University of Augsburg

Module Catalogue

Master's Programme Data Science

Faculty of Applied Computer Science

Winter Semester 2026/27

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Module INF-3031: Algorithms & Data Engineering *Algorithms & Data Engineering*	8 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. Fabian Panse Prof. Dr. Pascal Lenzner	

Learning Outcomes / Competences:

After successfully completing this module, students will have mastered the basic principles and techniques for designing, implementing and evaluating systems for data preparation and integration. In addition, students have subject-specific knowledge to understand basic problems in the field of data engineering and to solve them by applying the skills they have learned.

The module is divided into two parts. The first part deals with theoretical fundamentals. In addition to basic data structures and algorithmic solution paradigms (complexity classes, runtime analysis), this includes graph-theoretical algorithms, dynamic programming as well as search and hashing algorithms.

The second part is dedicated to their use in various techniques from the areas of data preparation and data integration. This includes data cleaning, schema matching and data matching.

Key qualifications: Independent work with textbooks; ability to abstract; analytical and structured problem-solving strategies; implementation of technical solution concepts in programs and models, ability to analyze and structure complex computer science problems; knowledge of the advantages/disadvantages of design alternatives and evaluation in the respective context; selection and correct application of suitable methods; knowledge of practice-relevant tasks; ability to solve problems under practice-oriented conditions;

Workload:

Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h exercise course (attendance)
60 h lecture (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)

Conditions: none		**Credit Requirements:** Passing the Module Exam
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Algorithms & Data Engineering (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each winter semester
Contact Hours: 4,00

Contents:

The lecture includes basic concepts from the field of algorithms and data structures and their application in concrete problems of data engineering.

Concrete contents are:

- basic data structures
- algorithmic solution paradigms (complexity classes, runtime analysis)
- graph-theoretical algorithms
- dynamic programming
- search and hashing algorithms
- data preparation
- data cleaning
- schema matching
- data matching

Assigned Courses:

Algorithms & Data Engineering (lecture)
*(in attendance) *

Part of the Module: Algorithms & Data Engineering (Exercise)

Mode of Instruction: exercise course
Language: English / German
Frequency: each winter semester
Contact Hours: 2,00

Assigned Courses:

Exercise for Algorithms & Data Engineering (exercise course)
*(in attendance) *

Examination

Algorithms & Data Engineering

written exam / length of examination: 90 minutes, graded

Test Frequency:

when a course is offered

Module INF-3033: Machine Learning

Machine Learning

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
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 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.

Key qualifications: 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.

Workload:
Total: 240 h
60 h lecture (attendance)
30 h exercise course (attendance)
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)

Conditions:
- Basic programming knowledge in Python
- Basic knowledge of probability theory
- Recommended: Basic knowledge in deep learning

Credit Requirements:
Passing the Module Exam

Frequency: each summer semester

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Machine Learning (Lecture)
Language: English
Frequency: each summer semester
Contact Hours: 4,00

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

Part of the Module: Machine Learning (Exercise)

Language: English
Frequency: each summer semester
Contact Hours: 2,00

Examination

Machine Learning

written exam / length of examination: 120 minutes, graded

Test Frequency:

when a course is offered

Module MTH-4270: Mathematical Methods in Data Science A

Mathematical Methods in Data Science A

8 ECTS/LP

Version 1.3.0
Person responsible for module: Prof. Dr. André Uschmajew

Contents:
- Basic mathematical concepts in data science and machine learning (least squares problems, regression, dimensionality reduction, singular value decomposition, convex and nonconvex optimization, gradient descent)
- Foundations of statistical learning theory
- Kernel methods and support vector machines
- Reproducing kernel Hilbert spaces

Learning Outcomes / Competences:
Students gain an overview of fundamental mathematical concepts in machine learning and data science. Furthermore, they acquire skills in advanced topics such as the basics of statistical learning theory or reproducing kernel Hilbert spaces. These concepts are applied to current learning models in order to analyze them.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematical Methods of Data Science A
Language: English
Frequency: each winter semester
Contact Hours: 4,00

Literature:

M. Mohri, A. Rostamizadeh, A. Talwalkar: Foundations of Machine Learning, MIT Press, 2018
F. Bach: Learning Theory from First Principles, MIT Press, 2024
I. Steinwart , A. Christmann: Support Vector Machines, Springer, 2008

Assigned Courses:

Übung: Mathematical Methods in Data Science A (exercise course)
**(in attendance) **

Examination
Advanced Mathematical Methods of Data Science A
written exam, graded
Test Frequency:
only in the winter semester

Module MTH-4280: Mathematical Methods in Data Science B *Mathematical Methods in Data Science B*	8 ECTS/LP
Version 1.5.0 (since WS25/26) Person responsible for module: Prof. Dr. André Uschmajew	
Contents: Possible topics include: - Statistical learning theory - Neural network models - Approximations theorems and deep learning - Reinforcement learning	
Learning Outcomes / Competences: Students gain an overview of fundamental mathematical concepts in machine learning and data science. Furthermore, they acquire skills in advanced topics such as statistical learning theory, approximation theorems, or reinforcement learning. These concepts are applied to current learning models in order to analyze them.	
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)	

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematical Methods of Data Science B
Language: English
Frequency: each summer semester
Contact Hours: 4,00

Literature:

F. Bach: Learning Theory from First Principles, MIT Press, 2024

C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006

M. Mohri, A. Rostamizadeh, A. Talwalkar: Foundations of Machine Learning, MIT Press, 2018

I. Steinwart , A. Christmann: Support Vector Machines, Springer, 2008

Examination
Advanced Mathematical Methods of Data Science B
written exam, graded
Test Frequency:
only in the summer semester

Module INF-0042: Project Module Software Methodologies for Distributed Systems *Projektmodul Softwaremethodiken für verteilte Systeme*	10 ECTS/LP

Version 1.0.0 (since SoSe13)
Person responsible for module: Prof. Dr. Bernhard Bauer

Contents:
Current research topics at the Software Methodology for Distributed Systems Lab

Learning Outcomes / Competences:
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;

Workload:
Total: 300 h
15 h seminar (attendance)
285 h internship / practical course (self-study)

Conditions:
none

Frequency: each semester	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Softwaremethodiken für verteilte Systeme
Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Current research topics at the Software Methodology for Distributed Systems Lab

Literature:
Provided for the respective topics.

Assigned Courses:

Oberseminar zu Softwaremethodik für verteilte Systeme
**(hybrid/mixed) **

Examination

Project acceptance, presentation, final report

internship, graded

Test Frequency:

when a course is offered

Module INF-0080: Project Module Databases and Information Systems

Projektmodul Datenbanken und Informationssysteme

10 ECTS/LP

Version 1.6.0 (since SoSe14)
Person responsible for module: Prof. Dr. Peter Michael Fischer

Learning Outcomes / Competences:
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.

Remarks:
language (D/E) as requested by the student

Workload:
Total: 300 h
15 h seminar (attendance)
285 h internship / practical course (self-study)

Conditions:	**Credit Requirements:**
Module Database Systems (INF-0073) - recommended Module Analysing Massive Data Sets (INF-0277) - recommended	Passing the module exam

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

Parts of the Module

Part of the Module: Project Module Databases and Information Systems

Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Work on current research topics

Literature:
- Current research articles on the topic of databases and Big Data
- Manuals

Assigned Courses:

Oberseminar Datenbanken und Informationssysteme
**(hybrid/mixed) **

Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unsere Forschungsthemen bzw. Themenvorschläge für studentische Arbeiten an und kontaktieren direkt einen Mitarbeiter, dessen Forschung Sie interessiert: https://www.uni-augsburg.de/de/fakultaet//fai/informatik/prof/dbis/ Die alleinige Teilnahme am Oberseminar ist freiwillig und gibt keine ECTS-Punkte!

Examination

Project Module Databases and Information Systems

internship, graded

Test Frequency:

when a course is offered

Module INF-0374: Project Module Resource Aware Algorithms *Projektmodul Resource Aware Algorithmics*	10 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:
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 discurss and present technical topics.

Key Qualifications: 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

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projekt Module Resource Aware Algorithmics
Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Autonome Mitarbeit an aktuelle Forschungsthemen.

Literature:
wissenschaftliche Papiere, Handbücher

Assigned Courses:

Oberseminar Resource Aware Algorithmics
**(in attendance) **
Das Oberseminar fasst Vorträge und Arbeitsbesprechungen zu Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unter Lehre (siehe https://www.uni-augsburg.de/de/fakultaet/fai/informatik/prof/raa/studium-und-lehre/) unsere Informationen zu Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen (unter Lehrveranstaltungen) an und kontaktieren direkt einen Mitarbeiter. Die alleinige Teilnahme am Oberseminar ist nicht möglich. Forschungsthemen des Lehrstuhls: Approximationsalgorithmen, Online Algorithmen, Algorithmen für Big Data

Examination

Projekt Module Resource Aware Algorithmics

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0436: Project Module Quantum Algorithms

Projektmodul Quantenalgorithmen

10 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

Learning Outcomes / Competences:
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.

Workload:
Total: 300 h
15 h seminar (attendance)
285 h internship / practical course (self-study)

Conditions: none		**Credit Requirements:** Passing the exam
Frequency: as needed	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Quantenalgorithmen
Mode of Instruction: internship
Language: English / German
Frequency: as needed

Contents:
Doing active research and participating on current reserach projects

Literature:
Case dependent

Assigned Courses:

Oberseminar Quantenalgorithmik
**(hybrid/mixed) **
Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unsere Forschungsthemen bzw. Themenvorschläge für studentische Arbeiten an und kontaktieren direkt einen Mitarbeiter, dessen Forschung Sie interessiert: https://www.uni-augsburg.de/de/fakultaet/fai/informatik/prof/qalg/
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Examination
Projektmodul Quantenalgorithmen
practical exam, graded
Test Frequency:
when a course is offered

Module INF-0461: Project Module Computational Linguistics

Projektmodul Computational Linguistics

10 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Annemarie Friedrich

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Sprachverstehen

Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Autonomous collaboration on current research topics.

Literature:
scientific papers, handbooks

Assigned Courses:

Oberseminar Natural Language Understanding

**(hybrid/mixed) **
Das aktuelle Programm des Seminars finden Sie hier: https://hlt-augsburg.github.io/ (siehe Events / HLT Seminar). Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unsere Forschungsthemen bzw. Themenvorschläge für studentische Arbeiten an und kontaktieren direkt einen Mitarbeiter, dessen Forschung Sie interessiert: https://www.uni-augsburg.de/de/fakultaet/fai/informatik/prof/coling/
Die alleinige Teilnahme am Oberseminar ist freiwillig und gibt keine ECTS-Punkte.

