2,00

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- D. DiVincenzo, Quantum Computation, Science **270**, 255-261 (1995)
- M. Nielsen and I. Chuang, Quantum Computation and Quantum Information (Cambridge University Press, 2000)
- J. Stolze and D. Suter, Quantum Computing (Wiley-VCH, 2004)
- E. Grumbling and M. Horowitz, Quantum Computing: Progress and Prospects (The National Academies Press, 2019)

**Examination**

**Quantum Computing**

oral exam / length of examination: 30 minutes, graded

<p><b>Module ZCS-2000: Soft Skills</b> Softskills</p>	<p>2 ECTS/LP</p>
<p>Version 1.0.0 (since SoSe16) Person responsible for module: Claudia Lange-Hetmann</p>	
<p><b>Contents:</b> Die Studierenden erwerben in den Softskill-Kursen, die diesem Modul zugeordnet sind je nach Kurswahl entweder kommunikative, soziale oder methodische Fähigkeiten, die unerlässlich für ihre künftige Berufsfähigkeit sind. Daher wird bei der Auswahl empfohlen, einen Kurs aus einem der drei Kompetenzgebiete zu wählen, die zur Stärkung der eigenen Persönlichkeit sinnvoll und wichtig sind. Zudem bildet die interdisziplinäre Zusammensetzung der Teilnehmer aus unterschiedlichen Fachrichtungen den typischen Wirkungskreis im späteren Arbeitsumfeld ab. Detailbeschreibungen zu Kursen und Anmeldeverfahren befinden sich auf <a href="https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK">https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK</a> bzw. im digicampus.</p>	
<p><b>Learning Outcomes / Competences:</b> Die Studierenden werden - abhängig von der Kursthemenwahl - - neben dem Erwerb der Fertigkeit der verständlichen, sicheren und überzeugenden Darbietung von Ideen, Konzepten und Ergebnissen bzw. dem Verständnis der psychologischen Grundlagen von Dialogen und Verhandlungen dieses Wissen anwenden können, um Interesse, Verständlichkeit und Sympathie zu erzeugen und zielorientiert zu präsentieren bzw. zu argumentieren. - die Kommunikations-, Dialog- und Teamprozesse in Bezug auf Motivation, Effektivität und kennen die Entstehung, Dynamik, Lösung und Prävention von Konflikten verstehen und können Moderationstechniken und ihre Fertigkeit zur Selbstreflexion anwenden, sie beherrschen die Regeln bei der Teamarbeit, bei Besprechungen bis hin zur Führung von Teams oder kennen den Nutzen von gesellschaftlichem Engagement für sich und die Gesellschaft. - grundlegende Konzepte des Projektmanagements (u.a. Entwurf von strategischen Projektstrukturplänen, Analyse der Projektumwelt/-risiken, Projektcontrolling) verstehen und können die Grundlagen der Motivationspsychologie und zentrale Führungstechniken zur Erreichung des Projekterfolgs anwenden. Oder sie können grundlegende Strategien und Methoden für die Entwicklung und Absicherung einer Unternehmensführung anwenden, sie kennen Marketing- u. Vertriebsstrategien, bewerten deren Erfolgsaussichten und haben Kenntnisse in Personal- und Finanzmanagement. Sie verstehen Probleme zu analysieren und können konstruktiv im Team eine Lösung erarbeiten und kommunizieren oder vertiefen Teilaspekte wie u.a. Kreativität, Innovationsfähigkeit mit innovativen Methoden. Besonderer Wert wird - je nach Kurs - auf die Weiterentwicklung der eigenen Präsentations- und Kommunikationsfähigkeit, der Teamkompetenz sowie die Anwendung des Methodenwissens und die Erreichung realistischer Ziele gelegt. Die interdisziplinäre Herangehensweise an eine Problemstellung wird durch die interdisziplinäre Zusammensetzung der Kleingruppen in den Kursen trainiert, durch praktische Übungen in den Kursen gefestigt und durch Selbstreflexion und Feedbackmethoden verinnerlicht, und diese in einen neuen Kontext zu transferieren.</p>	
<p><b>Remarks:</b> <u>Anmeldungspflicht:</u> Für die Teilnahme an den Kursen ist eine Anmeldung über digicampus erforderlich. <u>Anmeldephase:</u> Jan (für das folgende SS) bzw. Juli (für das folgende WS). Die Kurse finden größtenteils ab März bis letzten Sa* im April (SS) bzw. ab Sep. bis letzten Sa* im Okt. *vor Vorlesungsbeginn statt sowie einige in der Vorlesungszeit (Fr/Sa). Die Kurse haben eine limitierte Teilnehmerzahl pro Semester.</p>	
<p><b>Workload:</b> Total: 60 h 20 h seminar (attendance) 10 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 10 h studying of course content using provided materials (self-study)</p>	

<b>Conditions:</b> none		<b>Credit Requirements:</b> aktive Übungsteilnahme im Kurs
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Softskills</b>	
<b>Mode of Instruction:</b> course	
<b>Language:</b> German / English	
<b>Frequency:</b> each semester	
<b>Contact Hours:</b> 2,00	
<b>ECTS Credits:</b> 2.0	
<b>Contents:</b>	
<p>Zur Auswahl stehen nachfolgende Kurse/Themen:</p> <p>(1) <u>Kommunikationskompetenz</u></p> <ul style="list-style-type: none"> <li>- Kommunikationstraining</li> <li>- Rhetorik (dt./engl)</li> <li>- Präsentation / Present your work purposefully (engl.)</li> <li>- Strategische Gesprächsführung</li> <li>- Kommunikation in Projekten</li> <li>- agile Meeting moderieren</li> </ul> <p>(2) <u>Sozialkompetenz</u></p> <ul style="list-style-type: none"> <li>- Konfliktmanagement</li> <li>- Emotionale Intelligenz</li> <li>- Teams führen / Leadership Experience (engl).</li> <li>- Changemanagement</li> </ul> <p>(3) <u>Methodenkompetenz</u></p> <ul style="list-style-type: none"> <li>- Zeit-/Selbstmanagement</li> <li>- Innovationen entwickeln</li> <li>- Projektmanagement (dt./ engl.)</li> <li>- Unternehmerisch Denken</li> <li>- nachhaltig Wirtschaften / Corporat Responsibility</li> </ul> <p>Weiterehin können auch Kompakt-Kurse gewählt werden, bei denen die Teilnehmer o.g. Fähigkeiten erlernen und eine Projektaufgabe im Team bearbeiten. Der höhere Zeitaufwand wird mit mehr Erfahrung honoriert.</p> <ul style="list-style-type: none"> <li>- Kompaktkurs Projekte real erleben</li> <li>- Startup-Challenge</li> </ul> <p>Detailbeschreibungen zu allen Kursen sowie die konkreten Kursthemen und Termine pro Semester im digicampus.</p>	
<b>Lehr-/Lernmethoden:</b>	
Vortrag, Diskussion, Übungen, Praxisbeispiele, event. Projektarbeit unter Verwendung von multimedialen Techniken (Beamer, Flipchart, Pinwand)	
<b>Literature:</b>	
wird im Kurs bz. in die Kursbeschreibungen angegebenen bzw. vorab kommuniziert.	
<b>Assigned Courses:</b>	
<b>Kompaktkurs - Startup Challenge</b> (course) *(hybrid/mixed) *	
<b>Kurs Changemanagement</b> (course)	

*\*(in attendance) \**

**Kurs Inner-Leadership** (course)

*\*(in attendance) \**

**Kurs Innovationen entwickeln** (course)

*\*(in attendance) \**

**Kurs Kommunikationstraining** (course)

*\*(in attendance) \**

**Kurs Konfliktmanagement (Option 1)** (course)

*\*(in attendance) \**

**Kurs Konfliktmanagement (Option 2)** (course)

*\*(in attendance) \**

**Kurs Leadership experience (English)** (course)

*\*(in attendance) \**

**Kurs Nachhaltiges Wirtschaften** (course)

*\*(in attendance) \**

**Kurs Present your work purposefully to an interdisciplinary audience** (course)

*\*(in attendance) \**

**Kurs Project management (English)** (course)

*\*(in attendance) \**

**Kurs Projektmanagement** (course)

*\*(in attendance) \**

**Kurs Rhetorik (Option 1)** (course)

*\*(in attendance) \**

**Kurs Rhetorik (Option 2)** (course)

*\*(in attendance) \**

**Kurs Strategische Gesprächsführung (Option 1)** (course)

*\*(in attendance) \**

**Kurs Strategische Gesprächsführung (Option 2)** (course)

*\*(in attendance) \**

**Kurs Teams führen** (course)

*\*(in attendance) \**

**Kurs Zeit- und Selbstmanagement** (course)

*\*(in attendance) \**

**Startup Challenge (Projektstudium) - Bachelor**

*\*(hybrid/mixed) \**

### **Examination**

**Anwesenheit und aktive Übungsteilnahme im Kurs**

confirmed participation, not graded

<b>Module ZCS-3000: Soft Skills: Extended</b> <i>Softskills - Extended</i>		3 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Claudia Lange-Hetmann		
<b>Contents:</b> Die Studierenden erwerben in den Softskill-Kursen, die diesem Modul zugeordnet sind kommunikative, soziale oder methodische Kenntnisse und Fähigkeiten, die unerlässlich für ihre künftige Berufsfähigkeit sind. Detailbeschreibungen zu Kursen und Anmeldeverfahren befinden sich auf <a href="https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK">https://www.uni-augsburg.de/de/studium/zusatzqualifikationen/profilbildung/#Anker_skK</a> bzw. im digicampus.		
<b>Learning Outcomes / Competences:</b> Die Teilnehmer sind am Ende des extended Softskill-Kurses in der Lage selbständig innovative (Gründungs-)Projekte auszuarbeiten bzw. eigenständige Geschäftsideen zu entwickeln und diese selbstkritisch bezüglich ihrer Erfolgsaussichten und den Impact auf Märkte und Gesellschaft zu beurteilen und nachhaltig zu implementieren bzw. Weiterhin sind die Teilnehmer befähigt sich selbstständig in dieser Hinsicht fortzubilden		
<b>Remarks:</b> <ul style="list-style-type: none"> <li>• Anmeldepflicht: Für die Teilnahme an den Kursen ist eine Anmeldung über Digicampus erforderlich.</li> <li>• Anmeldephase: Januar (für das folgende SS) bzw. Juli (für das folgende WS).</li> <li>• Die Kurse finden in Präsenz wie auch online statt - siehe zugeordnete Lehrveranstaltung im Digicampus.</li> <li>• Die Kurse haben eine limitierte Teilnehmerzahl pro Semester.</li> </ul>		
<b>Workload:</b> Total: 90 h 30 h studying of course content using provided materials (self-study) 20 h studying of course content through exercises / case studies (self-study) 40 h (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Abhängig vom jeweiligen Kurs
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 3,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Softskills - Extended</b> <b>Mode of Instruction:</b> course <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 3,00 <b>ECTS Credits:</b> 3.0		
<b>Contents:</b> Kurse, die (un)regelmäßig angeboten werden: <ul style="list-style-type: none"> <li>• Startup-Challenge</li> </ul> Weitere Informationen finden sich im Digicampus.		
<b>Lehr-/Lernmethoden:</b> Vortrag / Präsentation sowie Übungen, Projektarbeit, Abchlußpräsentation, Diskussion, Reflexion		

**Literature:**

wird in den Kursbeschreibungen angegeben bzw. vorab kommuniziert.