Examination

Projektmodul Sprachverstehen

practical exam, graded

Test Frequency:

when a course is offered

Module INF-0481: Project Module Intelligent Perception in Technical Systems

Projektmodul Intelligente Perzeption in Technischen Systemen

10 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Project Module Intelligent Perception in Technical Systems

Mode of Instruction: internship
Language: English / German
Frequency: each semester
Contact Hours: 1,00

Contents:

Current research topics.

Literature:

Scientific papers, manuals

Assigned Courses:

Oberseminar Intelligente Perzeption in Technischen Systemen

**(in attendance) **

Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unsere Forschungsthemen bzw. Themenvorschläge für studentische Arbeiten an und kontaktieren direkt einen Mitarbeiter, dessen Forschung Sie interessiert: https://www.uni-augsburg.de/de/fakultaet/fai/informatik/prof/ips/ Die alleinige Teilnahme am Oberseminar ist freiwillig und gibt keine ECTS-Punkte. Über diesen Digicampus-

Kurs kommunizieren wir neben Vortragsankündigungen auch Neuigkeiten z.B. über Stellenangebote und Themenausschreibungen für Abschlussarbeiten und Forschungsmodule der Professur IPS. Tragen Sie sich in den Kurs ein, um unsere Ankündigungen zu erhalten.

Examination

Project Module Intelligent Perception in Technical Systems

practical exam, graded

Test Frequency:

when a course is offered

Module INF-3021: Project Module Data Engineering *Projektmodul Data Engineering*	10 ECTS/LP
Version 1.0.0 (since WS24/25) Person responsible for module: Prof. Dr. Fabian Panse	

Learning Outcomes / Competences:
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.

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Projektmodul Data Engineering
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:
Work on current research topics

Literature:
scientific papers, handbooks

Assigned Courses:

Oberseminar Data Engineering
**(hybrid/mixed) **
Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, kontaktieren Sie Prof. Panse. Die alleinige Teilnahme am Oberseminar ist freiwillig und gibt keine ECTS-Punkte.

Examination

Project Module Data Engineering

practical exam, graded

Test Frequency:

when a course is offered

Module INF-3063: Project Module Intelligent Energy Systems

Projektmodul Intelligente Energiesysteme

10 ECTS/LP

Version 1.0.0 (since SoSe26)
Person responsible for module: Prof. Dr. Nicole Ludwig

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Project Module Intelligent Energy Systems

Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:

Autonomous collaboration on current research topics.

Literature:

scientific papers, handbooks

Assigned Courses:

Oberseminar Intelligente Energiesysteme

**(in attendance) **

Das Oberseminar fasst Vorträge und Arbeitsbesprechungen zu Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unter Lehre (siehe TODO) unsere Informationen zu Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen (unter Lehrveranstaltungen) an und kontaktieren direkt einen Mitarbeiter.

Examination

Project Module Intelligent Energy Systems

practical exam, graded

Test Frequency:

when a course is offered

Module INF-3069: Project Module Machine Learning & Computer Vision *Projektmodul Machine Learning & Computer Vision*	10 ECTS/LP
Version 1.0.0 (since SoSe26) Person responsible for module: Prof. Dr. Rainer Lienhart	
Learning Outcomes / Competences: 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. **Key qualifications**: 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.	
Workload: Total: 300 h 15 h seminar (attendance) 285 h internship / practical course (self-study)	

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Project Module Machine Learning & Computer Vision

Mode of Instruction: internship
Language: German / English
Frequency: each semester
Contact Hours: 1,00

Contents:

The specific task from the wide-ranging field of machine learning & computer vision is designed individually for each student every year.

Literature:

scientific papers, handbooks

Assigned Courses:

Oberseminar Selected Aspects of Machine Learning and Computer Vision
**(in attendance) **

Examination

Project Module Machine Learning & Computer Vision

practical exam, graded

Test Frequency:

when a course is offered

Module MTH-4310: Mathematics Project

Mathematics Project

10 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:

Students can approach any professor in the mathematics department to get a project topic assigned to them. The precise content and task to complete depends on the assigned project topic and will be discussed individually with the professor.

Learning Outcomes / Competences:

After participating in the project module, students understand problems of higher complexity in the selected field of mathematics 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;

Workload:

Total: 300 h

Conditions:		**Credit Requirements:**
none		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
	Repeat Exams Permitted: according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematics Project for Data Science

Language: English / German

Examination

Mathematics Project for Data Science

portfolio exam, graded

Module MTH-4300: Mathematics Seminar

Mathematics Seminar

4 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Contents:
Depends on the topic of the seminar, please check in digicampus before the term starts.

Learning Outcomes / Competences:
Through self-study of mathematical topics,
talks and scientific discussion, the following goals are to be achieved:
Ability to work with scientific literature,
skills in formulating and presenting theoretical questions based on the mathematical methods learnt.
Integrated acquisition of key qualifications:
Working independently with scientific literature, trying out different presentation techniques and presentation media, conducting scientific discussions and communicating problem-solving approaches.

Workload:
Total: 120 h

Conditions: none		**Credit Requirements:** One needs to pass one of the offered seminars. The precise form of the exam (talk/homework/etc) will be announced in digicampus for the individual seminar before the term starts.
Frequency: each semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematics Seminar
Language: English / German

Assigned Courses:

Can we trust Dr. Black Box? (Bachelor / Master) (seminar)

**(in attendance) **

KI-Modelle können medizinische Risiken, Diagnosen und Prognosen erstaunlich gut vorhersagen. Aber in der Medizin reicht ein "das Modell sagt es" nicht aus. Wir wollen verstehen, warum ein Modell eine bestimmte Vorhersage trifft, welche Informationen wirklich relevant sind und wann Erklärungen selbst in die Irre führen können. In diesem Seminar geht es um Explainable AI, interpretierbares Machine Learning und statistisches Denken für medizinische Anwendungen. Themen sind unter anderem: • Black-box-Modelle vs. interpretierbare Modelle • Feature Effects: PDP, ICE und ALE • Feature Importance und SHAP-Werte • Validierung, Overfitting und Generalisierbarkeit • Grenzen von XAI in realen Anwendungen

Causality: The thing AI usually misses (Bachelor / Master) (seminar)

**(in attendance) **

KI erkennt Muster, schreibt Texte und trifft beeindruckende Vorhersagen. Aber eine einfache Frage bringt sie oft ins Schwitzen: Was verursacht was? In diesem Seminar geht es um Kausalität, kausale Inferenz und die Rolle der Statistik in einer Welt voller KI. Wir diskutieren, warum Korrelation nicht gleich Kausalität ist, weshalb KI kausale Zusammenhänge häufig übersieht und wie statistisches Denken zu besseren Entscheidungen führt. Themen sind

unter anderem: • Korrelation, Kausalität und Scheinkorrelationen • Confounding und versteckte Einflussfaktoren • Kausale Graphen • Was KI kann, was KI nicht kann und wo Statistik hilft

It's about time: Survival Analysis (Bachelor / Master) (seminar)

*(in attendance) *

In medizinischen Studien zählt oft nicht nur, ob etwas passiert, sondern wann: Rückfall, Hospitalisierung, Nebenwirkung, Tod oder Genesung. Solche Daten sind besonders: Manche Personen erleben das Ereignis, andere sind am Studienende noch ereignisfrei oder gehen im Follow-up verloren. Genau dafür braucht man Survival bzw. Time- to-Event Analysis. Wir lernen, wie man Zeit-bis-Ereignis-Daten beschreibt, vergleicht und modelliert - von Kaplan- Meier-Kurven bis zum Cox-Modell. Ausblicke gibt es auf competing risks, recurrent events und nicht- proportionale Hazards. Themen sind unter anderem: • Zensierung und Follow-up • Kaplan-Meier-Kurven • Log-rank-Test und Cox-Modell • Hazards, Risiken und Survival-Wahrscheinlichkeiten • Competing risks, recurrent events und non-PH

Riemannian Optimization (seminar)

*(in attendance) *

Seminar zu BV-Funktionen und Variationsproblemen in BV (seminar)

*(in attendance) *

Funktionen von beschränkter Variation spielen eine zentrale Rolle in zahlreichen Anwendungen der modernen Analysis und Variationsrechnung. Sie ermöglichen die mathematische Beschreibung von Sprüngen und Kanten und finden daher unter anderem Einsatz in der Bildverarbeitung, den Materialwissenschaften sowie der geometrischen Maßtheorie. Darüber hinaus bilden BV-Räume den natürlichen Lösungsraum für viele Variationsprobleme mit linearem Wachstum, etwa für das nicht-parametrische Minimalflächenproblem. Während Minimalfolgen (oder besser Infimalfolgen) in solchen Problemen im Allgemeinen lediglich im Sobolevraum W^{1,1} beschränkt sind, reichen dessen Kompaktheitseigenschaften für einen Existenzbeweis mittels der direkten Methode der Variationsrechnung nicht aus. Der Übergang zum BV-Raum stellt die notwendige Kompaktheit wieder her, erfordert aber eine Fortsetzung des Funktionals auf diesen Raum und ermöglicht so dann den Nachweis der Existenz sogenannter verallgemeinerter Minimierer. Im...

Seminar zur Stochastik (seminar)

*(in attendance) *

Vorkenntnisse: Stochastik, Optimierung Literatur: "Game Theory, Alive" von Anna Karlin und Yuval Peres (American Mathematical Society, 2017 Zielgruppe: Anrechenbar für Bachelor- und Masterstudium Mathematik / Wi-Mathe / Data Science, sowie Lehramt Mathematik Dozent: Prof. Markus Heydenreich Termin: Geplant als Blockseminar im Wintersemester 2026/27 1. Vorbesprechung: 13.07.2026 um 16:00 Uhr im L/3008 Anmeldung: Bei der Vorbesprechung oder per E-Mail beim Dozenten

Seminar zur Stochastik / Statistik - Statistical Methods in Finance (Master) (seminar)

*(in attendance) *

Fortgeschrittene statistische Modelle für Anwendungen im Bereich Fi- nance und Insurance; evtl. Programmierung illustrativer Beispiele in Python oder R

Examination

Mathematics Seminar Mathematics Seminar

portfolio exam, graded

Module INF-3059: Project Seminar Responsible Artificial Intelligence: Design, Evaluation and Challenges (Master) *Projektseminar zu Verantwortungswürdige Künstliche Intelligenz: Gestaltung, Bewertung und Herausforderungen (Master)*	4 ECTS/LP

Version 1.0.0 (since SoSe26)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
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.