**Examination**

**Softskills - Extended**

module exam, Prüfung anhängig vom spezifisch gewählten Kurs, not graded

**Test Frequency:**

when a course is offered

<b>Module INF-0136: Seminar Software- and Systems Engineering (Master)</b> <i>Seminar Software- und Systems Engineering (Master)</i>		4 ECTS/LP
Version 1.1.0 (since SoSe14) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b></p> <p>After successful completion of the seminar, students are able to understand, to learn, to analyse and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of software and systems engineering.</p> <p>They know the scientific methods, communication skills and the ability to use appropriate media to present a specific topic clearly and comprehensibly in speech and writing and to discuss challenging scientific topics from the aforementioned field critically. They will also be able to recognize the logical structures of reasoning and argumentation and use them.</p> <p>The participants are able to formulate clearly and understandably and to present specialist knowledge freely. They understand how to structure a presentation in a clear and comprehensible way and how to focus the presentation on the core messages and convey them in a comprehensible way even for complex and advanced subjects.</p> <p>Die Studierenden verstehen es, präsent aufzutreten und souverän mit gängigen Präsentationsmedien umzugehen und diese interaktiv einzusetzen. Sie schaffen es, einen Vortrag auf eine bestimmte Zielgruppe auszurichten und den Zuhörer auch bei längeren Vortragsdauern zu motivieren und verschiedene Moderationstechniken anzuwenden.</p> <p>The students understand how to present themselves and how to deal confidently with common presentation media. They manage to focus a presentation to a specific target group and to motivate the audience and they have working knowledge of moderation techniques to guide a discussion.</p> <p><b>Soft Skills:</b></p> <ul style="list-style-type: none"> <li>• Literature research</li> <li>• Independently work with English technical literature</li> <li>• Analytical competence</li> <li>• Working methodical</li> <li>• Principles of good scientific practice</li> <li>• Ability to present (written and oral) ideas, concepts and results in a comprehensible and convincing manner and to document them</li> <li>• Ability to think logically, abstractly, analytically and conceptually and to argue precisely</li> <li>• Awareness for quality aspects</li> <li>• Communication skills</li> <li>• Time management</li> <li>• Evaluation of solution approaches, procedures, techniques and technologies from different points of view</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 120 h                  90 h preparation of written term papers (self-study)                  30 h seminar (attendance)</p>		
<p><b>Conditions:</b></p> <p>none</p>		
<p><b>Frequency:</b> irregular (usu. winter semester)</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 2,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<b>Part of the Module: Seminar Software- und Systems Engineering (Master)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. winter semester) <b>Contact Hours:</b> 2,00
<b>Contents:</b> The topics of the seminar deal with current trends in Software and Systems Engineering on the level of graduate students. The topics change from year to year and are regularly adapted to reflect new developments.
<b>Literature:</b> Depends on the concrete topic.
<b>Examination</b> <b>Seminar Software- und Systems Engineering (Master)</b> written/oral exam / length of examination: 45 minutes work period for assignment: 3 months, graded <b>Test Frequency:</b> when a course is offered

<b>Module INF-0227: Seminar Database Systems (Master)</b> <i>Seminar Datenbanksysteme für Master</i>		4 ECTS/LP
Version 1.0.0 (since SoSe16) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of database systems in relation to the individual seminar topic from the mentioned field.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and understandable manner, both verbally and in writing, and to critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.</p> <p>The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions.</p> <p>The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.</p> <p>Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.</p>		
<b>Remarks:</b> language (D/E) as requested by the students		
<b>Workload:</b> Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)		
<b>Conditions:</b> Module Database Systems (INF-0073) - recommended		
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Datenbanksysteme für Master</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> irregular (usu. summer semester) <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Current research contributions from the field of "Databases and Information Systems".		

**Literature:**

Current research contributions

**Assigned Courses:**

**Seminar Datenbanksysteme für Master** (seminar)

*\*(hybrid/mixed) \**

**Examination**

**lecture and written elaboration**

seminar, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0251: Seminar Artificial Intelligence</b> <i>Seminar Artificial Intelligence</i>		4 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: PD Dr. Jonghwa Kim		
<b>Contents:</b> The seminar will take place as a block seminar at the end of June for summer term or mid-December for winter term. The topic area for this seminar will be redefined annually, taking into account new trends in "Artificial Intelligence and Intelligent Systems".		
<b>Learning Outcomes / Competences:</b> After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of "Artificial Intelligence and Intelligent Systems" in relation to the individual seminar topic from the mentioned field. They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques. <b>Key qualifications:</b> Evaluation of approaches, procedures, techniques and technologies from different points of view; literature research; independent work with English-language technical literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and in documenting them; skill in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management.		
<b>Workload:</b> Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> usu. at least once per acad. year	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar Artificial Intelligence</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> usu. at least once per acad. year <b>Contact Hours:</b> 2,00 <b>ECTS Credits:</b> 4.0		

**Contents:**

The seminar will take place as a block seminar at the end of June for summer term or mid-December for winter term. The topic area for this seminar will be redefined annually, taking into account new trends in "Artificial Intelligence and Intelligent Systems".

**Literature:**

current research literature

**Examination**

**Seminar Artificial Intelligence**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0314: Seminar IT Infrastructure in Medical Information Systems (Master)</b> <i>Seminar IT-Infrastrukturen in der Medizin für Master</i>		4 ECTS/LP
Version 1.0.0 (since SoSe19) Person responsible for module: Prof. Dr. Frank Kramer Dr. Dominik Müller		
<b>Learning Outcomes / Competences:</b> <b>Learning Outcomes:</b> Upon completion of the seminar, students are able to independently develop, analyze, and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of IT infrastructures for translational medical research, with reference to their individual seminar topic within this domain. They possess the scientific methodology, communication skills, and ability to use appropriate media to present a specialized topic clearly and comprehensibly in both written and oral form, and to critically and argumentatively discuss and evaluate scientifically demanding topics within this field. Furthermore, they can recognize logical structures of reasoning and argumentation and apply them purposefully.  Participants can formulate clearly and comprehensibly and deliver subject content freely. They understand how to structure a presentation clearly and coherently, and even with complex content, how to focus the presentation on key messages and convey them intelligibly. They skillfully apply chains of argumentation and strategies for handling disruptions. Students understand how to maintain a confident presence, handle common presentation media competently, and employ them interactively. They are able to tailor a presentation to a specific target audience, motivate listeners even during longer presentations, and apply various moderation techniques. <b>Key Competencies:</b> Literature research; independent work with English-language specialist literature; analytical-methodological competence; scientific methodology; principles of good scientific practice; ability to present (practical or theoretical) ideas, concepts, and results in a comprehensible, confident, and convincing manner (both written and oral) and to document them; ability for logical, abstract, analytical, and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of solution approaches, procedures, techniques, and technologies from multiple perspectives.		
<b>Workload:</b> Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar IT Infrastructure in Medical Information Systems for Master Students</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English / German <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00		

**Contents:**

Current topics in IT Infrastructures in Medicine

**Literature:**

Literature will be presented in the respective kickoff event.

**Assigned Courses:**

**Seminar IT Infrastructure in Medical Information Systems for Master Students** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar IT Infrastructure in Medical Information Systems for Master Students**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0320: Seminar Process Mining</b> <i>Seminar Process Mining</i>		4 ECTS/LP
Version 1.0.0 (since WS19/20) Person responsible for module: Prof. Dr. Robert Lorenz		
<b>Contents:</b> Basic knowledge of process mining		
<b>Learning Outcomes / Competences:</b> After attending the seminar, the students can independently work out and analyse advanced problems, concepts, methods, procedures, techniques, and technologies from the field of process mining and evaluate them in relation to the individual seminar topic.  Participants possess scientific methodology, communication skills, and the ability to present a special topic clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively.  Furthermore, they learn to recognise logical structures of thinking and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a talk that is clear and easy to follow. Additionally, the students know how to focus on essential messages and convey them in a comprehensible way, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to confidently deal with common presentation media and use them interactively. They manage to gear a talk to a specific target group, apply various moderation techniques, and keep their audience engaged even over a longer period.  <b>Key qualifications:</b> Presentation techniques; literature research; principles of good scientific practice; evaluating solution approaches, procedures, techniques, and technologies from different points of view.		
<b>Remarks:</b> The accompanying literature is written in English. If foreign students with insufficient German language skills participate, the language of instruction will be English.		
<b>Workload:</b> Total: 120 h 45 h preparation of presentations (self-study) 45 h preparation of written term papers (self-study) 30 h seminar (attendance)		
<b>Conditions:</b> Grundkenntnisse in Process Mining  Module Process Mining (INF-0243) - required		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar Process Mining</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00 <b>ECTS Credits:</b> 4.0		

**Contents:**

Current Research Topics in the Field of Process Mining: Process Discovery, Conformance Checking, Enhancement, Preprocessing of logs (clustering, filtering), Handling of Noise, Synthesis based methods, Process Mining and Data Mining, Statistical methods in Process Mining, case studies, tooling.

Das Seminar eignet sich zur Vorbereitung auf Abschlussarbeiten und Projektmodule.

**Literature:**

Literature depends on the chosen topic

**Examination**

**Seminar Process Mining**

written/oral exam / length of examination: 60 minutes

work period for assignment: 2 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0337: Seminar Embedded Systems (Master)</b> <i>Seminar Embedded Systems (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of embedded systems in relation to the individual seminar topic from the named field.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the aforementioned field in a critical and argumentative manner. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.</p> <p>The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a scientific presentation in a clear and comprehensible way and how to focus the presentation on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a presentation to a specific target group and to motivate the listener even during longer presentation durations and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Embedded Systems (Master)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00</p>		

**Contents:**

In the seminar, topics from the field of embedded systems will be covered. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written paper and a presentation on the topic covered.

**Literature:**

given individually and self research

**Assigned Courses:**

**Seminar Embedded Systems (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Embedded Systems (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0344: Seminar Software Engineering of Distributed Systems (Master)</b> <i>Seminar Software Engineering verteilter Systeme (MA)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students can independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in software engineering for distributed systems about the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus the study on essential messages, and understandably convey them, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.</p> <p>Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<p><b>Conditions:</b></p> <p>The previous course "Seminar on Software Engineering of Distributed Systems (MA)" (INF-0039) must not have been taken due to overlaps.</p>		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Software Engineering verteilter Systeme (MA)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Current software engineering topics from industry and research.		
<b>Literature:</b> Will be presented in the respective kick-off event.		
<b>Assigned Courses:</b>		

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**Seminar Software Engineering verteilter Systeme (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Software Engineering verteilter Systeme (MA)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0346: Seminar Automotive Software and Systems Engineering (Master)</b> <i>Seminar Automotive Software and Systems Engineering (MA)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students can independently analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in Automotive Software &amp; Systems Engineering about the particular seminar topic from the named area. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus the study on important messages, and understandably convey them, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.</p> <p>Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<p><b>Conditions:</b></p> <p>The previous course "Seminar Fundamentals of Software Engineering for Automotive Systems (MA)" (INF-0040) must not have been taken due to overlaps.</p>		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Automotive Software and Systems Engineering (MA)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>Current software engineering topics from industry and research.</p>		
<p><b>Literature:</b></p> <p>Will be presented in the respective kick-off event.</p>		

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**Examination**

**Seminar Automotive Software and Systems Engineering (MA)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0348: Seminar Avionic Software and Systems Engineering (Master)</b> <i>Seminar Avionic Software and Systems Engineering (MA)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students can independently analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in Avionic Software &amp; Systems Engineering about the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably focus the study on important messages and understandably convey them, even in the case of complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.</p> <p>Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<p><b>Conditions:</b></p> <p>The previous course "Seminar Grundlagen des Software Engineering für Avionic Systems (MA)" (INF-0041) must not have been taken due to overlaps.</p>		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Avionic Software and Systems Engineering (MA)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Current software engineering topics from industry and research.		
<b>Literature:</b> Will be presented in the respective kick-off event.		

**Examination**

**Seminar Avionic Software and Systems Engineering (MA)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0349: Seminar Human-Centred Artificial Intelligence</b> <i>Seminar Menschzentrierte Künstliche Intelligenz</i>		4 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently work out, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of "human-centered artificial intelligence" related to the individual seminar topic from the mentioned field. They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and to critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Human-Centered Artificial Intelligence</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Topics in the field of "Human-Centered Artificial Intelligence"		
<b>Literature:</b> References will be announced at the preliminary meeting.		