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 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.

Key qualifications: Presentation techniques; literature research; principles of good scientific practice; evaluating solution approaches, procedures, techniques, and technologies from different points of view.

Remarks:
Sofern Ihre PO vorschreibt, dass Sie ein Seminar belegen müssen, kann dieses Modul **nicht** dafür verwendet werden, da das Projektseminar nicht als Seminar zählt!

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of presentations (self-study)

Conditions: none		**Credit Requirements:** Passing the module examination
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Digital Ethics (Master)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 2,00

Contents:
The topics of the seminar change over time, in order to reflect up-to-date developments

Literature:
Literature depends on the chosen topic

Examination

Seminar Digital Ethics (Master)

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

Test Frequency:

when a course is offered

Module KTH-9000: Ethics & Computer Science *Ethics & Computer Science*	4 ECTS/LP

Version 1.0.0 (since WS25/26)
Person responsible for module: Prof. Dr. Kerstin Schlögl-Flierl

Learning Outcomes / Competences:
After completing the module, students will be able to identify, analyze, and evaluate ethical issues that arise in the development and application of computer science and artificial intelligence (AI). They gain knowledge of central ethical theories of AI, with special focus on the embedded ethics approach and both individual- and social-ethical perspectives.

A core outcome of the module is the development of fundamental ethical competence. Students learn to recognize ethically relevant aspects of technical work, to assess them critically, and to integrate ethical reflection into research and practice. They are able to apply ethical frameworks, evaluate alternative approaches, and propose well-reasoned solutions.

Key Learning Objectives:

- Fundamental ethical theories should be recognized.
- Independent ethical judgment should be encouraged.
- The field of AI ethics should be understood in overview.
- The specific problems of data ethics should be understood.

Key Qualifications: Fundamental ethical competence in the context of computer science; Literature research and independent engagement with English-language academic sources; Analytical-methodical competence; Ability to apply ethical concepts, theories, and methods; principles of good scientific practice; Logical, abstract, and conceptual thinking; Structured ethical argumentation; Communication skills; Oral and written presentation of ideas, arguments, and results in a clear and convincing manner.Basic ethical reflection skills should be developed. The ability to identify problems for the other modules should be developed.

Workload:
Total: 120 h
30 h (attendance)
30 h studying of course content using provided materials (self-study)
60 h studying of course content using literarture (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Ethics & Computer Science
Language: English
Frequency: each summer semester
Contact Hours: 2,00

Contents:

The ethical debate surrounding AI currently revolves around various principles and guidelines from policy papers. The topics of bias and explainability are particularly prominent in these ethical debates. However, the focus should also be broadened to include environmental and climate ethics issues. The issue of human rights violations in various fields is also a pressing one and can only be addressed repeatedly in relation to new applications. The principles of what exactly constitutes responsible use of these technologies need to be clarified.

Literature:

- Deutscher Ethikrat, Mensch und Maschine, Berlin 2023.
- Hagendorff, T. (September 2024). Mapping the Ethics of Generative AI: A Comprehensive Scoping Review. *Minds And Machines*, *34*(4). https://doi.org/10.1007/s11023-024-09694-w
- Kate Crawford: Atlas der KI. Die materielle Wahrheit hinter den Datenimperien, München 2024.
- Laine, J., Minkkinen, M. & Mäntymäki, M. (May 2024). Ethics-based AI auditing: A systematic literature review on conceptualizations of ethical principles and knowledge contributions to stakeholders. *Information & Management*, *61*(5), 103969. https://doi.org/10.1016/j.im.2024.103969
- Rome Call for AI Ethics.
- Schlögl-Flierl, Kerstin; Ziethmann, Paula (2025): KI und Wir: warum der Einsatz von Künstlicher Intelligenz das Prinzip der Multiakteursverantwortung braucht und forciert. In: Sebastian Böhmer, Thorsten Unger (Hg.): Technisches Handeln und Verantwortung. Wiesbaden: Springer VS (Magdeburger Forschungen zu Bildungs-, Kultur- und Sozialwissenschaften), S. 35-53. DOI: 10.1007/978-3-658-46631-2_3
- Obrenovic, B., Gu, X., Wang, G., Godinic, D. & Jakhongirov, I. (March 2024). Generative AI and human–robot interaction: implications and future agenda for business, society and ethics. *AI & Society*. https://doi.org/10.1007/s00146-024-01889-0
- Willem, T., Fritzsche, M., Zimmermann, B. M., Sierawska, A., Breuer, S., Braun, M., Ruess, A. K., Bak, M., Schönweitz, F. B., Meier, L. J., Fiske, A., Tigard, D., Müller, R., McLennan, S. & Buyx, A. (December 2024). Embedded Ethics in Practice: A Toolbox for Integrating the Analysis of Ethical and Social Issues into Healthcare AI Research. *Science And Engineering Ethics*, *31*(1). https://doi.org/10.1007/s11948-024-00523-y

Examination

Ethics & Computer Science

oral exam / length of examination: 30 minutes, graded

Test Frequency:

when a course is offered

Module MTH-2021: Master Thesis with Colloquium *Master Thesis with Colloquium*		30 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: Students are familiar with the current state of research in a specialised field and the relevant literature. They are able to apply modern mathematical methods to the in-depth study of a current research question. They have the competence to independently work on a mathematical problem within a given time frame using scientific methods and to present the scientific basis of the problem and their results in writing. Integrated acquisition of key qualifications: ability to work in a team, perseverance, ability to document one's own scientific results in writing, critical reflection on one's own results in an international scientific context, principles of good scientific practice.		
Workload: Total: 900 h		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 0,00	**Repeat Exams Permitted:** once	

Parts of the Module

Part of the Module: Master Thesis with Colloquium

Mode of Instruction: colloquium
Language: German / English
Frequency: each semester
Contact Hours: 0,00
ECTS Credits: 30.0

Contents:

Appropriately chosen topic

Prerequisites: Basic knowledge in most mathematical subdisciplines, in-depth knowledge in a specialised field.

Examination

Master Thesis with Colloquium

Master's thesis / length of examination: 6 months, graded

Module INF-0066: Organic Computing II *Organic Computing II*	5 ECTS/LP

Version 1.3.0 (since SoSe14)
Person responsible for module: Prof. Dr. Jörg Hähner

Learning Outcomes / Competences:
Participants will be able to reproduce the essential concepts and methods of the research field of Organic Computing (OC).

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.

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.

Key qualifications: 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.

Remarks:
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

Workload:
Total: 150 h
15 h studying of course content using literarture (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)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Organic Computing II (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: each summer semester
Contact Hours: 2,00

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 Verlagfür Hochschulschriften, 2012, ISBN 978-3838131337

Part of the Module: Organic Computing II (Übung)

Mode of Instruction: exercise course

Language: German / English

Frequency: each summer semester

Contact Hours: 2,00

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.

Module INF-0243: Process Mining *Process Mining*	6 ECTS/LP

Version 1.3.0 (since SoSe17)
Person responsible for module: Prof. Dr. Robert Lorenz

Learning Outcomes / Competences:
Participants understand the following essential concepts of computer science at an advanced scientific level, including their mathematical and formal foundations: event log, Petri net, concurrency, 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.
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;

Remarks:
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.

Workload:
Total: 180 h
45 h lecture (attendance)
15 h exercise course (attendance)
23 h studying of course content using literarture (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)

Conditions:		**Credit Requirements:**
none		Passing the module examination
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Process Mining (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: each summer semester
Contact Hours: 3,00

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

- Modeling techniques: Transition systems, Petri nets, workflow nets, process trees, direct follows graphs
- Discovering algorithms: Alpha Miner, Inductive Miner, Direct Follows Miner, Synthesis based discovery techniques
- Conformance checking: fitness measures

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

Part of the Module: Process Mining (Übung)

Mode of Instruction: exercise course

Language: German / English

Frequency: each summer semester

Contact Hours: 1,00

Examination

Process Mining

written exam / length of examination: 90 minutes, graded

Test Frequency:

when a course is offered

Module INF-0277: Analysing Massive Data Sets

Analyzing Massive Data Sets

8 ECTS/LP

Version 1.2.0 (since SoSe18)
Person responsible for module: Prof. Dr. Peter Michael Fischer

Learning Outcomes / Competences:
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:

- Fundamentals of information retrieval
- Similarity search and clustering
- Analysis of data streams and temporal data
- Web graphs: Link analysis and social networks
- Dynamic networks and information diffusion
- Recommender systems and online advertising
- Computational methods for massive data sets

Students will also be able to implement technical solution concepts for analyzing large data sets in programs.
Key Skills: 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;

Workload:
Total: 240 h
30 h studying of course content using literarture (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)

Conditions:
Module Database Systems (INF-0073) - recommended
Module Discrete Structures for Computer Scientists (INF-0109) - recommended
Module Computer Science 3 (INF-0111) - recommended

Credit Requirements:
Passing the module exam

Frequency: Sommersemester

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Analyzing Massive Data Sets (Vorlesung)
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 4,00

Contents:

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.

Literature:

- Mining of Massive Datasets. J. Leskovec, A. Rajaraman, J.D. Ullman. Cambridge UniversityPress, 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

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

Examination

Analyzing Massive Data Sets

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0293: Advanced Deep Learning *Advanced Deep Learning*	8 ECTS/LP
Version 1.1.0 (since WS18/19) Person responsible for module: Prof. Dr. Rainer Lienhart	

Learning Outcomes / Competences:
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.
Key qualifications:

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

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
120 h studying of course content through exercises / case studies (self-study)
20 h lecture (attendance)
40 h exercise course (attendance)

Conditions:	**Credit Requirements:**
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")	Passing the portfolio examination

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

Parts of the Module

Part of the Module: Advanced Deep Learning (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each winter semester
Contact Hours: 2,00

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

Assigned Courses:

Advanced Deep Learning (lecture)
*(in attendance) **

Part of the Module: Advanced Deep Learning (Tutorial)

Mode of Instruction: exercise course
Language: English / German
Frequency: each winter semester
Contact Hours: 4,00

Assigned Courses:

Übung zu Advanced Deep Learning (exercise course)
*(in attendance) **

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.

Module INF-0309: Real-Time Systems *Echtzeitsysteme*	8 ECTS/LP

Version 1.11.0 (since WS19/20)
Person responsible for module:
Prof. Dr. Sebastian Altmeyer

Learning Outcomes / Competences:
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.

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.

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.

Key qualifications: 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.