**Examination**

**Seminar Human-Centered Artificial Intelligence**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0364: Seminar Software Engineering in Safety- and Security-Critical Systems (Master)</b> <i>Seminar Software Engineering in sicherheitskritischen Systemen (MA)</i>		4 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Bernhard Bauer		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students can independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in software engineering in safety-critical systems and related disciplines about the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus on essential messages, and coherently convey them, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.</p> <p>Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Software Engineering in sicherheitskritischen Systemen (MA)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Current software engineering topics from industry and research.		
<b>Literature:</b> Will be presented in the respective kick-off event.		
<b>Assigned Courses:</b>		

**Seminar Software Engineering in sicherheitskritischen Systemen (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Software Engineering in sicherheitskritischen Systemen (MA)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0385: Seminar Resource Aware Algorithmics (Master)</b> <i>Seminar Resource Aware Algorithmics (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe21) Person responsible for module: Prof. Dr. Tobias Mömke		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, the students are able to understand basic algorithmic concepts, methods, tools and techniques in a self-sufficient manner.</p> <p>They have acquired communication skills, knowledge about work processes and the use of media to present a specific scientific topic both as a talk and in written form.</p> <p>The participants have learned to express technical contents in a structured, understandable and inspiring manner. They have learned to confidently stand in front of the audience, using state of the art presentation tools and media. They are able to tailor the talk to the respective audience.</p> <p><b>Key Qualifications:</b> Literature research; work with scientific literature in English language; analytic competences; clean scientific practice; ability to present technical content in confident, understandable and structured manner (both in written and spoken form); abstract, logical and analytical thinking; ability to argue formally; aim for high quality; communication skills; time management.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h</p> <p>30 h seminar (attendance)</p> <p>90 h preparation of written term papers (self-study)</p>		
<p><b>Conditions:</b></p> <p>Good knowledge of content taught in mathematical Bachelor classes such as "Mathematik für Informatiker 1" and "Diskrete Strukturen und Logik."</p> <p>Knowledge about algorithms and data structures (Informatik 3) is useful.</p>		<p><b>Credit Requirements:</b></p> <p>Passing of the module exam</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>2,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Seminar Resource Aware Algorithmics (Master)</b></p> <p><b>Mode of Instruction:</b> seminar</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular</p> <p><b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>The topics of the seminar are related to research in resource aware algorithmics. The precise topics change over time, in order to reflect up-to-date developments.</p>		
<p><b>Literature:</b></p> <p>Depending on the topic of the seminar.</p>		
<p><b>Assigned Courses:</b></p> <p><b>Seminar Resource Aware Algorithmics (Master) - Traveling Salesman Problem</b> (seminar)</p> <p><i>*(online/digital) *</i></p>		

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**Examination**

**Seminar Resource Aware Algorithmics (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0388: Seminar Biomedical Computer Science (Master)</b> <i>Seminar zur biomedizinischen Informatik (Master)</i>		4 ECTS/LP
Version 3.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Matthias Schlesner		
<p><b>Learning Outcomes / Competences:</b> After attending the seminar, students will be able to independently research and understand the methods and techniques of biomedical informatics in basic biomedical research applications as well as in clinical applications. They will have acquired the working techniques, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and to discuss issues in the aforementioned field in a critical and argumentative manner. They will also be able to recognize and use logical structures of reasoning and argumentation in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present topic-specific content freely. They understand how to structure a presentation in a clear and coherent way and how to focus the presentation on essential messages and convey them in a comprehensible manner. The students understand how to present themselves and how to deal confidently with common presentation media. They manage to align a presentation to a specific target group, to motivate the listener and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English topic-specific technical literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skills in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skills in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management.</p>		
<p><b>Workload:</b> Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 5.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar zur biomedizinischen Informatik (Master)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b> In the seminar, topics from the field of biomedical informatics will be covered. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written paper and a presentation on the topic covered.</p>		
<p><b>Literature:</b> given individually and self-research</p>		
<b>Assigned Courses:</b>		

**Seminar zur biomedizinischen Informatik (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar zur biomedizinischen Informatik (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0422: Seminar Organic Computing (Master)</b> <i>Seminar Organic Computing (Master)</i>		4 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, the students are able to independently work out advanced problems, concepts, methods, procedures, techniques and technologies in the fields of organic computing and to analyse and evaluate them in relation to the individual seminar topic from the named field.</p> <p>They possess the scientific methodology, communication skills and ability to use appropriate media to present a special topic clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognise the logical structures of thinking and argumentation and use them in a goal-oriented manner.</p> <p>Participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a presentation clearly and reasonable and how to focus on essentials and convey those in a comprehensible way, even with complex content. They skilfully apply lines of argument and solution strategies in the event of disruptions.</p> <p>The students understand how to present themselves and confidently deal with common presentation media, using them interactively. They manage to gear a talk to a specific target group, motivate the listener even during longer talks and apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; independent work with English-language specialist literature; Analytical-methodical competence; scientific methodology; principles of good scientific practice; Ability to describe and document (practical and theoretical) ideas, concepts and results in a comprehensible, confident and convincing manner (written and oral); Ability to think logically, abstractly, analytically and conceptually and to argue formally; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies.</p>		
<p><b>Remarks:</b></p> <p>Seminar papers can be written in either German or English.</p> <p>Presentations will be held in English.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h</p> <p>30 h seminar (attendance)</p> <p>90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Organic Computing (Master)</b></p> <p><b>Mode of Instruction:</b> seminar</p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> each semester</p> <p><b>Contact Hours:</b> 2,00</p> <p><b>ECTS Credits:</b> 4.0</p>		

**Contents:**

The topics of the seminar are determined each year and adapted to current trends.

**Literature:**

Literature depending on the current topics: scientific papers or books.

**Assigned Courses:**

**Seminar Organic Computing (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Presentation and written paper.**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0439: Seminar Quantum Algorithms (Master)</b> <i>Seminar Quantum Algorithms (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann		
<b>Contents:</b> The seminar deepens the content covered in the lecture "Quantum Algorithms." Attending the lecture at the same time is recommended. Specific topics are based on current research. Application examples and topics covered in the lecture are explored in greater depth, and new topics are introduced. The seminar is suitable as preparation for a thesis in the field of quantum algorithms.		
<b>Learning Outcomes / Competences:</b> After attending the seminar, students will be able to independently develop, analyze, and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of quantum algorithms in relation to the individual seminar topic from the aforementioned field. They will have the scientific methodology, communication skills, and ability to use appropriate media to present a specific topic clearly and comprehensibly in both written and spoken form and to critically discuss and evaluate scientifically demanding topics from the specified field. In addition, they will be able to recognize the logical structures of thinking and argumentation and use them in a goal-oriented manner. Participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a presentation clearly and comprehensibly and, even with complex content, focus the presentation on key messages and convey these in an understandable way. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. Students know how to present themselves confidently and use common presentation media interactively. They are able to tailor a presentation to a specific target group, motivate the audience even during longer presentations, and apply various moderation techniques.		
<b>Workload:</b> Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Seminar Quantum Algorithms (Master)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00
<b>Contents:</b> The topics of the seminar are redefined each time and adapted to current developments.
<b>Literature:</b> Depends on chosen topic
<b>Assigned Courses:</b> <b>Seminar Quantenalgorithmen (Bachelor &amp; Master)</b> (seminar)

*\*(hybrid/mixed) \**

**Examination**

**Seminar Quantum Algorithms (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0443: Seminar on Theory of Distributed and Parallel Systems (Master)</b> <i>Seminar Theorie verteilter und paralleler Systeme (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Kirstin Peters		
<p><b>Learning Outcomes / Competences:</b></p> <p>Nach dem Besuch des Seminars sind die Studierenden in der Lage, weiterführende Problemstellungen, Konzepte, Methoden, Verfahren, Techniken und Technologien auf dem Gebiet der Theorie verteilter und paralleler Systeme selbstständig zu erarbeiten, zu analysieren und bezogen auf das individuelle Seminarthema aus dem genannten Gebiet zu bewerten.</p> <p>Sie verfügen über die wissenschaftliche Methodik, Kommunikationsfähigkeit und Fähigkeit zum Einsatz entsprechender Medien, um ein spezielles Thema in Wort und Schrift klar und verständlich zu präsentieren und wissenschaftlich anspruchsvolle Themenstellungen aus dem genannten Gebiet kritisch und argumentativ zu diskutieren und zu bewerten. Außerdem können sie die logischen Strukturen des Denkens und Argumentierens erkennen und zielführend einsetzen.</p> <p>Die Teilnehmenden können klar und verständlich formulieren und Fachinhalte frei vortragen. Sie verstehen es, einen Vortrag klar und nachvollziehbar zu strukturieren und auch bei komplexen Inhalten den Vortrag auf wesentliche Botschaften auszurichten und diese verständlich zu vermitteln. Argumentationsketten und Lösungsstrategien bei Störungen wenden sie gekonnt an.</p> <p>Die Studierenden verstehen es, präsent aufzutreten und souverän mit gängigen Präsentationsmedien umzugehen und diese interaktiv einzusetzen. Sie schaffen es, einen Vortrag auf eine bestimmte Zielgruppe auszurichten und den Zuhörer auch bei längeren Vortragsdauern zu motivieren und verschiedene Moderationstechniken anzuwenden.</p> <p><b>Schlüsselqualifikationen:</b> Literaturrecherche; Eigenständiges Arbeiten mit englischsprachiger Fachliteratur; Analytisch-methodische Kompetenz; Wissenschaftliche Methodik; Grundsätze guter wissenschaftlicher Praxis; Fertigkeit der verständlichen, sicheren und überzeugenden (schriftlichen und mündlichen) Darstellung von (praktischen oder theoretischen) Ideen, Konzepten und Ergebnissen und zu deren Dokumentation; Fertigkeit zum logischen, abstrakten, analytischen und konzeptionellen Denken und formaler Argumentation; Qualitätsbewußtsein, Akribie; Kommunikationsfähigkeit; Zeitmanagement; Bewertung von Lösungsansätzen, Verfahren, Techniken und Technologien unter unterschiedlichen Gesichtspunkten</p>		
<p><b>Workload:</b></p> <p>Total: 120 h</p> <p>90 h preparation of written term papers (self-study)</p> <p>30 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Theorie verteilter und paralleler Systeme (Master)</b></p> <p><b>Mode of Instruction:</b> seminar</p> <p><b>Language:</b> German</p> <p><b>Frequency:</b> irregular</p> <p><b>Contact Hours:</b> 2,00</p>		

**Contents:**

Die Themen des Seminars werden jedes Mal neu festgelegt und an aktuelle Entwicklungen angepasst.