Workload:
Total: 240 h
30 h studying of course content using literarture (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)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Real-Time Systems (Lecture)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 4,00

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

Assigned Courses:

Real-Time Systems (lecture)

*(in attendance) *

Real-time systems are computer systems whose correctness is defined not only by the correct result of a computation, but also by correct timing behavior. Put simply: if an embedded system responds too late, it is just as useless as if it had not responded at all or had responded incorrectly. For example, an airbag should deploy before the driver's head hits the steering wheel. Similarly, a self-driving vehicle must brake autonomously in time to prevent an accident from occurring, and a coffee machine should stop dispensing coffee before the cup overflows. In this lecture, we will examine the timing behavior of such embedded real-time systems. We will learn how to influence and validate the timing behavior of these systems, as well as how different design decisions affect their timing behavior.

Part of the Module: Real-Time Systems (Exercise)

Mode of Instruction: exercise course
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Assigned Courses:

Exercise for Real-Time Systems (exercise course)

*(in attendance) *

Examination

Real-Time Systems

written exam / length of examination: 90 minutes, graded

Test Frequency:

this semester

Module INF-0316: Machine Learning and Computer Vision *Machine Learning and Computer Vision*	8 ECTS/LP
Version 1.0.0 (since SoSe19) Person responsible for module: Prof. Dr. Rainer Lienhart	

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
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 literarture (self-study)

Conditions:		**Credit Requirements:**
none		Passing the Module Exam
Frequency: each summer semester (except for summer term 2026)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Machine Learning and Computer Vision (Lecture)
Mode of Instruction: lecture
Language: German
Frequency: each summer semester
Contact Hours: 4,00

Contents:
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 Adaboot), Data Reduction (Quantization (K-Means Clustering, Affinity Propagation), Dimensionality Reduction Techniques (PCA, NMF, Random Projection, MDS)) and Image Processing & Computer Vision (Salient Feature Points and Feature Descriptors, Object Detection (Face/Car/People Detection), Object Recognition (Face Recognition), Image Search with pLSA).

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

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

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.

Module INF-0367: Advanced Machine Learning and Computer Vision

Advanced Machine Learning and Computer Vision

5 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
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.

Key qualifications: 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

Workload:
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 literarture (self-study)
15 h studying of course content using provided materials (self-study)

Conditions:	**Credit Requirements:**
"Knowledge of Machine Learning and Computer Vision" (Master's lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")	Passing the module examination

Frequency: each winter semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Machine Learning and Computer Vision (Lecture)
Mode of Instruction: lecture
Language: German / English
Frequency: each winter semester
Contact Hours: 2,00

Contents:

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.

Literature:

Will be announced at the beginning of the semester.

Assigned Courses:

Advanced Machine Learning and Computer Vision (lecture)

**(online/digital) **

Diese Vorlesung findet im WS 26/27 nicht statt

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

Assigned Courses:

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

**(in attendance) **

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.

Module INF-0368: Embedded Hardware *Embedded Hardware*	5 ECTS/LP
Version 1.2.0 (since WS20/21) Person responsible for module: Prof. Dr. Sebastian Altmeyer	

Learning Outcomes / Competences:

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.

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.

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.

Key qualifications: 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.

Workload:

Total: 150 h
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions: none		
Frequency: irregular (usu. winter semester)	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embedded Hardware (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

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

Module INF-0371: Approximation Algorithms

Approximation Algorithms

5 ECTS/LP

Version 1.3.0 (since WS20/21)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:
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.

Key Skills: Ability to build intuitive understanding of mathematical formalisms; ability to identify core properties of optimization problems; deep understanding of powerful mathematical tools

Remarks:
You can take this course only when you did not visit the course *INF-0420: Approximationsalgorithmen*!

Workload:
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 literarture (self-study)
15 h studying of course content using provided materials (self-study)

Conditions:
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").

Credit Requirements:
Passing the module exam

Frequency: irregular

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
4,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Approximation Algorithms (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:

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.

Literature:

- David P. Williamson and David B. Shmoys, The Design of Approximation Algorithms, Cambridge University Press.
- Vijay V. Vazirani, Approximation Algorithms, Springer.

Assigned Courses:

Approximation Algorithms (lecture)

*(online/digital) *

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.

Part of the Module: Approximation Algorithms (Übung)

Mode of Instruction: exercise course

Language: English / German

Frequency: irregular

Contact Hours: 2,00

Assigned Courses:

Übung zu Approximation Algorithms (exercise course)

*(online/digital) *

Examination

Approximation Algorithms

oral exam / length of examination: 120 minutes, graded

Test Frequency:

when a course is offered

Module INF-0383: Algorithms for Big Data

Algorithmen für Big Data

5 ECTS/LP

Version 1.1.0 (since SoSe21)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:
Development and understanding of central copetences in algorithm design for situations, where there are large amounts of data such that not all of them can be accessed without restrictions; aquisition of knowledge of mathematical tools to analyze algorithms; improvement of copetences in abstract thinking and analyzing problems in a systematic manner.

Key Qualifications: Ability to develop an intuitive understanding of mathematical formalisms; ability to identify the core properties of algirthmic problems; deep understanding of useful mathematical tools

Workload:
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 literarture (self-study)

Conditions: Basic knowledge in algorithms and data structures (for example Informatik 3 (INF-0111)) and in probability theory (for example Stochastik für Informatiker (MTH-6040)).		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Algorithms for Big Data (lecture)

Mode of Instruction: lecture
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:

In modern data processing, we increasingly have the problem that there are large quantities of data whcih con 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.

Literature:

Wissenschaftliche Papiere, Surveys, Skripte

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

Mode of Instruction: exercise course
Language: English / German
Frequency: irregular
Contact Hours: 2,00

Examination

Algorithms for Big Data

oral exam / length of examination: 90 minutes, graded

Test Frequency:

when a course is offered

Module INF-0408: Extremal Combinatorics

Extremal Combinatorics

5 ECTS/LP

Version 1.0.0 (since SoSe22)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:

Knowledge

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.

Methodical Competences

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 develp novel solution approaches, as solutions to relevant questions are usually not unique

Key Skills

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

Workload:
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 literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)

Conditions: Basic knowledge in mathematics, in particular linear algebra is necessary. Basic knowledge in graph theory is recommended.		**Credit Requirements:** Passing the module exam
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Extremal Combinatorics (Vorlesung)
Mode of Instruction: lecture
Language: English / alle Sprachen
Frequency: irregular
Contact Hours: 2,00

Contents:

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.

Literature:

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

Module INF-0432: Isabelle-Lab *Isabelle-Lab*	8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Kirstin Peters	
Contents: 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.	
Learning Outcomes / Competences: **Knowledge:** 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. **Skills:** 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. **Competences:** 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. **Key skills:** 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.	
Workload: 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 literarture (self-study) 60 h exercise course (attendance) 30 h lecture (attendance)	
Conditions: none	**Credit Requirements:** Bestehen der Modulprüfung

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

Parts of the Module

Part of the Module: Isabelle-Lab (Vorlesung)
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
Contact Hours: 2,00

Contents:

We discuss the basic design of Isabelle and how to work with this interactive theorem prover. In particular we study:

- higher-order logic (HOL)
- isabelle syntax and semantics
- proof strategies
- induction and induction principles
- formalisation of theories in Isabelle/HOL
- proof support (proof tactics and external assistance)
- proof language Isar

Literature:

https://isabelle.in.tum.de/documentation.html

Assigned Courses:

Isabelle-Lab (lecture)

*(in attendance) *

Praktische Einführung in das interaktive Beweisen von Theoremen mit dem Beweiser Isabelle/HOL. An introduction to interactive theorem proving with Isabelle/HOL. Consists of a lecture with exercises and practical session to work on the project task with supervision.

Part of the Module: Isabelle-Lab (Übung)
Mode of Instruction: exercise course
Language: English
Frequency: each winter semester
Contact Hours: 4,00

Assigned Courses:

Übung zu Isabelle-Lab (exercise course)

*(in attendance) *

An introduction to interactive theorem proving with Isabelle/HOL. Information to the lecture can be found in the main course.

Examination
Isabelle-Lab

practical exam, graded

Test Frequency:

when a course is offered

Module INF-0440: Quantum Algorithms

Quantum Algorithms

5 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

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

Learning Outcomes / Competences:

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.

Workload:

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)

Conditions:		**Credit Requirements:**
Linear Algebra (basics)		Passing the exam
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Quantum Algorithms (Vorlesung)
Mode of Instruction: lecture
Language: English / German
Frequency: each summer semester
Contact Hours: 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)

Part of the Module: Quantum Algorithms (Übung)

Mode of Instruction: exercise course

Language: English

Frequency: each summer semester

Contact Hours: 2,00

Examination

Quantum Algorithms

oral exam / length of examination: 25 minutes, graded

Test Frequency:

when a course is offered

Module INF-0466: Biophotonics *Biophotonics*	5 ECTS/LP

Version 1.4.0 (since WS23/24)
Person responsible for module: Prof. Dr. Sebastian Zaunseder
Sahl, Fabienne

Learning Outcomes / Competences:
Subject-related competences:

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.

Methodological competencies:

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.

Interdisciplinary Competencies:

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.

Key skills:

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.

Workload:
Total: 150 h
30 h exercise course (attendance)
30 h lecture (attendance)
60 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using provided materials (self-study)

Conditions:		**Credit Requirements:**
basic math skills; basic programming skills		Passing the module exam
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Biophotonics (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
Contact Hours: 2,00

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 OpticsFrom light interactions with cells to complex imaging systems. Blurb

Assigned Courses:

Biophotonics (lecture)

**(in attendance) **

The lecture provides a comprehensive overview on biophotonics. It is divided in two main parts. Part 1 covers fundamental aspects with respect to photonics on an entry-level. It overviews basic properties of light together with general ways to describe light and the interaction of light with its surroundings. It further contains basic principles of light generation and light sensing. Part 2 focuses on diagnostic techniques based on biophotonics such as microscopy, oximetry, optical coherence tomography, laser speckle imaging and photoacoustic imaging. With respect to such techniques, the lectures present basic ideas, concrete implementations and illustrate medical use cases.

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

Assigned Courses:

Tutorial for Biophotonics (exercise course)

**(in attendance) **

Within the exercises, students work on computational tasks related to biophotonics. Covered topics include modelling and simulation of light-tissue interaction as well as image processing tasks.

Examination

Biophotonics

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0476: Computer Vision for Intelligent Systems

Computer Vision für Intelligente Systeme

5 ECTS/LP

Version 1.1.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 150 h
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions:
- Basic programming knowledge in Python
- Advantageous: Basic knowledge in Deep Learning

Credit Requirements:
Passing the module exam

Frequency: irregular (usu. winter semester)

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
4,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Computer Vision for Intelligent Systems (Lecture)
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2,00

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

Assigned Courses:

Computer Vision for Intelligent Systems (Computer Vision für Intelligente Systeme) (lecture)

**(in attendance) **

This course covers modern methods for computer vision for intelligent systems such as, for example, deep learning, visual simultaneous localization and mapping, object detection and pose estimation using deep learning, or neural radiance fields and Gaussian splatting. Please also see the wiki for a tentative course schedule.

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

Mode of Instruction: exercise course
Language: English / German
Contact Hours: 2,00

Assigned Courses:

Exercises for Computer Vision for Intelligent Systems (Übungen zu Computer Vision für Intelligente Systeme) (exercise course)

**(in attendance) **

Examination

Computer Vision for Intelligent Systems

written exam / length of examination: 90 minutes, graded

Test Frequency:

when a course is offered

Module INF-0499: Foundation Models in Deep Learning *Foundation Models in Deep Learning*	5 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. Rainer Lienhart	

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
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 literarture (self-study)

Conditions:	**Credit Requirements:**
Knowledge in machine learning and machine vision (Master lecture INF-0092 "Multimedia II" or INF-0316 "Machine Learning and Computer Vision")	Passing the module examination

Frequency: each summer semester except summer term 2026	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Probabilistic Robotics (Lecture)
Mode of Instruction: lecture
Language: German / English
Frequency: each summer semester except summer term 2026
Contact Hours: 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 RobotLocalization: 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.

Module INF-0504: Medical Monitoring and Advanced Sensor Data Processing *Medical Monitoring and Advanced Sensor Data Processing*		8 ECTS/LP
Version 1.4.0 (since SoSe24) Person responsible for module: Prof. Dr. Sebastian Zaunseder Aublin, Pierre, Dr.; Idrobo-Ávila, Ennio, Dr.		
Learning Outcomes / Competences: **Subject-related competences**: 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. **Methodological competencies**: 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. **Interdisciplinary Competencies**: 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. **Key skills**: 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.		
Workload: Total: 150 h 60 h studying of course content using provided materials (self-study) 60 h exercise course (attendance) 90 h studying of course content through exercises / case studies (self-study) 30 h lecture (attendance)		
Conditions: basic math skills; basic programming skills; basic knowledge on handling digital signals		**Credit Requirements:** Passing the module exam
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Medical monitoring and advanced sensor data processing (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: each summer semester
Contact Hours: 2,00

Contents:

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:

- Fundamentals of medical monitoring (basic ideas, history, current solutions, trends)
- Fundamentals of sensor data fusion
- Preprocessing approaches (e.g. denoising by conventional filters, Kalman filters and autoencoders)
- Dimension reduction and source separation (e.g. principal component analysis and independent component analysis)
- Feature extraction by functional transforms (e.g. time-frequency transforms)
- Basic detection/classification approaches

Literature:

- S. Bernhard, A. Brensing, and K.-H. Witte, *Biosignalverarbeitung*. De Gruyter, 2019. doi: 10.1515/9783110442434.

Part of the Module: Medical Monitoring and Advanced Sensor Data Processing (Exercise)
Mode of Instruction: exercise course
Language: English
Frequency: each summer semester
Contact Hours: 4,00

Contents:

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:

- Familiarization with techniques of data acquisition and handling data
- Denoising of data of variable origin
- Application of feature extraction and dimension reduction techniques
- Prediction/detection of (patho)physiological states
- Techniques for visualization and interpretation of sensor data

Examination

Medical Monitoring and Advanced Sensor Data Processing

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0506: Search Engines and Neural Information Retrieval *Search Engines and Neural Information Retrieval*	8 ECTS/LP

Version 1.8.0 (since SoSe24)
Person responsible for module: Prof. Dr. Annemarie Friedrich

Learning Outcomes / Competences:
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:

- Basics of traditional information retrieval methods
- Vector-based document and query representations (topic modeling and neural representations)
- Ranking with embeddings
- Question answering, entity search, and knowledge graphs
- Multimodal retrieval
- Interactive information retrieval and personalization

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.

Key skills: 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.

Workload:
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 literarture (self-study)
15 h studying of course content using provided materials (self-study)

Conditions: Recommended: linear algebra, basic probability theory, basics in machine learning, Python programming.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Search Engines and Neural Information Retrieval (Lecture)
Language: English / German
Frequency: each winter semester
Contact Hours: 4,00

Contents:

The course content is roughly divided into two parts. The 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: 10.1561/1500000061.
- Tonellotto, 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

Assigned Courses:

Search Engines and Neural Information Retrieval (Lecture) (lecture)

**(in attendance) **

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 event, students are able to explain the concepts and methods, procedures, techniques and technologies related to neural information retrieval. In particular, the course covers: • Basics of traditional information retrieval methods • Vector-based document and query representations (topic modeling and neural representations) • Ranking with embeddings • Question answering, entity search, and knowledge graphs • Multimodal retrieval • Interactive information retrieval and personalization This on-site course will be taught in an interactive way. NOTE: The exerc...

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

Language: English / German

Frequency: each winter semester

Contact Hours: 2,00

Contents:

The tutorial part of the course includes hands-on programming exercises as well as participating in a group project, exercising all phases of research in neural information retrieval or semantic text processing.

Assigned Courses:

Search Engines and Neural Information Retrieval (Tutorial) (exercise course)

**(in attendance) **

Examination

Search Engines and Neural Information Retrieval

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-0509: Embodied Artificial Intelligence

Embodied Artificial Intelligence

8 ECTS/LP

Version 1.0.0 (since SoSe24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
60 h exercise course (attendance)

Conditions:
- Basic programming knowledge in Python
- Basic knowledge in Deep Learning

Credit Requirements:
Passing the module exam

Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Embodied Artificial Intelligence (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

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 contempory 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

Part of the Module: Embodied Artificial Intelligence (Exercises)

Mode of Instruction: exercise course
Language: English
Frequency: irregular (usu. summer semester)
Contact Hours: 4,00

Examination

Embodied Artificial Intelligence

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-3037: Graph Algorithms

Graph Algorithms

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Pascal Lenzner

Learning Outcomes / Competences:
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.

Key skills: 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

Workload:
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 literarture (self-study)
30 h exercise course (attendance)
60 h lecture (attendance)

Conditions:
No fixed prerequisites, but basic knowledge in the design and analysis of algorithms as well in compexity theory from the Bachelor studies will be assumed.

Credit Requirements:
Passing the module exam

Frequency: irregular

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Graph Algorithms (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: irregular
Contact Hours: 4,00

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.

Literature:

- Cormen, Leiserson, Rivest, Stein: Cormen, Leiserson, Rivest, Stein. MIT Press
- Kleinberg, Tardos: Algorithm Design. Pearson
- Ahuja, Magnanti, Orlin: Network Flows: Theory and Applications. Prentice Hall
- Korte, Vygen: Combinatorial Optimization. Springer

Assigned Courses:

Graph Algorithms (lecture)
**(in attendance) **

Part of the Module: Graph Algorithms (Exercise)
Mode of Instruction: exercise course
Language: English / German
Frequency: irregular
Contact Hours: 2,00

Assigned Courses:

Exercise for Graph Algorithms (exercise course)
**(in attendance) **

Examination
Graph Algorithms
oral exam / length of examination: 30 minutes, graded
Test Frequency:
each semester

Module INF-3049: Trustworthy Artificial Intelligence *Trustworthy Artificial Intelligence*	5 ECTS/LP

Version 1.0.0 (since WS25/26)
Person responsible for module: Prof. Dr. Bernhard Bauer
Dr. Fabian Stieler

Learning Outcomes / Competences:
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.

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.

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.

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.

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.

Workload:
Total: 150 h
30 h lecture (attendance)
30 h exercise course (attendance)
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)
60 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Basic knowledge of machine learning is an advantage.	Passing the module exam

Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Trustworthy Artificial Intelligence (Vorlesung)
Mode of Instruction: lecture
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

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

Assigned Courses:

Trustworthy Artificial Intelligence (lecture)

*(in attendance) *

Die Studierenden erwerben Kenntnisse über zentrale Konzepte und Prinzipien vertrauenswürdiger KI, einschließlich ethischer, rechtlicher und gesellschaftlicher Rahmenbedingungen sowie technischer Anforderungen. Sie verstehen, wie vertrauenswürdige KI-Systeme gestaltet, bewertet und dokumentiert werden können, und sind in der Lage, diese theoretischen Grundlagen auf praxisnahe Fragestellungen zu übertragen. Im Rahmen der Veranstaltung werden Methoden und Ansätze vorgestellt, die Transparenz, Erklärbarkeit, Fairness, Sicherheit, Robustheit und Datenschutz in KI-Systemen gewährleisten können. Dazu gehören beispielsweise Methoden des interpretierbaren Maschinellen Lernens. Die Studierenden lernen, typische Herausforderungen wie Bias, Sicherheitsrisiken und Datenschutzfragen zu identifizieren und geeignete Lösungsansätze zu entwickeln. Dies umfasst auch Cybersecurity im Kontext von KI-Systemen, wobei die Studierenden spezifische Angriffszenarien kennenlernen und geeignete Schutzmechanismen k...

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

Assigned Courses:

Übung zu Trustworthy Artificial Intelligence (exercise course)

*(in attendance) *

Die Veranstaltung vermittelt Grundlagen vertrauenswürdiger KI-Systeme, einschließlich ethischer und rechtlicher Rahmenbedingungen, sowie technische Konzepte zur Implementierung von Transparenz, Fairness und Interpretierbarkeit in KI-Systemen, MLOps-Praktiken, Cybersecurity im Kontext von KI-Systemen sowie Governance, Verantwortlichkeit und Nachhaltigkeit.

Examination

Trustworthy Artificial Intelligence

oral exam / length of examination: 30 minutes, graded

Test Frequency:

when a course is offered

Module INF-3071: Energy Systems: Modelling and Optimisation *Energy Systems: Modelling and Optimisation*	5 ECTS/LP
Version 1.0.0 (since WS26/27) Person responsible for module: Prof. Dr. Nicole Ludwig	

Learning Outcomes / Competences:
Upon completion of this course, students are able to independently formulate, implement, and solve large-scale models of energy systems for planning and operation. They can apply advanced optimisation methods, including stochastic and robust formulations, and integrate machine learning approaches such as reinforcement learning and decision-focused learning into the analysis and operation of energy systems. They are able to analyse the design and dynamics of electricity markets, to evaluate carbon pricing and climate policy instruments using economic principles, and to assess the role of weather and climate models across operational, planning, and investment decisions. They can critically compare modelling and decision-making approaches with respect to their assumptions, tractability, and practical relevance.