**Literature:**

Abhängig vom gewählten Thema

**Examination**

**Seminar Theorie verteilter und paralleler Systeme (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0444: Seminar Generative Artificial Intelligence</b> <i>Seminar Generative Künstliche Intelligenz</i>		4 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently work out, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of "Generative Artificial Intelligence" in relation to the individual seminar topic from the mentioned field. They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Generative Artificial Intelligence</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Topics in the field of "Generative Artificial Intelligence"		
<b>Literature:</b> References will be announced at the preliminary meeting.		
<b>Assigned Courses:</b> <b>Seminar Generative Künstliche Intelligenz</b> (seminar)		

*\*(in attendance) \**

**Examination**

**Seminar Generative Artificial Intelligence**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<p><b>Module INF-0446: Seminar Software and Artificial Intelligence for Production Systems (Master)</b>  <i>Seminar Software und Künstliche Intelligenz in der Produktion (Master)</i></p>		4 ECTS/LP
<p>Version 1.0.0 (since SoSe23)                  Person responsible for module: Prof. Dr. Wolfgang Reif</p>		
<p><b>Learning Outcomes / Competences:</b>                  After successful completion of the seminar, students are able to understand, to learn, to analyse and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of software and systems engineering.                  They know the scientific methods, communication skills and the ability to use appropriate media to present a specific topic clearly and comprehensibly in speech and writing and to discuss challenging scientific topics from the aforementioned field critically. They will also be able to recognize the logical structures of reasoning and argumentation and use them.                  The participants are able to formulate clearly and understandably and to present specialist knowledge freely. They understand how to structure a presentation in a clear and comprehensible way and how to focus the presentation on the core messages and convey them in a comprehensible way even for complex and advanced subjects.                  Die Studierenden verstehen es, präsent aufzutreten und souverän mit gängigen Präsentationsmedien umzugehen und diese interaktiv einzusetzen. Sie schaffen es, einen Vortrag auf eine bestimmte Zielgruppe auszurichten und den Zuhörer auch bei längeren Vortragsdauern zu motivieren und verschiedene Moderationstechniken anzuwenden.                  The students understand how to present themselves and how to deal confidently with common presentation media. They manage to focus a presentation to a specific target group and to motivate the audience and they have working knowledge of moderation techniques to guide a discussion.</p> <p><b>Soft Skills:</b></p> <ul style="list-style-type: none"> <li>• Literature research</li> <li>• Independently work with English technical literature</li> <li>• Analytical competence</li> <li>• Working methodical</li> <li>• Principles of good scientific practice</li> <li>• Ability to present (written and oral) ideas, concepts and results in a comprehensible and convincing manner and to document them</li> <li>• Ability to think logically, abstractly, analytically and conceptually and to argue precisely</li> <li>• Awareness for quality aspects</li> <li>• Communication skills</li> <li>• Time management</li> <li>• Evaluation of solution approaches, procedures, techniques and technologies from different points of view</li> </ul>		
<p><b>Workload:</b>                  Total: 120 h                  90 h preparation of written term papers (self-study)                  30 h seminar (attendance)</p>		
<p><b>Conditions:</b>                  none</p>		
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b>                  from 1.</p>	<p><b>Minimal Duration of the Module:</b>                  1 semester[s]</p>
<p><b>Contact Hours:</b>                  2,00</p>	<p><b>Repeat Exams Permitted:</b>                  according to the examination regulations of the study program</p>	

**Parts of the Module**

**Part of the Module: Seminar Software und Künstliche Intelligenz in der Produktion (Master)**

**Mode of Instruction:** seminar

**Language:** German / English

**Frequency:** irregular

**Contact Hours:** 2,00

**Contents:**

The topics of the seminar deal with current trends in Software and Systems Engineering on the level of graduate students. The topics change from year to year and are regularly adapted to reflect new developments.

**Literature:**

Depends on the concrete topic.

**Examination**

**Seminar Software und Künstliche Intelligenz in der Produktion (Master)**

written/oral exam / length of examination: 45 minutes

work period for assignment: 3 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0448: Seminar on Concurrent Systems (Master)</b> <i>Seminar zu nebenläufigen Systemen (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Robert Lorenz		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, the students can independently work out and analyse advanced problems, concepts, methods, procedures, techniques, and technologies from the field of digital ethics and evaluate them in relation to the individual seminar topic.</p> <p>Participants possess scientific methodology, communication skills, and the ability to present a special topic clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively.</p> <p>Furthermore, they learn to recognise logical structures of thinking and argumentation and use them in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a talk that is clear and easy to follow. Additionally, the students know how to focus on essential messages and convey them in a comprehensible way, even with complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to confidently deal with common presentation media and use them interactively. They manage to gear a talk to a specific target group, apply various moderation techniques, and keep their audience engaged even over a longer period.</p> <p><b>Key qualifications:</b> Presentation techniques; literature research; principles of good scientific practice; evaluating solution approaches, procedures, techniques, and technologies from different points of view.</p>		
<p><b>Remarks:</b></p> <p>The accompanying literature is written in English. If foreign students with insufficient German language skills participate, the language of instruction will be English.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of presentations (self-study) 30 h seminar (attendance)</p>		
<p><b>Conditions:</b></p> <p>Basic knowledge of Petri Nets Module Process Mining (INF-0243) - recommended</p>		<p><b>Credit Requirements:</b></p> <p>Passing the module examination</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 2,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Seminar Digital Ethics (Master)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English / German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00 <b>ECTS Credits:</b> 4.0</p>		
<p><b>Contents:</b></p> <p>The topics of the seminar change over time, in order to reflect up-to-date developments</p>		

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**Literature:**

Literature depends on the chosen topic

**Examination**

**Seminar Digital Ethics (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0453: Seminar Diagnostic Sensing (Master)</b> <i>Seminar Diagnostische Sensorik (Master)</i>		4 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Sebastian Zaunseder Aublin, Pierre, Dr.		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently work out and understand basic problems, concepts, methods, procedures, techniques and technologies in the field of Diagnostic Sensing.</p> <p>They have the working techniques, communication skills and the ability to use appropriate media to present a specific topic clearly and comprehensibly, both verbally and in writing, and to discuss topics from the aforementioned field critically and argumentatively. They will also be able to recognize and use logical structures of reasoning and argumentation in a goal-oriented manner.</p> <p>The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a talk in a clear and comprehensible way and how to focus the talk on essential messages and convey them in a comprehensible way.</p> <p>The students understand how to present themselves and how to deal confidently with common presentation media. They manage to gear a lecture to a specific target group and to motivate the listener and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or th</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing of the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Diagnostic Sensing (Master)</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00 <b>ECTS Credits:</b> 4.0</p>		
<b>Contents:</b> The topics of the seminar change over time, in order to reflect up-to-date developments		
<b>Literature:</b> Literature depends on the chosen topic		
<p><b>Assigned Courses:</b></p> <p><b>Seminar Diagnostische Sensorik (Master)</b> (seminar) <i>*(hybrid/mixed) *</i></p>		

**Examination**

**Seminar Diagnostic Sensing (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0468: Seminar Natural Language Understanding (Master)</b> <i>Seminar Natural Language Understanding (Master)</i>		4 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Annemarie Friedrich		
<p><b>Contents:</b></p> <p>The seminar on natural language understanding delves into the fascinating realm of artificial intelligence and linguistics, exploring how machines can comprehend and process human language. Computational semantics is a subfield of natural language processing (NLP) and computational linguistics that focuses on the development of algorithms, models, and systems for understanding and representing the meaning of natural language text in a way that computers can process and manipulate. Exemplary topics discussed in this seminar include: representing word, sentence, or text meaning, semantic role labeling, semantic parsing, discourse and pragmatics.</p> <p>The number of participants is limited.</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of embedded systems in relation to the individual seminar topic from the named field.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and to discuss and evaluate scientifically challenging topics from the aforementioned field in a critical and argumentative manner. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.</p> <p>The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a scientific presentation in a clear and comprehensible way and how to focus the presentation on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a presentation to a specific target group and to motivate the listener even during longer presentation durations and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.</p>		
<p><b>Remarks:</b></p> <p>The course will be taught by Dr. Jakob Prange, who will join the department in October.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<p><b>Conditions:</b></p> <p>none</p>		<p><b>Credit Requirements:</b></p> <p>Presentation and term paper</p>
<p><b>Frequency:</b> irregular</p>	<p><b>Recommended Semester:</b></p> <p>1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>2,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

**Parts of the Module**

**Part of the Module: Seminar Natural Language Understanding (Master)**

**Mode of Instruction:** seminar

**Language:** German / English

**Frequency:** irregular

**Contact Hours:** 2,00

**Contents:**

In the seminar, topics from the field of embedded systems will be covered. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written paper and a presentation on the topic covered.

**Literature:**

given individually and self research

**Examination**

**Seminar Natural Language Understanding (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0471: Seminar Networked Systems and Communication Networks (Master)</b> <i>Seminar Vernetzte Systeme und Kommunikationsnetze (Master)</i>		4 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Michael Seufert		
<b>Learning Outcomes / Competences:</b> Nach dem Besuch des Seminars sind die Studierenden in der Lage, weiterführende Problemstellungen, Konzepte, Methoden, Verfahren, Techniken und Technologien auf dem Gebiet der vernetzten Systeme und Kommunikationsnetze selbstständig zu erarbeiten, zu analysieren und bezogen auf das individuelle Seminarthema aus dem genannten Gebiet zu bewerten. Sie verfügen über die wissenschaftliche Methodik, Kommunikationsfähigkeit und Fähigkeit zum Einsatz entsprechender Medien, um ein spezielles Thema in Wort und Schrift klar und verständlich zu präsentieren und wissenschaftlich anspruchsvolle Themenstellungen aus dem genannten Gebiet kritisch und argumentativ zu diskutieren und zu bewerten. Außerdem können sie die logischen Strukturen des Denkens und Argumentierens erkennen und zielführend einsetzen. Die Teilnehmenden können klar und verständlich formulieren und Fachinhalte frei vortragen. Sie verstehen es, einen Vortrag klar und nachvollziehbar zu strukturieren und auch bei komplexen Inhalten den Vortrag auf wesentliche Botschaften auszurichten und diese verständlich zu vermitteln. Argumentationsketten und Lösungsstrategien bei Störungen wenden sie gekonnt an. Die Studierenden verstehen es, präsent aufzutreten und souverän mit gängigen Präsentationsmedien umzugehen und diese interaktiv einzusetzen. Sie schaffen es, einen Vortrag auf eine bestimmte Zielgruppe auszurichten und den Zuhörer auch bei längeren Vortragsdauern zu motivieren und verschiedene Moderationstechniken anzuwenden. <b>Schlüsselqualifikationen:</b> Literaturrecherche; Eigenständiges Arbeiten mit englischsprachiger Fachliteratur; Analytisch-methodische Kompetenz; Wissenschaftliche Methodik; Grundsätze guter wissenschaftlicher Praxis; Fertigkeit der verständlichen, sicheren und überzeugenden (schriftlichen und mündlichen) Darstellung von (praktischen oder theoretischen) Ideen, Konzepten und Ergebnissen und zu deren Dokumentation; Fertigkeit zum logischen, abstrakten, analytischen und konzeptionellen Denken und formaler Argumentation; Qualitätsbewußtsein, Akribie; Kommunikationsfähigkeit; Zeitmanagement; Bewertung von Lösungsansätzen, Verfahren, Techniken und Technologien unter unterschiedlichen Gesichtspunkten		
<b>Workload:</b> Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar Vernetzte Systeme und Kommunikationsnetze (Master)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		

**Contents:**

Die Themen des Seminars werden jedes Jahr neu festgelegt und aktuellen Entwicklungen, Herausforderungen und Lösungen im Bereich der vernetzten Systeme und Kommunikationsnetze angepasst.

**Literature:**

individuell gegeben und Selbstrecherche

**Assigned Courses:**

**Seminar Vernetzte Systeme und Kommunikationsnetze (Master)** (seminar)  
*\*(in attendance) \**

**Examination**

**Seminar Vernetzte Systeme und Kommunikationsnetze (Master)**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0479: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision</b> <i>Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision</i>		4 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, the students are able to work out, analyze and evaluate further problems, concepts, methods, techniques and technologies in the field of embodied artificial intelligence and computer vision, methods, procedures, techniques and technologies in the field of Embodied Artificial Intelligence and Computer Vision independently, analyze and evaluate them in relation to the individual seminar topic from the mentioned field. They possess the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and comprehensible manner, both verbally and in writing, and critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. In addition, they can recognize the logical structures of thought and argumentation and use them in a goal-oriented manner. Participants are able to formulate clearly and comprehensibly and present scientific content freely. They understand how to structure a presentation clearly and comprehensibly and, even with complex content, how to focus the presentation on essential messages and convey them in a comprehensible manner. The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a presentation to a specific target group, to motivate the listener and to apply various moderation techniques.</p> <p><b>Key qualifications:</b> Literature research; independent work with English-language scientific literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Ability to present comprehensible, confident and convincing (written and oral); presentation of (practical or theoretical) ideas, concepts, and results and to document them; ability to logical, abstract, analytical and conceptual thinking and formal reasoning; quality consciousness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques and technologies from different points of view.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> English / German <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		

**Contents:**

The seminar will cover current research topics in the field of Embodied Artificial Intelligence and Computer Vision. Each seminar participant will be assigned individual literature references, which will then be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written report and a presentation on the topic covered.