Key Skills: Mathematical modelling and large-scale optimisation; formulation and solution of energy system models using state-of-the-art frameworks such as PyPSA and ASSUME; integration of machine learning and optimisation for decision-making under uncertainty; critical evaluation of modelling assumptions and methods; ability to connect technical, economic, and climate perspectives on energy systems; engagement with current research in computational energy system analysis.

Workload:
Total: 150 h
60 h studying of course content through exercises / case studies (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)
15 h studying of course content using provided materials (self-study)
15 h studying of course content using literarture (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each winter semester	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Energy Systems: Modelling and Optimisation (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
Contact Hours: 2,00

Contents:
This course develops the mathematical and computational methods used to model, plan, and operate modern energy systems. Students learn to formulate and solve large-scale optimisation problems, to analyse electricity markets and the economics of carbon pricing and climate policy, and to combine optimisation with machine learning for decision-making under the uncertainty introduced by weather, climate, and renewable generation. Working with state-of-the-art frameworks such as PyPSA and ASSUME, the course connects these methods to current research and practice in energy system planning and operation.

Literature:
Bibliography will be given in the lecture

Assigned Courses:

Energy Systems: Modelling and Optimisation (Lecture) (lecture)
*(in attendance) **

Part of the Module: Energy Systems: Modelling and Optimisation (Tutorial)
Mode of Instruction: exercise course
Language: English
Frequency: each winter semester
Contact Hours: 2,00

Assigned Courses:

Energy Systems: Modelling and Optimisation (Tutorial) (exercise course)
*(in attendance) **

Examination
Energy Systems: Modelling and Optimisation
portfolio exam, graded
Test Frequency:
when a course is offered

Module INF-3073: Artificial Intelligence Assisted Engineering of Software-Intensive Systems *Artificial Intelligence Assisted Engineering of Software-Intensive Systems*	5 ECTS/LP

Version 1.0.0 (since WS26/27)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
Students critically examine and research methods for integrating AI, with a strong focus on Large Language Models (LLMs), into the development lifecycle of software-intensive systems. They are able to design AI-augmented architectural approaches, evaluate their technical and organizational impact, and document evidence-based integration strategies. Students can analyze the advantages and limitations of AI-assisted design alternatives (K4), assess their suitability for specific SiS application contexts (K6), and independently identify research gaps and practical challenges in AI-driven system engineering (K4). They will systematically design and prototype AI-integrated architectural patterns (K5) and validate their feasibility in realistic scenarios (K3). Furthermore, students develop competencies in analyzing enterprise architecture transformation under AI influence, select appropriate research and evaluation methods for AI integration, and critically assess emerging AI approaches to make well-informed decisions. The module emphasizes research-oriented problem solving, critical AI capability assessment, and systematic documentation of AI integration pathways.

Key competencies: Competence in interdisciplinary research and technology integration; academic and technical communication; independent research and literature analysis; critical evaluation of AI capabilities and limitations; quality-oriented engineering practices; ability to clearly present and document research findings; practical research experience and professional readiness in AI-enhanced software engineering.

Workload:
Total: 150 h
15 h exercise course (attendance)
30 h lecture (attendance)
28 h studying of course content using provided materials (self-study)
48 h studying of course content through exercises / case studies (self-study)
29 h studying of course content using literarture (self-study)

Conditions:	**Credit Requirements:**
• Basic knowledge of software development and software engineering • Knowledge of object-oriented programming • Basic knowledge of modeling languages (e.g., UML) • Basic knowledge of software architectures and design patterns • Basic familiarity with AI/LMM concepts is recommended	Passing the module exam

Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Artificial Intelligence Assisted Engineering of Software-Intensive Systems (Lecture)
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Contents:

The lecture focuses on research-driven exploration of AI and LLM integration in the development of software-intensive systems. Key topics include:

• AI-assisted architectural modeling, pattern recognition, and requirement-to-architecture translation
• LLM-based code generation, architecture synthesis, and automated documentation
• Evaluation frameworks for assessing AI integration in system design and enterprise architecture
• Research methodologies for measuring the impact of AI/LLMs on SiS complexity, safety, and real-time constraints
• Critical analysis of AI limitations, bias, security, and governance in system engineering workflows
• Evidence-based integration strategies, validation methods, and emerging research directions in AI-augmented system engineering

Literature:

- • Bass et al.: Software Architecture in Practice
  • Clements et al.: Documenting Software Architectures
  • Clements et al.: Evaluation of Software Architectures
  • Peer-reviewed research on LLMs in software engineering (e.g., IEEE/ACM TSE, ICSE, proceedings)
  • Empirical studies on AI integration in enterprise systems, architecture automation, and AI governance
  • Component: AI-assisted Engineering of Software-intensive Systems (Exercise)

Assigned Courses:

Artificial Intelligence Assisted Engineering of Software-Intensive Systems (lecture)
*(in attendance) **

Part of the Module: Artificial Intelligence Assisted Engineering of Software-Intensive Systems (Tutorial)
Mode of Instruction: exercise course
Language: English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Contents:

Hands-on research and practical exercises focusing on AI/LLM integration in SiS development. Students will conduct structured literature reviews, design AI-assisted architectural prototypes, evaluate AI-generated design alternatives against quality attributes, and document research findings. Case studies will explore real-world integration challenges, validation methodologies, ethical/security considerations of LLMs in system engineering, and strategies for bridging AI capabilities with SiS constraints (e.g., safety, determinism, traceability).

Assigned Courses:

Artificial Intelligence Assisted Engineering of Software-Intensive Systems (Tutorial) (exercise course)
*(in attendance) **

Examination
Artificial Intelligence Assisted Engineering of Software-Intensive Systems
oral exam / length of examination: 30 minutes, graded
Test Frequency:
each semester

Module INF-3075: Modern Data Architectures: Modeling, Processing, and Optimization *Modern Data Architectures: Modeling, Processing, and Optimization*	5 ECTS/LP

Version 1.0.0 (since WS26/27)
Person responsible for module: Prof. Dr. Peter Michael Fischer

Learning Outcomes / Competences:
After participating in this course, students will be able to design, implement, and optimize scalable data management solutions using modern, multi-paradigm data architectures. Students will transition from foundational relational concepts to advanced multi-model systems, gaining the ability to analyze and structure complex problems in data science and business informatics.

Core Competencies:

- Analyze and evaluate different data modeling paradigms (Relational, Document/JSON, Graph, Vector) to select the most appropriate architecture for specific, real-world constraints.
- Apply advanced query languages (Classical SQL, SQL/PGQ) to retrieve, manipulate, and analyze complex, nested, and interconnected data structures.
- Understand the internal mechanisms of query processing, including relational algebra implementations and orchestrations.
- Assess, evaluate, and optimize database performance through statistical analysis, execution plan assessment, and manual tuning techniques.

Key Skills: Ability to think logically, analytically and conceptually for architectural design; subject-specific in-depth knowledge of multi-paradigm systems; competence to implement subject-specific solution concepts in programs and models across diverse data structures; knowledge of the advantages and disadvantages of design alternatives and their evaluation in the respective application context; selection and confident application of suitable methods for system optimization; ability to analyse and structure complex computer science problems; knowledge of practice-relevant tasks; ability to make scientifically meaningful evaluations using suitable methods for performance assessment; competence in recognizing significant technical developments.

Remarks:
This course may only be taken if *INF-0078: Datenbankprogrammierung (Oracle)* has not been passed.

Workload:
Total: 150 h
15 h studying of course content using literarture (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)
30 h exercise course (attendance)

Conditions: Fundamental knowledge on database systems recommended, e.g., from the lecture [INF-0073] Datenbanksysteme		**Credit Requirements:** Passing the module exam
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Modern Data Architectures: Modeling, Processing, and Optimization (Lecture)
Mode of Instruction: lecture
Language: English / German
Frequency: each winter semester
Contact Hours: 2,00

Contents:

The lecture explores advanced data architectures, moving from traditional relational structures to modern, multi-model paradigms and their internal processing mechanics.

Topics covered include:

- **Foundations Recap:** Relational data models and purely relational SQL.
- **Complex and Nested Data Models:** Object-oriented user-defined data types, nested tables, JSON integration, document databases, and NoSQL concepts.
- **Graph Data:** Classical SQL recursion and graph query languages (SQL/PGQ).
- **Vector Databases:** Principles and applications of vector data management.
- **Analytical Data Systems:** Data warehousing and OLAP methodologies.
- **Query Processing:** Implementation of relational algebra, query orchestration, statistics, and performance metrics.
- **Optimization and Tuning:** Understanding and assessing query plans (with practical examples in Oracle), manual tuning, and the use of tuning advisors.
- **Extended Capabilities:** System extensibility and spatial data processing.

Literature:

to be provided in the lecture

Assigned Courses:

Modern Data Architectures: Modeling, Processing and Optimization (lecture)

*(in attendance) *

This course may only be taken if INF-0078: Datenbankprogrammierung (Oracle) has not been passed. The lecture explores advanced data architectures, moving from traditional relational structures to modern, multi-model paradigms and their internal processing mechanics. Topics covered include: Foundations Recap: Relational data models and purely relational SQL. Complex and Nested Data Models: Object-oriented user-defined data types, nested tables, JSON integration, document databases, and NoSQL concepts. Graph Data: Classical SQL recursion and graph query languages (SQL/PGQ). Vector Databases: Principles and applications of vector data management. Analytical Data Systems: Data warehousing and OLAP methodologies. Query Processing: Implementation of relational algebra, query orchestration, statistics, and performance metrics. Optimization and Tuning: Understanding and assessing query plans (with practical examples in Oracle), manual tuning, and the use of tuning advisors. Extended Capabiliti...

Part of the Module: Modern Data Architectures: Modeling, Processing, and Optimization (Exercises)
Mode of Instruction: exercise course
Language: English / German
Frequency: each winter semester
Contact Hours: 2,00

Assigned Courses:

Übung zu Modern Data Architectures: Modeling, Processing and Optimization (exercise course)

*(in attendance) *

Examination

Modern Data Architectures: Modeling, Processing, and Optimization

portfolio exam, graded

Test Frequency:

when a course is offered

Module INF-3815: Advanced Biomedical Systems Modelling and Data Science

5 ECTS/LP

Advanced Biomedical Systems Modeling and Data Science

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Andreas Raue

Learning Outcomes / Competences:
This interdisciplinary course provides advanced-level knowledge of computational techniques in systems modeling and data science applied to complex biomedical challenges.

Students will expand their expertise in mathematical modeling, machine learning, and biological data analysis. The course emphasizes both theoretical understanding and practical application through project-based learning.

A solid background in biology, mathematics (calculus, linear algebra, differential equations), and programming (Python) is required.

The goal of this course is to prepare students for a career path as scientists in biomedical, biotechnology or pharmaceutical industry, or for continuing their academic training and research by acquiring a PhD degree.

Objectives:

- Deepen understanding of systems modeling and data science principles.
- Develop expertise in handling complex datasets and applying advanced models and methods.
- Enhance proficiency in interpreting and presenting biomedical data using advanced models.
- Strengthen project design and critical evaluation skills for scientific research.

Workload:
Total: 150 h
15 h studying of course content using literarture (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)

Conditions:		**Credit Requirements:**
none		Passing the module exam
Frequency: each semester	**Recommended Semester:** 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Biomedical Systems Modeling and Data Science (Lecture)
Mode of Instruction: lecture
Language: English / alle Sprachen
Frequency: each semester
Contact Hours: 2,00

Contents:

Part 1: Data Science

- Statistical Theory & Applications
- Machine Learning Techniques
- Omics Data Integration
- Artificial Ground Truth

Part 2: Systems Modeling

- Dynamical Systems & Modeling Concepts
- Model Development & Analysis
- Experimental Design
- Advanced Model Classes

Note: The syllabus may be adjusted based on class progress and instructor discretion.

Literature:

- "Introduction to System Biology" by Edda Klipp
- "A First Course in Systems Biology" by Eberhard O. Voit
- "Introduction to Machine Learning" by Ethem Alpaydin
- "Machine Learning" by Tom M. Mitchell

For further reading, not a blueprint for this lecture!

Additional research papers and online resources will be provided throughout the course.

Assigned Courses:

Advanced Biomedical Systems Modeling and Data Science (lecture)

**(in attendance) **

This interdisciplinary course provides advanced-level knowledge of computational techniques in systems modeling and data science applied to complex biomedical challenges. Students will expand their expertise in mathematical modeling, machine learning, and biological data analysis. The course emphasizes both theoretical understanding and practical application through project-based learning. A solid background in biology, mathematics (calculus, linear algebra, differential equations), and programming (Python) is required. The goal of this course is to prepare students for a career path as scientists in biomedical, biotechnology or pharmaceutical industry, or for continuing their academic training and research by acquiring a PhD degree. Objectives: • Deepen understanding of systems modeling and data science principles. • Develop expertise in handling complex datasets and applying advanced models and methods. • Enhance proficiency in interpreting and presenting biomedical data using advanc...

Part of the Module: Advanced Biomedical Systems Modeling and Data Science (Computer Exercise)

Mode of Instruction: exercise course
Language: English / alle Sprachen
Frequency: each semester
Contact Hours: 2,00

Contents:

- We will apply the concepts covered in each week's lecture to relevant biomedical data
- Exercises will be posted as Python Jupyter Notebooks that include tasks that need to be completed
- A virtual environment will be provided, but students are also encouraged to use their own setups

Assigned Courses:

Übung zu Advanced Biomedical Systems Modeling and Data Science (exercise course)

**(in attendance) **

Examination

Introduction to Biomedical Systems Modeling and Data Science

portfolio exam, graded

Test Frequency:

when a course is offered

Description:

The portfolio exam will consist of two parts:

- Practice/homework coding tasks: You will be able to largely complete those during the computer practice or at home.
- Written exam: Questions will cover the comprehension of the contents of the lectures.

Module INF-3829: Digital Biomarkers *Digital Biomarkers*	5 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr.-Ing Muthuraman Muthuraman
Manuel Bange

Learning Outcomes / Competences:
Fachbezogene Kompetenzen:

After attending the lecture, students will gain knowledge about selected digital biomarkers (e.g. bioimaging, kinetics, and kinematics) in medicine. They will acquire fundamental skills for developing and evaluating novel biomarkers based on forceplates and video based pose estimation and will understand the underlying requirements. Students will know the mechanisms of digital techniques for diagnostics and will develop the ability to analyze and interpret the data obtained. Furthermore, they will be equipped to contribute to the advancement and development of these procedures.

Methodische Kompetenzen:

Students can independently engage with the applications of digital biomarker tools from the domains of imaging, kinetics, and kinematics. They are capable of processing various measurement data using common scripting languages such as Matlab or Python and appropriately documenting and interpreting the application of methods for data analysis.

Fachübergreifende Kompetenzen:

The students are able to apply the acquired knowledge to any area of their studies that deals with diagnostically relevant data. Moreover, the module imparts essential problem-solving skills, teaching abstract thinking and a structured approach to problem-solving.

Key skills:

Skills in logical, analytical, and conceptual thinking; ability to present and document results understandably; skill in communicating effectively in writing and verbally in a situation-appropriate and audience-specific manner; ability to collaborate in teams; proficiency in problem-solving under practical conditions; capability to independently expand existing knowledge; awareness of quality.

Workload:
Total: 150 h
20 h studying of course content using literarture (self-study)
30 h studying of course content through exercises / case studies (self-study)
40 h preparation of written term papers (self-study)
30 h lecture (attendance)
30 h exercise course (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each summer semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Digital Biomarkers (Lecture)
Language: English
Frequency: each summer semester
Contact Hours: 2,00

Contents:

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

- Basics of imaging
- Basics of kinematic movement analysis
- Basics of kinetic movement analysis
- Selected applications in medicine (including various diseases and medical conditions)
- Introduction to basic and advanced methods for developing and validating Biomarkers

Part of the Module: Digital Biomarkers (Exercise)
Language: English
Frequency: each summer semester
Contact Hours: 2,00

Contents:

The exercise imparts practical skills in the context of the application of digital biomarkers. Furthermore, recent developments and novel biomarkers will be presented and discussed. The focus is on understanding the possible applications and relevant challenges of developing digital biomarkers. The following contents are covered:

- Presentation and discussion of selected applications in medicine (including various diseases and medical conditions)
- Handling of measurement data
- Validating biomarkers

Examination
Digital Biomarkers
portfolio exam, graded
Test Frequency:
when a course is offered

Module MTH-1488: Algebraic Geometry I *Algebraische Geometrie I*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: Im Rahmen der Vorlesung haben die Studenten gelernt, ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen anhand konkreter Probleme aus der algebraischen Geometrie anzuwenden. Daneben ist neben einem mathematischen auch ein gutes intuitives Verständnis für geometrische Konstuktionen wie den projektiven Raum, Faserbündel, Produkte und Aufblasungen erreicht worden.		
Remarks: Wer MTH-1480 oder MTH-1481 oder MTH-1482 bereits bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.		
Workload: Total: 240 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Geometrie I
Mode of Instruction: lecture, exercise course
Language: German
Contact Hours: 6,00

Contents:

- Algebraische Varietäten
- Rationale Äquivalenz
- Divisoren
- Vektorbündel und Chernsche Klassen
- Kegel und Segresche Klassen
- Schnittprodukte
- Schnittmultiplizitäten
- Schnitte nicht-singulärer Varietäten
- Dynamisches Schnittverhalten
- Graßmannsche Varietäten
- Riemann-Rochscher Satz für nicht-singuläre Varietäten
- Bivariante Schnitttheorie
- Riemann-Rochscher Satz für singuläre Varietäten

Literature:

- W. Fulton: Intersection Theory. Springer-Verlag.
- I. Shafarevich: Basic Algebraic Geometry (I + II). Springer-Verlag.

Examination

Algebraische Geometrie

portfolio exam, graded

Test Frequency:

each semester

Description:

Eine Prüfungsanmeldung und eine Prüfung zu diesem Modul kann in jedem Semester erfolgen. In den Semestern, in denen die zugehörige Veranstaltung nicht stattfindet, werden die Kompetenzen abweichend in einer mündlichen Prüfung geprüft.

Module MTH-1489: Algebraic Geometry II

Algebraische Geometrie II

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:
Im Rahmen der Vorlesung haben die Studenten gelernt, ihr im Bachelorstudium im Bereich der Algebra erworbenes Wissen anhand konkreter Probleme aus der algebraischen Geometrie anzuwenden. Daneben ist neben einem mathematischen auch ein gutes intuitives Verständnis für geometrische Konstuktionen wie den projektiven Raum, Faserbündel, Produkte und Aufblasungen erreicht worden.

Remarks:
Wer MTH-1480 oder MTH-1481 oder MTH-1482 bestanden hat, kann für dieses Modul nicht zugelassen werden: die Inhalte sind identisch.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Geometrie II
Mode of Instruction: lecture + exercise
Language: German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:

- Algebraische Varietäten
- Rationale Äquivalenz
- Divisoren
- Vektorbündel und Chernsche Klassen
- Kegel und Segresche Klassen
- Schnittprodukte
- Schnittmultiplizitäten
- Schnitte nicht-singulärer Varietäten
- Dynamisches Schnittverhalten
- Graßmannsche Varietäten
- Riemann-Rochscher Satz für nicht-singuläre Varietäten
- Bivariante Schnitttheorie
- Riemann-Rochscher Satz für singuläre Varietäten

Literature:

W. Fulton: Intersection Theory. Springer-Verlag.
I. Shafarevich: Basic Algebraic Geometry (I + II). Springer-Verlag.

Examination

Algebraische Geometrie II

oral exam, graded

Test Frequency:

each semester

Description:

Die genauen Prüfungsmodalitäten werden am Anfang der Vorlesung bekannt gegeben.

Module MTH-1518: Riemannian Geometry *Riemannsche Geometrie*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke	

Contents:

What is the geometry of our space? Euclidean? But how are we to know whether two parallels behind the next bush still have the same distance? How are we to judge geometry on a large scale, even in outer space, when we can hardly move away from our patch of earth? Riemannian geometry introduces a concept flexible enough to describe a geometry that looks locally Euclidean, but about whose global structure we may have no knowledge. The distinguishing feature from Euclidean geometry is curvature, the most important concept in this theory. We will study this geometry in small and large scale. Naturally, we will also cover the basics of Einstein's General Relativity, in which the geometry of space and time is coupled with the mass distribution in the universe.

Submanifolds of Euclidean space
Covariant derivative (Levi-Civita derivative)
Curvature
General relativity
Geodesics in the small and large
Completeness
Role of curvature for topology

Learning Outcomes / Competences:

Combining geometric thinking with analytical methods, understanding the interrelationships of local and global geometry.