**Literature:**

Scientific literature announced in the kick-off meeting and self research

**Examination**

**Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0515: Seminar Movement Analysis in Medicine</b> <i>Seminar Movement Analysis in Medicine</i>		4 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr.-Ing Muthuraman Muthuraman		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently work out and understand basic problems, concepts, methods, procedures, techniques and technologies of movement analysis in the medical domain. They know the techniques, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly, both verbally and in writing, and to discuss topics from the aforementioned field critically. They will also be able to recognize and use logical structures of reasoning and argumentation in a goal-oriented manner. The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a scientific presentation in a clear and comprehensible way and how to focus it on essential messages.</p> <p>The students understand how to present themselves and how to deal confidently with common presentation media. They manage to gear a presentation to a specific target group and to motivate the listener and to apply various presentation techniques.</p> <p>Key qualifications: Literature research; Independent work with English-language expert literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Ability for comprehensive, confident and convincing (written and oral) presentation and documentation of practical or theoretical ideas, concepts, and results; Logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness; Time management.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 5.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar Movement Analysis in Medicine</b>		
<b>Mode of Instruction:</b> seminar		
<b>Language:</b> English		
<b>Frequency:</b> each semester		
<b>Contact Hours:</b> 2,00		
<p><b>Contents:</b></p> <p>In the seminar, topics from the field of movement analysis will be covered. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will end with a written paper and a presentation on the topic covered.</p>		
<p><b>Literature:</b></p> <p>given individually and self research</p>		
<b>Assigned Courses:</b>		
<b>Seminar Movement Analysis in Medicine</b> (seminar)		

*\*(in attendance) \**

**Examination**

**Seminar Movement Analysis in Medicine**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3019: Seminar Data Engineering (Master)</b> <i>Seminar Data Engineering Master</i>		4 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Fabian Panse		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students are able to independently develop, analyze and evaluate advanced problems, concepts, methods, procedures, techniques and technologies in the field of database systems in relation to the individual seminar topic from the mentioned field.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic in a clear and understandable manner, both verbally and in writing, and to critically and argumentatively discuss and evaluate scientifically challenging topics from the named field. They will also be able to recognize the logical structures of reasoning and argumentation and use them in a goal-oriented manner.</p> <p>The participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a lecture in a clear and comprehensible way and how to focus the lecture on essential messages and convey them in a comprehensible way, even in the case of complex content. They skilfully apply chains of argumentation and solution strategies in the event of disruptions.</p> <p>The students understand how to present themselves and how to deal confidently with common presentation media and to use them interactively. They manage to gear a lecture to a specific target group and to motivate the listener even during longer lecture durations and to apply various moderation techniques.</p> <p>Key qualifications: Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Skill in the comprehensible, confident and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts and results and for their documentation; Skill in logical, abstract, analytical and conceptual thinking and formal argumentation; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h</p> <p>30 h seminar (attendance)</p> <p>90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular (usu. winter semester)	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Data Engineering Master</b></p> <p><b>Language:</b> German / English</p> <p><b>Frequency:</b> irregular (usu. winter semester)</p> <p><b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> Current research topics from the field of data engineering, such as data cleaning, schema matching, or entity matching.		
<b>Literature:</b> Current research papers in the field of data engineering, such as data cleaning, schema matching, or entity matching. Will be provided at the beginning of the course.		

**Assigned Courses:**

**Seminar Data Engineering Master** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Data Engineering Master**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3023: Seminar Software Engineering for Artificial Intelligence Systems (Master)</b> <i>Seminar Software Engineering for Artificial Intelligence Systems Master</i>		4 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Bernhard Bauer		
<b>Learning Outcomes / Competences:</b> After attending the seminar, the students are able to independently work out, analyze and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of Software Engineering for Artificial Intelligence Systems concerning the particular seminar topic from the named field. They have the scientific methodology, communication skills, and ability to use appropriate media to present a specific case clearly and comprehensibly in speech and writing and to discuss and evaluate scientifically challenging topics from the named field critically and argumentatively. Furthermore, they can recognize the logical structures of thinking and argumentation and use them goal-oriented. The participants can formulate clearly and comprehensibly and present subject content freely. They understand how to structure a lecture clearly and understandably, focus the study on important messages, and convey them in a comprehensible way, even with complex content. They skillfully apply chains of argumentation and solution strategies in the event of disruptions. The students understand how to present themselves and confidently deal with joint presentation media and use them interactively. They manage to gear a lecture to a specific target group, motivate the listener even during longer lecture durations, and apply various moderation techniques.  Key qualifications: Literature research; independent work with English-language specialist literature; analytical-methodical competence; scientific methodology; principles of good scientific practice; skills in the understandable, confident, and convincing (written and oral) presentation of (practical or theoretical) ideas, concepts, and results and in documenting them; skills in logical, abstract, analytical and conceptual thinking and formal argumentation; quality awareness, meticulousness; communication skills; time management; evaluation of approaches, procedures, techniques, and technologies from different points of view. Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)		
<b>Workload:</b> Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Seminar Software Engineering for Artificial Intelligence Systems Master</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00		
<b>Contents:</b> This seminar will cover the basics of Software Engineering for Artificial Intelligence Systems. Various topics are to be worked on, which are to serve as a basis for a subsequent practical course.		
<b>Literature:</b> Will be presented at the respective kick-off event.		

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**Assigned Courses:**

**Seminar Software Engineering for Artificial Intelligence Systems Master** (seminar)

*\*(in attendance) \**

**Examination**

**Presentation and written paper**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3029: Seminar Theoretical Computer Science (Master)</b> <i>Seminar Theoretical Computer Science - Master</i>		4 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students will be able to independently develop and analyze advanced problems, concepts, methods, procedures, techniques and technologies in the field of theoretical computer science and evaluate them in relation to the individual seminar topic from the aforementioned field.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly both verbally and in writing and to discuss and evaluate scientifically demanding topics from the aforementioned field critically and argumentatively. In addition, they can recognize the logical structures of thinking and argumentation and apply them in a goal-oriented manner.</p> <p>Participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a presentation in a clear and comprehensible manner and how to focus the presentation on key messages and convey these in an understandable way, even in the case of complex content. They can skillfully apply chains of argumentation and solution strategies in the event of disruptions.</p> <p>Students know how to present themselves and confidently handle common presentation media and use them interactively. They are able to tailor a presentation to a specific target group and motivate the audience even during longer presentations and apply various moderation techniques.</p> <p><b>Key skills:</b> Literature research; Independent work with English-language specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Ability to present (practical or theoretical) ideas, concepts and results in a comprehensible, confident and convincing (written and oral) manner and to document them; Ability to think logically, abstractly, analytically and conceptually and to argue formally; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 5.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Theoretical Computer Science - Master</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> German / English <b>Frequency:</b> irregular <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> There are new topics every semester		
<b>Literature:</b> Scientific papers		

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**Assigned Courses:**

**Seminar Theoretical Computer Science Master (Topic: Algorithmic Game Theory)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Theoretical Computer Science - Master**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3045: Seminar Cyber Security (Master)</b> <i>Seminar Cyber Security Master</i>		4 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Frank Breitingger		
<p><b>Learning Outcomes / Competences:</b></p> <p>After attending the seminar, students will be able to independently develop and analyze advanced problems, concepts, methods, procedures, techniques and technologies in the field of cyber security and evaluate them in relation to the individual seminar topic from the area mentioned.</p> <p>They have the scientific methodology, communication skills and ability to use appropriate media to present a specific topic clearly and comprehensibly in written and spoken form and to discuss and evaluate scientifically demanding topics from the above-mentioned field critically and argumentatively. In addition, they can recognize the logical structures of thinking and argumentation and apply them in a goal-oriented manner.</p> <p>Participants can formulate clearly and comprehensibly and present specialist content freely. They understand how to structure a presentation in a clear and comprehensible manner and how to focus the presentation on key messages and convey these in an understandable way, even in the case of complex content. They can skillfully apply chains of argumentation and solution strategies in the event of disruptions.</p> <p>Students know how to present themselves and confidently handle common presentation media and use them interactively. They are able to tailor a presentation to a specific target group and motivate the audience even during longer presentations and apply various moderation techniques.</p> <p><b>Key skills:</b> Literature research; Independent work with specialist literature; Analytical-methodical competence; Scientific methodology; Principles of good scientific practice; Ability to present (practical or theoretical) ideas, concepts and results in a comprehensible, confident and convincing (written and oral) manner and to document them; Ability to think logically, abstractly, analytically and conceptually and to argue formally; Quality awareness, meticulousness; Communication skills; Time management; Evaluation of approaches, procedures, techniques and technologies from different points of view</p>		
<p><b>Remarks:</b></p> <p>The lecture and exercise will be given in EN. In case all participants are German speaking, this may change.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 30 h seminar (attendance) 90 h preparation of written term papers (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar Cyber Security Master</b></p> <p><b>Mode of Instruction:</b> seminar <b>Language:</b> English / German <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p>		
<p><b>Contents:</b></p> <p>We set a new focus every semester, see details in Digicampus.</p>		

**Literature:**

Scientific papers

**Assigned Courses:**

**Seminar Cyber Security Master** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Cyber Security Master**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3057: Seminar on Machine Learning and Computer Vision Master</b> <i>Seminar on Machine Learning and Computer Vision Master</i>		4 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Rainer Lienhart		
<p><b>Learning Outcomes / Competences:</b></p> <p>Upon completion of the seminar, students will be able to independently acquire, analyze, and evaluate advanced problems, concepts, methods, procedures, techniques, and technologies in the field of Multimedia Computing and Computer Vision (e.g., image processing, video processing, machine vision/listening and learning, image/video retrieval) within the context of their individual seminar topic.</p> <p>They possess scientific methodological competence, communication skills, and the ability to use modern media to present a specific topic clearly and comprehensibly, both orally and in writing. They are able to critically discuss, argue, and evaluate scientifically complex topics within the aforementioned field. Furthermore, they are able to recognize and effectively apply logical structures of reasoning and argumentation.</p> <p>Participants can articulate themselves clearly and comprehensibly and present technical content freely. They know how to structure a presentation in a clear and logical manner and, even with complex content, focus the presentation on key messages and convey them understandably. They skillfully apply chains of argumentation and solution strategies to handle disruptions. Students demonstrate stage presence and handle common presentation media confidently and interactively. They are able to tailor a presentation to a specific target audience, keep listeners engaged even during longer presentations, and apply various moderation techniques.</p> <p><b>Key Qualifications:</b> Acquisition of presentation techniques; literature research; working with English technical literature; principles of good scientific practice; evaluation of solution approaches, procedures, techniques, and technologies from different perspectives.</p>		
<p><b>Workload:</b></p> <p>Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Seminar on Machine Learning and Computer Vision Master</b></p> <p><b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00</p>		
<b>Contents:</b> The specific topic of the seminar within the broad field of Multimedia is defined annually and adapted to current topics.		
<b>Literature:</b> Current research literature		
<b>Assigned Courses:</b> <b>Seminar on Machine Learning and Computer Vision Master</b> (seminar)		

*\*(in attendance) \**

**Examination**

**Seminar on Machine Learning and Computer Vision Master**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3061: Seminar Intelligent Energy Systems Master</b> <i>Seminar Intelligent Energy Systems</i>		4 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b> Upon completion of this seminar, students are able to independently engage with advanced topics in energy informatics, analysing current challenges, critically evaluating proposed solutions from the literature, and communicating their findings in both written and oral form. They can perform an in-depth critical analysis of a specific paper or design and implement a computational approach applied to real energy data. In both cases, they are able to present their work clearly and convincingly to a specialist audience, engage in scientific discussion, and construct well-reasoned arguments. Through a structured peer-review process, students furthermore develop the ability to assess the work of others constructively and apply the quality standards of good academic practice from both sides of the review process.</p> <p><b>Key Qualifications:</b> Critical reading and synthesis of scientific literature at the intersection of computing and energy systems; knowledge of practice-relevant problem settings including smart grids, demand response, building energy management, and renewable energy integration; analytical thinking for evaluating and contextualising research contributions; practical experience either implementing a computational approach on real energy data or conducting a rigorous critical analysis of a research paper; scientific writing and oral presentation skills; experience with peer review and good academic practice.</p>		
<p><b>Workload:</b> Total: 120 h 90 h preparation of written term papers (self-study) 30 h seminar (attendance)</p>		
<p><b>Conditions:</b> Students should have a solid foundation in machine learning or optimisation, and basic programming skills in Python. Prior exposure to energy systems is beneficial but not required.</p>		<p><b>Credit Requirements:</b> Passing the module exam</p>
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b> 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 2,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<p><b>Parts of the Module</b></p> <p><b>Part of the Module: Seminar Intelligent Energy Systems</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2,00</p> <p><b>Contents:</b> This seminar introduces students to the rapidly growing field of energy informatics, which sits at the intersection of computer science, data science, and energy systems. Starting from the fundamentals of modern energy systems and their challenges, students engage with current research on how computational methods, including machine learning, optimisation, and data-driven modelling, are being used to understand, control, and improve energy systems across a wide range of applications. Topics span smart grids, demand response, building energy management, electric mobility, energy markets, and the integration of renewable energy sources.</p>
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**Literature:**

dependent on individual topic

**Assigned Courses:**

**Seminar Intelligent Energy Systems (Master)** (seminar)

*\*(in attendance) \**

**Examination**

**Seminar Intelligent Energy Systems**

written/oral exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0042: Project Module Software Methodologies for Distributed Systems</b> <i>Projektmodul Softwaremethodiken für verteilte Systeme</i>		10 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Bernhard Bauer		
<b>Contents:</b> Current research topics at the Software Methodology for Distributed Systems Lab		
<b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of software methodologies for distributed systems and have in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques, and technologies of the mentioned field in research projects and are able to apply innovative approaches in solving problems. This enables them to link up with international research and make their scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the area, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.  Key qualifications: Ability to think logically, analytically, and conceptually; Independent work with literature; Understandable, confident, and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;		
<b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Projektmodul Softwaremethodiken für verteilte Systeme</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00
<b>Contents:</b> Current research topics at the Software Methodology for Distributed Systems Lab
<b>Literature:</b> Provided for the respective topics.
<b>Assigned Courses:</b> <b>Oberseminar zu Softwaremethodik für verteilte Systeme</b> <i>*(hybrid/mixed) *</i>

**Examination**

**Project acceptance, presentation, final report**

internship, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0059: Project Module Theoretical Computer Science</b> <i>Projektmodul Theoretische Informatik</i>		10 ECTS/LP
Version 2.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Pascal Lenzner		
<p><b>Learning Outcomes / Competences:</b> After successful participation in the project module, the students will be able to understand problems of increased complexity in the field of Theoretical Computer Science. They will possess the skills to develop concepts, methods, procedures, and techniques in research projects, and to apply innovative methods in solving arising problems. In this way, the students acquire good prerequisites for autonomous scientific work and for linking to international research. Furthermore, they will be able to communicate and conduct literature research and have a scientific methodology that enables them to discuss issues of Theoretical Computer Science; they can define intermediate goals, evaluate solution proposals critically and present own approaches.</p> <p><b>Key Qualifications:</b> Logical, analytical, and conceptual competence; quality awareness; meticulousness; independent work; time management; self-contained literature research; work with English technical literature; fundamentals of good scientific practice.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Project Module Theoretical Computer Science</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Collaboration on current research topics.</p>
<p><b>Literature:</b> Scientific papers, manuals.</p>

<p><b>Examination</b> <b>Oral presentation and written paper.</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-0072: Project Module Organic Computing</b> <i>Projektmodul Organic Computing</i>		10 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Jörg Hähner		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, the students understand problems of higher complexity in the field of "Organic Computing" and have deeper specialist knowledge and skills in this area. They can develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; Independent work with literature in English. Understandable, confident and convincing presentation of ideas, concepts and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>	
<b>Part of the Module: Projektmodul Organic Computing</b>	
<b>Mode of Instruction:</b> internship	
<b>Language:</b> German / English	
<b>Frequency:</b> each semester	
<b>Contact Hours:</b> 1,00	
<b>Contents:</b> Collaboration on current research topics.	
<b>Literature:</b> Depending on the topic to be worked on: <ul style="list-style-type: none"> <li>• Paper</li> <li>• Book</li> <li>• Handbook</li> </ul>	
<b>Assigned Courses:</b>	
<b>Oberseminar Organic Computing</b> <i>*(online/digital) *</i>	

**Examination**

**Presentation and final report.**

internship, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0080: Project Module Databases and Information Systems</b> <i>Projektmodul Datenbanken und Informationssysteme</i>		10 ECTS/LP
Version 1.6.0 (since SoSe14) Person responsible for module: Prof. Dr. Peter Michael Fischer		
<b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity levels in the field of databases and information systems and have deeper professional knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas. Key Skills: Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.		
<b>Remarks:</b> language (D/E) as requested by the student		
<b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)		
<b>Conditions:</b> Module Database Systems (INF-0073) - recommended Module Analysing Massive Data Sets (INF-0277) - recommended		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Project Module Databases and Information Systems</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00		
<b>Contents:</b> Work on current research topics		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Current research articles on the topic of databases and Big Data</li> <li>• Manuals</li> </ul>		
<b>Assigned Courses:</b> <b>Oberseminar Datenbanken und Informationssysteme</b> <i>*(hybrid/mixed) *</i>		

**Examination**

**Project Module Databases and Information Systems**

internship, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0108: Project Module Teaching Professorship for Computer Science</b> <i>Projektmodul Lehrprofessur für Informatik</i>		10 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Robert Lorenz		
<p><b>Learning Outcomes / Competences:</b> After participating in this project module, students understand problems of higher complexity in the fields of <i>concurrent systems</i>, <i>petri nets</i> or <i>process mining</i> and have more in-depth specialist knowledge and skills there. They can develop concepts, methods, procedures, techniques, and technologies in the mentioned field in research projects and can apply innovative methods in solving problems. This enables them to connect to international research and make their scientific contribution to the field. In addition, students have teamwork and communication skills, the ability to research literature, the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine, and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; Independent work with specialist literature; Comprehensible, confident and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Ability to work in teams and understand team processes; Principles of good scientific practise; Project management skills; Scientific methodology.</p>		
<p><b>Remarks:</b> Participants take part in a research project and receive individual supervision. Foreign participants who do not have sufficient German language skills are supervised in English.</p>		
<p><b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)</p>		
<p><b>Conditions:</b> Basic knowledge in the research fields of <i>concurrent systems</i>, <i>petri nets</i> or <i>process mining</i></p>		<p><b>Credit Requirements:</b> Bestehen der Modulprüfung</p>
<p><b>Frequency:</b> each semester</p>	<p><b>Recommended Semester:</b> from 1.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 1,00</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Projektmodul Lehrprofessur für Informatik</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>		
<p><b>Contents:</b> Collaboration on current research topics of the group</p>		
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• J. Desel, W. Reisig, G. Rozenberg: Lectures on Concurrency and Petri Nets, Springer, Lecture Notes in Computer Science 3098, 2004</li> <li>• Wil M. P. van der Aalst: Process Mining. Data Science in Action. Springer, 2016.</li> </ul>		
<p><b>Assigned Courses:</b> <b>Oberseminar zu Lehrprofessur für Informatik</b></p>		

*\*(in attendance) \**

**Examination**

**Projektmodul Lehrprofessur für Informatik**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0137: Project Module Software- and Systems Engineering</b> <i>Projektmodul Software- und Systems Engineering</i>		10 ECTS/LP
Version 1.1.0 (since SoSe14) Person responsible for module: Prof. Dr. Wolfgang Reif		
<p><b>Learning Outcomes / Competences:</b></p> <p>After participating in the project module, students understand problems of higher complexity from the field of software and systems engineering and have more in-depth knowledge and skills. They are able to develop concepts, methods, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Soft Skills:</b></p> <ul style="list-style-type: none"> <li>• Skill in logical, analytical and conceptual thinking.</li> <li>• Ability to work independently with technical literature, including English literature</li> <li>• Clear, confident and convincing presentation of ideas, concepts and results</li> <li>• Awareness for quality aspects</li> <li>• Communication skills</li> <li>• Ability to work in teams and understand team processes</li> <li>• Principles of good scientific practice</li> <li>• Competencies in project management</li> <li>• Research methodology</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Project Module Software- and Systems Engineering</b></p> <p><b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>		
<b>Contents:</b> Contribution to current research projects of the chair for Software Engineering		
<b>Literature:</b> Depends on the project: Scientific papers, system documentation, books, ...		
<b>Assigned Courses:</b>		

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**Oberseminar Software- und Systems Engineering**

*\*(online/digital) \**

**Examination**

**Project Module Software- and Systems Engineering Project Presentation**

practical exam / work period for assignment: 2 months, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0170: Project Module Human-Centred Multimedia</b> <i>Projektmodul Human-Centered Multimedia</i>		10 ECTS/LP
Version 1.0.0 (since SoSe13) Person responsible for module: Prof. Dr. Elisabeth André		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of "Human-Centered Multimedia" and have deeper expertise and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;</p>		
<p><b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Project Module Human-Centered Multimedia</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<b>Contents:</b> Collaborate on current research topics.
<b>Literature:</b> Literature references will be given at the beginning of the module depending on the topic.
<p><b>Assigned Courses:</b> <b>Oberseminar Human-Centered Multimedia</b> <i>*(hybrid/mixed) *</i></p>

<p><b>Examination</b> <b>Project Module Human-Centered Multimedia</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-0302: Project Module on Mechatronics</b> <i>Projektmodul Mechatronik</i>		10 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. Lars Mikelsons		
<b>Learning Outcomes / Competences:</b> Subject-related competences: After participating in the project module, students understand problems of higher complexity in the field of mechatronics and have deeper technical knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas. Key Competencies: Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology;		
<b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Project Module on Mechatronics</b> <b>Mode of Instruction:</b> internship <b>Lecturers:</b> Prof. Dr. Lars Mikelsons <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00		
<b>Contents:</b> In the seminar, current research topics from the field of mechatronics will be dealt with. Each seminar participant receives individual literature references, which are then to be supplemented in the course of the seminar by further independently compiled references. The seminar will conclude with a written paper, a prototypical design or implementation, and a presentation on the topic covered.		
<b>Literature:</b> depending on the specific project: scientific essays, documentation		
<b>Assigned Courses:</b> <b>Oberseminar zur Mechatronik</b> <i>*(in attendance) *</i>		

**Examination**

**Project acceptance**

internship, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0328: Project Module IT Infrastructure in Medical Information Systems</b> <i>Projektmodul IT-Infrastrukturen in der Medizin</i>		10 ECTS/LP
Version 1.0.0 (since WS19/20) Person responsible for module: Prof. Dr. Frank Kramer		
<p><b>Learning Outcomes / Competences:</b> Upon completion of the project module, students understand problems of higher complexity in the field of IT infrastructures in translational medical research and possess in-depth specialized knowledge and skills in this area. They can develop concepts, methods, procedures, techniques, and technologies of the aforementioned field within research projects and are capable of applying innovative methods to solve problems. This enables them to connect with international research and make their own scientific contribution in this field. Furthermore, students possess the teamwork and communication skills, the ability to conduct literature research, and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, contextualize, combine, and present intermediate results and innovative ideas.</p> <p><b>Key Competencies:</b> Ability for logical, analytical, and conceptual thinking; independent work with English-language specialist literature; comprehensible, confident, and convincing presentation of ideas, concepts, and results; quality awareness; communication skills; ability to collaborate in teams and understand team processes; principles of good scientific practice; project management skills; scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Project Module IT Infrastructure in Medical Information Systems</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00 <b>ECTS Credits:</b> 10.0</p>		
<b>Contents:</b> Current research topics in the field of IT infrastructures in translational medical research.		
<b>Literature:</b> scientific essays, text books		
<p><b>Assigned Courses:</b> <b>Oberseminar IT-Infrastrukturen für die Translationale Medizinische Forschung</b> <i>*(online/digital) *</i></p>		

**Examination**

**Project Module IT Infrastructure in Medical Information Systems**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0340: Project Module Embedded Systems</b> <i>Projektmodul Embedded Systems</i>		10 ECTS/LP
Version 1.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Sebastian Altmeyer		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of embedded systems and have more in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Projektmodul Embedded Systems</b>  <b>Mode of Instruction:</b> internship  <b>Language:</b> German / English  <b>Frequency:</b> each semester  <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Autonomous collaboration on current research topics.</p>
<p><b>Literature:</b> scientific papers, handbooks</p>
<p><b>Assigned Courses:</b>  <b>Oberseminar Embedded Systems</b>  <i>*(hybrid/mixed) *</i></p>

<p><b>Examination</b>  <b>Projektmodul Embedded Systems</b>  practical exam, graded  <b>Test Frequency:</b>  when a course is offered</p>
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<b>Module INF-0374: Project Module Resource Aware Algorithmics</b> <i>Projektmodul Resource Aware Algorithmics</i>		10 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Tobias Mömke		
<p><b>Learning Outcomes / Competences:</b> After attending this research module, the students are able to understand algorithmic problems and solutions of medium difficulty in the area of resource aware algorithmics. They have acquired a detailed understanding of up-to-date topics within the area and can actively participate in research projects. Furthermore, they understand some deep concepts, methods, tools and technologies and can apply the acquired knowledge in research projects. Besides the technical abilities, they train their team and communication skills, the ability to perform literature research and to discuss and present technical topics.</p> <p><b>Key Qualifications:</b> Ability to perform analytical and logic thinking; self-sufficient work with scientific literature in English language; ability to present results and ideas in form of understandable and inspiring presentations; aim for high-quality results; communication skills; ability to work with a team and to understand team processes; respect for clean scientific practices</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Projekt Module Resource Aware Algorithmics</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>		
<b>Contents:</b> Autonome Mitarbeit an aktuelle Forschungsthemen.		
<b>Literature:</b> wissenschaftliche Papiere, Handbücher		
<p><b>Assigned Courses:</b> <b>Oberseminar Resource Aware Algorithmics</b> <i>*(in attendance) *</i></p>		
<p><b>Examination</b> <b>Projekt Module Resource Aware Algorithmics</b> portfolio exam, graded <b>Test Frequency:</b> when a course is offered</p>		

<b>Module INF-0431: Project Module Theory of distributed and parallel Systems</b> <i>Projektmodul Theorie verteilter und paralleler Systeme</i>		10 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Kirstin Peters		
<b>Learning Outcomes / Competences:</b> Nach der Teilnahme am Projektmodul verstehen die Studierenden Problemstellungen höherer Komplexität auf dem Gebiet der Theorie verteilter und paralleler Systeme und verfügen dort über tiefergehende Fachkenntnisse und Fähigkeiten. Sie können Konzepte, Methoden, Verfahren, Techniken und Technologien des genannten Gebiets in Forschungsprojekten entwickeln und sind fähig, innovative Methoden bei der Lösung von Problemen anzuwenden. Dadurch ist es ihnen möglich, an die internationale Forschung anzuknüpfen und ihren eigenen wissenschaftlichen Beitrag auf diesem Gebiet zu leisten. Darüber hinaus verfügen die Studierenden über die Team- und Kommunikationsfähigkeit, die Fähigkeit zur Literaturrecherche und die wissenschaftliche Methodik, um Problemstellungen auf dem Gebiet zu diskutieren, Zwischenziele zu definieren, sowie Zwischenergebnisse und innovative Ideen kritisch zu bewerten, einzuordnen, zu kombinieren und zu präsentieren.		
<b>Schlüsselqualifikationen:</b> Fertigkeit zum logischen, analytischen und konzeptionellen Denken; Eigenständige Arbeit mit englischsprachiger Fachliteratur; Verständliche, sichere und überzeugende Präsentation von Ideen, Konzepten und Ergebnissen; Qualitätsbewußtsein; Kommunikationsfähigkeit; Fertigkeit der Zusammenarbeit in Teams und Verstehen von Teamprozessen; Grundsätze guter wissenschaftlicher Praxis; Projektmanagementfähigkeiten; Wissenschaftliche Methodik;		
<b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Projektmodul Theorie verteilter und paralleler Systeme</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00		
<b>Contents:</b> Mitarbeit an aktuellen Forschungsthemen des Lehrstuhls		
<b>Literature:</b> Wissenschaftliche Aufsätze, abhängig vom Thema		
<b>Assigned Courses:</b> <b>Oberseminar Theorie verteilter und paralleler Systeme</b> *(in attendance) *		

**Examination**

**Projektmodul Theorie verteilter und paralleler Systeme**

homework, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0436: Project Module Quantum Algorithms</b> <i>Projektmodul Quantenalgorithmen</i>		10 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann		
<b>Learning Outcomes / Competences:</b> After participating in the project module, students will understand highly complex problems in the field of quantum algorithms and will have in-depth specialist knowledge and skills in this area. They will be able to develop concepts, methods, procedures, techniques, and technologies in this field in research projects and will be able to apply innovative methods to solve problems. This enables them to connect with international research and make their own scientific contribution in this field. In addition, students will have the teamwork and communication skills, the ability to conduct literature research, and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine, and present interim results and innovative ideas.		
<b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the exam
<b>Frequency:</b> as needed	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module:</b> <b>Projektmodul Quantenalgorithmen</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English / German <b>Frequency:</b> as needed
<b>Contents:</b> Doing active research and participating on current reserach projects
<b>Literature:</b> Case dependent
<b>Assigned Courses:</b> <b>Oberseminar Quantenalgorithmik</b> <i>*(hybrid/mixed) *</i>

<b>Examination</b> <b>Projektmodul Quantenalgorithmen</b> practical exam, graded <b>Test Frequency:</b> when a course is offered
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<b>Module INF-0455: Project Module Diagnostic Sensing</b> <i>Projektmodul Diagnostische Sensorik</i>		10 ECTS/LP
Version 1.0.0 (since SoSe23) Person responsible for module: Prof. Dr. Sebastian Zaunseder		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of diagnostic sensing and have deeper expertise and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research the literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key Skills:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module examination
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Projektmodul Diagnostic Sensing</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Current research topics</p>
<p><b>Literature:</b> Scientific articles</p>
<p><b>Assigned Courses:</b> <b>Oberseminar Diagnostische Sensorik</b> <i>*(hybrid/mixed) *</i></p>

<p><b>Examination</b> <b>Projektmodul Diagnostic Sensing</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-0461: Project Module Computational Linguistics</b> <i>Projektmodul Computational Linguistics</i>		10 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Annemarie Friedrich		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of embedded systems and have more in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Projektmodul Sprachverstehen</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Autonomous collaboration on current research topics.</p>
<p><b>Literature:</b> scientific papers, handbooks</p>
<p><b>Assigned Courses:</b> <b>Oberseminar Natural Language Understanding</b> <i>*(hybrid/mixed) *</i></p>

<p><b>Examination</b> <b>Projektmodul Sprachverstehen</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-0474: Project Module Networked Systems and Communication Networks</b> <i>Projektmodul Vernetzte Systeme und Kommunikationsnetze</i>		10 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Michael Seufert		
<p><b>Learning Outcomes / Competences:</b> Nach der Teilnahme am Projektmodul verstehen die Studierenden Problemstellungen höherer Komplexität auf dem Gebiet der vernetzten Systeme und Kommunikationsnetze und verfügen dort über tiefere Fachkenntnisse und Fähigkeiten. Sie können Konzepte, Methoden, Verfahren, Techniken und Technologien des genannten Gebiets in Forschungsprojekten entwickeln und sind fähig, innovative Methoden bei der Lösung von Problemen anzuwenden. Dadurch ist es ihnen möglich, an die internationale Forschung anzuknüpfen und ihren eigenen wissenschaftlichen Beitrag auf diesem Gebiet zu leisten. Darüber hinaus verfügen die Studierenden über die Team- und Kommunikationsfähigkeit, die Fähigkeit zur Literaturrecherche und die wissenschaftliche Methodik, um Problemstellungen auf dem Gebiet zu diskutieren, Zwischenziele zu definieren, sowie Zwischenergebnisse und innovative Ideen kritisch zu bewerten, einzuordnen, zu kombinieren und zu präsentieren.</p> <p><b>Schlüsselqualifikationen:</b> Fertigkeit zum logischen, analytischen und konzeptionellen Denken; Eigenständige Arbeit mit englischsprachiger Fachliteratur; Verständliche, sichere und überzeugende Präsentation von Ideen, Konzepten und Ergebnissen; Qualitätsbewußtsein; Kommunikationsfähigkeit; Fertigkeit der Zusammenarbeit in Teams und Verstehen von Teamprozessen; Grundsätze guter wissenschaftlicher Praxis; Projektmanagementfähigkeiten; Wissenschaftliche Methodik</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Projektmodul Vernetzte Systeme und Kommunikationsnetze</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English / German <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>		
<b>Contents:</b> Autonome Mitarbeit an aktuelle Forschungsthemen.		
<b>Literature:</b> wissenschaftliche Papiere, Handbücher		
<b>Assigned Courses:</b> <b>Oberseminar Vernetzte Systeme und Kommunikationsnetze</b> <i>*(online/digital) *</i>		

**Examination**

**Projektmodul Vernetzte Systeme und Kommunikationsnetze**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0481: Project Module Intelligent Perception in Technical Systems</b> <i>Projektmodul Intelligente Perzeption in Technischen Systemen</i>		10 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Jörg-Dieter Stückler		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of intelligent perception in technical systems and have deeper expertise and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Ability to think logically, analytically and conceptually; Independent work with English-language scientific literature; Understandable, confident and convincing presentation of ideas, concepts and results; Quality awareness; Communication skills; Skill of working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Project Module Intelligent Perception in Technical Systems</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English / German <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Current research topics.</p>
<p><b>Literature:</b> Scientific papers, manuals</p>
<p><b>Assigned Courses:</b> <b>Oberseminar Intelligente Perzeption in Technischen Systemen</b> <i>*(in attendance) *</i></p>

**Examination**

**Project Module Intelligent Perception in Technical Systems**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3021: Project Module Data Engineering</b> <i>Projektmodul Data Engineering</i>		10 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Fabian Panse		
<b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity levels in the field of data engineering and have deeper professional knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas. Key Skills: Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.		
<b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Projektmodul Data Engineering</b> <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00
<b>Contents:</b> Work on current research topics
<b>Literature:</b> scientific papers, handbooks
<b>Assigned Courses:</b> <b>Oberseminar Data Engineering</b> <i>*(hybrid/mixed) *</i>

<b>Examination</b> <b>Project Module Data Engineering</b> practical exam, graded <b>Test Frequency:</b> when a course is offered
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<b>Module INF-3043: Project Module Cyber Security</b> <i>Projektmodul Cyber Security</i>		10 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Frank Breitinger		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of cyber security and have more in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the Module Exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<p><b>Part of the Module: Projektmodul Cyber Security</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>
<p><b>Contents:</b> Autonomous collaboration on current research topics.</p>
<p><b>Literature:</b> scientific papers, handbooks</p>
<p><b>Assigned Courses:</b> <b>Oberseminar Cybersecurity</b> <i>*(hybrid/mixed) *</i></p>

<p><b>Examination</b> <b>Project Module Cyber Security</b> practical exam, graded <b>Test Frequency:</b> when a course is offered</p>
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<b>Module INF-3063: Project Module Intelligent Energy Systems</b> <i>Projektmodul Intelligente Energiesysteme</i>		10 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Nicole Ludwig		
<p><b>Learning Outcomes / Competences:</b> After participating in the project module, students understand problems of higher complexity in the field of intelligent energy systems and have more in-depth specialist knowledge and skills there. They are able to develop concepts, methods, procedures, techniques and technologies of the mentioned field in research projects and are able to apply innovative methods in solving problems. This enables them to connect to international research and make their own scientific contribution to the field. In addition, students have the teamwork and communication skills, the ability to research literature and the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine and present intermediate results and innovative ideas.</p> <p><b>Key qualifications:</b> Skill in logical, analytical, and conceptual thinking; Independent work with English-language literature; Intelligible, confident, and persuasive presentation of ideas, concepts, and results; Quality awareness; Communication skills; Skill in working in teams and understanding team processes; Principles of good scientific practice; Project management skills; Scientific methodology.</p>		
<p><b>Workload:</b> Total: 300 h 285 h internship / practical course (self-study) 15 h seminar (attendance)</p>		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<p><b>Part of the Module: Project Module Intelligent Energy Systems</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00</p>		
<b>Contents:</b> Autonomous collaboration on current research topics.		
<b>Literature:</b> scientific papers, handbooks		
<b>Assigned Courses:</b> <b>Oberseminar Intelligente Energiesysteme</b> <i>*(in attendance) *</i>		

**Examination**

**Project Module Intelligent Energy Systems**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-3069: Project Module Machine Learning &amp; Computer Vision</b> <i>Projektmodul Machine Learning &amp; Computer Vision</i>		10 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Rainer Lienhart		
<b>Learning Outcomes / Competences:</b> After participating in this project module, students understand problems of higher complexity in the field of machine learning & computer vision and have more in-depth specialist knowledge and skills there. They can develop concepts, methods, procedures, techniques, and technologies in the mentioned field in research projects and can apply innovative methods in solving problems. This enables them to connect to international research and make their scientific contribution to the field. In addition, students have teamwork and communication skills, the ability to research literature, the scientific methodology to discuss problems in the field, define intermediate goals, and critically evaluate, classify, combine, and present intermediate results and innovative ideas. <b>Key qualifications:</b> Ability to think logically, analytically and conceptually; Independent work with specialist literature; Comprehensible, confident and convincing presentation of ideas, concepts, and results; Quality awareness; Communication skills; Ability to work in teams and understand team processes; Principles of good scientific practise; Project management skills; Scientific methodology.		
<b>Workload:</b> Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Passing the module exam
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Project Module Machine Learning &amp; Computer Vision</b> <b>Mode of Instruction:</b> internship <b>Language:</b> German / English <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00		
<b>Contents:</b> The specific task from the wide-ranging field of machine learning & computer vision is designed individually for each student every year.		
<b>Literature:</b> scientific papers, handbooks		
<b>Assigned Courses:</b> <b>Oberseminar Selected Aspects of Machine Learning and Computer Vision</b> <i>*(in attendance) *</i>		

**Examination**

**Project Module Machine Learning & Computer Vision**

practical exam, graded

**Test Frequency:**

when a course is offered

<b>Module INF-0221: Introduction to Scientific Work</b> <i>Anleitung zu wissenschaftlichen Arbeiten</i>		0 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module:		
<b>Learning Outcomes / Competences:</b> Die Teilnehmer wissen, wie sie an wissenschaftliche Arbeiten heran gehen, welche Vorgehensweise sie ans Ziel führt und welche Maßstäbe gelten, damit ihre Arbeit als wissenschaftlich angesehen wird.		
<b>Remarks:</b> Dies ist eine freiwillige Veranstaltung und gibt <b>keine</b> ECTS-Punkte!		
<b>Workload:</b> Total: 15 h		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1,00	<b>Repeat Exams Permitted:</b> none	

<b>Parts of the Module</b>
<b>Part of the Module: <a href="#">Anleitung zu wissenschaftlichen Arbeiten</a></b> <b>Language:</b> German <b>Frequency:</b> each semester <b>Contact Hours:</b> 1,00
<b>Contents:</b> Begleitung bei der Anfertigung von Seminar-/Bachelor-/Master-/Diplomarbeiten und Dissertationen.
<b>Assigned Courses:</b>  <b>Anleitung zu wissenschaftlichen Arbeiten</b> <i>*(in attendance) *</i> <b>Anleitung zu wissenschaftlichen Arbeiten</b> <i>*(in attendance) *</i> <b>Anleitung zu wissenschaftlichen Arbeiten Software- und Systems Engineering</b> <i>*(online/digital) *</i> <b>Anleitung zum wissenschaftlichen Arbeiten</b> <i>*(in attendance) *</i> <b>Anleitung zum wissenschaftlichen Arbeiten</b> <i>*(in attendance) *</i> <b>Anleitung zum wissenschaftlichen Arbeiten Quantum Computing</b> <i>*(in attendance) *</i>

<b>Module INF-0222: Advanced Seminar Computer Science</b> <i>Oberseminar Informatik</i>		0 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module:		
<b>Learning Outcomes / Competences:</b> Im Oberseminar werden wissenschaftliche Themen z.B. in Form von Abschlussarbeiten oder Vorträgen zu Praxis-/Forschungs-/Projektmodulen vorgestellt und diskutiert. Die Studierenden erhalten somit Einblicke in wissenschaftliches Arbeiten.		
<b>Remarks:</b> Dies ist eine freiwillige Veranstaltung und gibt <b>keine</b> ECTS-Punkte!		
<b>Workload:</b> Total: 30 h 30 h seminar (attendance)		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2,00	<b>Repeat Exams Permitted:</b> none	

<b>Parts of the Module</b>
<b>Part of the Module: Oberseminar Informatik</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> German <b>Frequency:</b> each semester <b>Contact Hours:</b> 2,00
<b>Assigned Courses:</b> <b>Oberseminar Biomedizinische Datenanalyse und Systemmodellierung</b> <i>*(in attendance) *</i> <b>Oberseminar Cybersecurity</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar Data Engineering</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar Datenbanken und Informationssysteme</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar Diagnostische Sensorik</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar Embedded Systems</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar Human-Centered Multimedia</b> <i>*(hybrid/mixed) *</i> <b>Oberseminar IT-Infrastrukturen für die Translationale Medizinische Forschung</b> <i>*(online/digital) *</i> <b>Oberseminar Informatik in der Medizintechnik</b> <i>*(in attendance) *</i>

**Oberseminar Intelligente Energiesysteme**

*\*(in attendance) \**

**Oberseminar Intelligente Perzeption in Technischen Systemen**

*\*(in attendance) \**

**Oberseminar Natural Language Understanding**

*\*(hybrid/mixed) \**

**Oberseminar Organic Computing**

*\*(online/digital) \**

**Oberseminar Quantenalgorithmmik**

*\*(hybrid/mixed) \**

**Oberseminar Resource Aware Algorithmics**

*\*(in attendance) \**

**Oberseminar Selected Aspects of Machine Learning and Computer Vision**

*\*(in attendance) \**

**Oberseminar Software- und Systems Engineering**

*\*(online/digital) \**

**Oberseminar Theoretische Informatik**

*\*(online/digital) \**

**Oberseminar Theorie verteilter und paralleler Systeme**

*\*(in attendance) \**

**Oberseminar Vernetzte Systeme und Kommunikationsnetze**

*\*(online/digital) \**

**Oberseminar zu Grundlagen Reaktiver Systeme**

*\*(online/digital) \**

**Oberseminar zu Lehrprofessur für Informatik**

*\*(in attendance) \**

**Oberseminar zu Softwaremethodik für verteilte Systeme**

*\*(hybrid/mixed) \**

**Oberseminar zur Mechatronik**

*\*(in attendance) \**

**Oberseminar zur Produktionsinformatik**

*\*(online/digital) \**

**Oberseminar zur Regelungstechnik**

*\*(online/digital) \**

**Oberseminar zur biomedizinischen Informatik**

*\*(online/digital) \**

<b>Module INF-0485: Interdisciplinary Lecture Series in Ethics and Artificial Intelligence</b> <i>Interdisziplinäre Ringvorlesung in Ethik und Künstlicher Intelligenz</i>		0 ECTS/LP
Version 1.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Robert Lorenz		
<p><b>Learning Outcomes / Competences:</b></p> <p>Die Teilnehmenden sollen ein grundlegendes Verständnis von künstlicher Intelligenz (KI) und ihrem interdisziplinären Charakter erwerben.</p> <p>Dabei werden verschiedene übergreifende Themen wie</p> <ul style="list-style-type: none"> <li>• die Zusammenhänge zwischen ethischen Überlegungen, sowie technischen, rechtlichen und regulatorischen Rahmenbedingungen,</li> <li>• die Bedeutung von Transparenz und Erklärbarkeit von KI-Systemen,</li> <li>• die Rolle von KI in Bezug auf soziale Gerechtigkeit und Diskriminierung,</li> <li>• die risikobasierte Bewertung von KI-Entscheidungen</li> </ul> <p>für KI in Theorie und Praxis dargestellt und aktuelle Lösungen vermittelt und diskutiert.</p> <p>Ausgehend von den technischen Voraussetzungen von KI, liegt einer der Schwerpunkte der Ringvorlesung auf den sozialen und gesellschaftlichen Auswirkungen von KI. Es geht darum, die Frage nach der Vertrauenswürdigkeit der KI zu problematisieren.</p> <p>Die Teilnehmenden sollen dabei</p> <ul style="list-style-type: none"> <li>• die ethischen Herausforderungen und Risiken im Zusammenhang mit KI-Anwendungen verstehen</li> <li>• ethische Konzepte und Werte in realen KI-Anwendungen identifizieren</li> <li>• kritisch über mögliche Lösungsansätze für ethische Herausforderungen im Bereich KI reflektieren</li> <li>• das Konzept der Multiakteursverantwortung und Haftung bei KI-Entscheidungen verstehen</li> <li>• die Bedeutung von Kompetenz-, Bildungs- und Sensibilisierungsmaßnahmen in Bezug auf KI und Ethik erkennen</li> <li>• die Rolle von Ethikkommissionen und Ethikgremien bei der Bewertung von KI-Projekten kennenlernen</li> <li>• ethische Richtlinien für KI-Entwicklung und -Nutzung in ihrem zukünftigen beruflichen Kontext anwenden können</li> </ul>		
<p><b>Remarks:</b></p> <p>Die Ringvorlesung kann von Studierenden <b>aller Bachelor- und Masterstudiengänge</b> aus Informatik, Wirtschaftswissenschaften, Jura, Philosophie und Ethik besucht werden.</p>		
<p><b>Workload:</b></p> <p>Total: 30 h 30 h lecture (attendance)</p>		
<p><b>Conditions:</b></p> <p>none</p>		<p><b>Credit Requirements:</b></p> <p>Es werden keine Leistungspunkte vergeben.</p>
<p><b>Frequency:</b> irregular (usu. winter semester)</p>	<p><b>Recommended Semester:</b></p> <p>from 1.</p>	<p><b>Minimal Duration of the Module:</b></p> <p>1 semester[s]</p>
<p><b>Contact Hours:</b></p> <p>2,00</p>	<p><b>Repeat Exams Permitted:</b></p> <p>according to the examination regulations of the study program</p>	

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**Parts of the Module**

**Part of the Module: Interdisziplinäre Ringvorlesung in Ethik und Künstlicher Intelligenz**

**Mode of Instruction:** lecture

**Language:** German

**Frequency:** irregular (usu. winter semester)

**Contact Hours:** 2,00

**Contents:**

Künstliche Intelligenz in allen neuen Erscheinungsformen - von manchen verteufelt, von manchen hochgelobt.

In dieser Ringvorlesung beleuchten wir die neuen Möglichkeiten aus unterschiedlichsten Perspektiven wie Recht und Technik, Theorie und Praxis, Ethik und Philosophie.

Dazu werden KI-Expert:innen aus Augsburg, aber auch Gäste aus der weiteren KI-Community sprechen, zuhören und diskutieren.