Workload:

Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: Introduction to Geometry		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Riemannsche Geometrie

Language: English
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

Literature:

J.-H. Eschenburg, J. Jost: Differentialgeometrie und Minimalflächen. Springer, 2007.
W. Kühnel: Differentialgeometrie. Vieweg, 1999.
S.Gallot, D.Hulin, J.Lafontaine: Riemannian Geometry. Springer, 1990.
J. Jost: Riemannian Geometry and Geometric Analysis. Springer, 2008.
M. Do Carmo: Riemannian Geometry. Birkhäuser, 1992.
D.Gromoll, W.Klingenberg, W.Meyer: Riemannsche Geometrie im Großen. Springer LN 55, 1975.

Examination

Riemannian Geometry

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-1528: Differential Topology *Differentialtopologie*	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Bernhard Hanke	

Contents:

This lecture is devoted to the theory of differentiable manifolds from the point of view of analysis and topology. The material covered is fundamental for a deeper understanding of differential geometry and global analysis.

Differentiable manifolds
Tangent space
Flows
Foliations
Fiber bundles
Transversality
de Rham cohomology
Chern-Weil theory
exotic spheres
H-Cobordism Theorem

Learning Outcomes / Competences:

Development and training of geometrical intuition while mastering modern mathematical language and reasoning. Understanding of the basic concepts of differential topology. Development of basic knowledge for special lectures in geometry and topology.

Remarks:

Cannot be combined together with MTH-1520.

Workload:

Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: Knowledge to elementary geometry and topology		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Differential Topology

Language: German / English
Frequency: every 4th semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:

-

Literature:

R. Bott, L. Tu: Differential Forms in Algebraic Topology. GTM Springer.
L. Conlon: Differentiable Manifolds - A First Course. Birkhäuser.
M. Hirsch: Differential Topology. GTM Springer.
J. Milnor: Topology from the Differentiable Viewpoint. Princeton University Press.
J. Milnor: Lectures on the H-Cobordism Thereom. Princeton University Press.

Assigned Courses:

Differential Topology (lecture + exercise)
**(in attendance) **

Examination

Differential Topology
portfolio exam / length of examination: 30 minutes, graded

Test Frequency:
this semester

Module MTH-1538: Algebraic Topology *Algebraische Topologie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Bernhard Hanke		
Contents: This module provides an introduction to algebraic topoolgy, that is, the systematic use of algebraic tools in the study of topological problems. Mathematical content includes: Fundamental group, covering spaces, categories, cellular complexes, cellular and singular homology and cohomology, homotopy theory, fiber bundles.		
Learning Outcomes / Competences: Students will be able to use algebraic tools that allow them to translate geometric notion into exact arguments.		
Remarks: Dieses Modul kann nicht gleichzeitig mit MTH-1530 eingebracht werden		
Workload: Total: 240 h		
Conditions: Basic knowledge in algebra and geometry.		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Topologie I
Language: English / German
Contact Hours: 6,00

Contents:

Dieses Modul bietet eine Einführung in die Algebraische Topoolgie, also die systematische Nutzung algebraischer Hilfsmittel beim Studium topologischer Fragestellungen.

Mathematische Inhalte sind unter anderem: Fundamentalgruppe, Überlagerungen, Kategorien, Zellkomplexe, zelluläre und singuläre Homologie und Kohomologie, Homotopietheorie, (Ko-)Faserungen

Lehr-/Lernmethoden:

Vorlesung und Übung

Literature:

Bredon, G.E.: Topology and Geometry, vol. 139, Graduate Texts in Mathematics. Springer-Verlag, 1993.

Dold, A.: Lectures on Algebraic Topology, vol. 200. Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen, Springer-Verlag, 1972.

Spanier, E.: Algebraic Topology. McGraw-Hill, 1966.

May, J.P.: A Concise Course in Algebraic Topology, University of Chicago Press, 1999.

Assigned Courses:

Algebraische Topologie (lecture + exercise)
**(in attendance) **

Examination

Algebraische Topologie

portfolio exam, graded

Test Frequency:

this semester

Module MTH-1548: Calculus of Variations

Variationsrechnung

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Bernd Schmidt

Learning Outcomes / Competences:
Die Student(inn)en kennen klassische Herangehensweisen sowie moderne Zugänge zu Problemen der Variationsrechnung. Sie sind in der Lage, theoretische Modelle naturwissenschaftlicher Probleme in einfachen Fällen selbst zu formulieren, solche Modelle aber auch in komplexen Situationen zu verstehen und problemorientiert zu analysieren.

Remarks:
Kann nicht gemeinsam mit MTH-1540 eingebracht werden

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: none		**Credit Requirements:** Solide Analysiskenntnisse, die die wesentlichen Inhalte der Vorlesungen Analysis 1, 2 und 3 sowie der Funktionalanalysis abdecken.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Variationsrechnung
Language: English / German
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
klassische Probleme der Variationsrechnung, Euler-Lagrange-Gleichungen, Funktionenraeume, (semi-)konvexe Analysis, direkte Methode der Variationsrechnung, Anwendungen
Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung sowie der Grundlagen der Funktionalanalysis.

Literature:
Dacorogna: Direct Methods in the Calculus of Variations. Springer.

Assigned Courses:

Variationsrechnung (lecture + exercise)
**(in attendance) **

Examination

Variationsrechnung

portfolio exam, graded

Test Frequency:

this semester

Module MTH-1558: Nonlinear Partial Differential Equations

Nichtlineare partielle Differentialgleichungen

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Bernd Schmidt

Learning Outcomes / Competences:
Die Student(inn)en kennen moderne Zugänge zu ausgewählten Beispielklassen in der Theorie der partiellen Differentialgleichungen. Sie sind in der Lage, aufbauend auf den Inhalten der Vorlesung Forschungsliteratur in diesen Gebieten zu lesen und sich selbstständig in weiterführende Aspekte einzuarbeiten.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:	**Credit Requirements:**
none	Solide Analysiskenntnisse, die die wesentlichen Inhalte der Vorlesungen Analysis 1, 2 und 3 sowie der Funktionalanalysis abdecken. Es wird dringend empfohlen, eine einführende Veranstaltung zu partiellen Differentialgleichungen gehört zu haben.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nichtlineare Partielle Differentialgleichungen
Language: English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Ausgewählte Aspekte der Theorie der Nichtlinearen Partiellen Differentialgleichungen

Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung, Funktionalanalysis sowie der schwachen Lösungtheorie linearer elliptischer Gleichungen.

Literature:
* Gilbarg, D., Trudinger, N.S.: Elliptic Partial Differential Equations of Second Order (Springer, 1977)

* Giusti, E.: Direct Methods in the Calculus of Variations (World Scientific Publishing, 2003)

* Giaquinta, M., Martinazzi, L.: An Introduction to the Regularity Theory for Elliptic Systems, Harmonic Maps and Minimal Graphs (Edizioni della Normale, 2012,

* Evans, L.C.: Partial Differential Equations (AMS, 1998),

* Renardy, M., Rogers, R.C.: An Introduction to Partial Differential Equations (Springer, 1993),

* Schweizer, B.: Partielle Differentialgleichungen (Springer, 2013)

Examination

Nichtlineare Partielle Differentialgleichungen

oral exam / length of examination: 25 keine Einheit gewählt, graded

Test Frequency:

not this semester

Module MTH-1568: Stochastic Differential Equations

Stochastische Differentialgleichungen

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
This module introduces the theory of stochastic differential equations.
Ito formula, Ito isometry, Ito integral, martingales, Brownian motion, existence and uniqueness theorem, diffusion processes, partial differential equations, Black-Scholes formula, Option pricing

Learning Outcomes / Competences:
The students know the fundamental terms, concepts and phenomena of stochastic
of stochastic analysis, especially of stochastic differential equations.
Ability to independently compile further literature
for applications in the field of financial mathematics and stochastic dynamics,
Competences in the independent processing of problems,
Skills in the formulation and processing of theoretical questions using the
theoretical questions with the help of the methods learned
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
Scientific thinking, in-depth competences in the independent processing of problems, skills in formulating and processing theoretical questions.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
A good basic knowledge of probability theory and analysis is required.
and calculus.
Helpful, but not absolutely necessary, is previous knowledge of
in ordinary differential equations
and stochastic processes.

Credit Requirements:
Oral exam

Frequency: each summer semester	**Recommended Semester:** 1. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Stochastische Differentialgleichungen
Mode of Instruction: lecture
Lecturers: Prof. Dr. Dirk Blömker
Language: English
Frequency: each summer semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:

This module introduces the theory of stochastic differential equations.
Ito formula, Ito isometry, Ito integral, martingales, Brownian motion, existence and uniqueness theorem, diffusion processes, partial differential equations, Black-Scholes formula, Option pricing

Literature:

Oksendal: Stochastic Differential Equations. Springer.
Karatzas Shreve: Brownian Motion and Stochastic Calculus. Springer.
Evans: An Introduction to Stochastic Differential Equations.
Steele: Stochastic Calculus and Financial Applications. Springer.

Examination

Stochastische Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

each semester

Module MTH-1578: Dynamical Systems *Dynamische Systeme*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Dirk Blömker	
Contents: among others: dynamical systems, attractors, invariant manifolds, semi-flows, Markov semigroups, invariant measures, iterated mappings, chaos	
Learning Outcomes / Competences: The students know the basic terms, concepts and phenomena in the field of in the field of dynamical systems. Ability to work independently on further literature, Competences in the independent processing of problems, Skills to formulate and work on theoretical questions using the questions with the aid of the methods learnt. Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, scientific thinking, in-depth competences in the independent processing of problems, Skills in formulating and working on theoretical questions.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: Good knowledge of linear algebra and analysis. Basic knowledge of functional analysis and differential equations is helpful.	**Credit Requirements:** oral exam

Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Dynamische Systeme

Mode of Instruction: lecture
Language: English
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
among others: dynamical systems, attractors, invariant manifolds, semi-flows, Markov semigroups, invariant measures, iterated mappings, chaos

Examination

Dynamische Systeme
oral exam / length of examination: 30 minutes, graded
Test Frequency:
this semester

Module MTH-1588: Control Theory

Kontrolltheorie

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Tatjana Stykel

Learning Outcomes / Competences:
Förderung von abstraktem Denken, Anwenden analytischer und geometrischer Methoden im Anwendungszusammenhang. Die Studenten sollen in einem mathematisch relativ einfachen, linearen Kontext die grundlegenden Fragestellungen der Kontrolltheorie und Konzepte zu deren Lösung lernen. Ferner sollen sie die Befähigung zum selbständigen Erarbeiten der aktuellen Forschungsliteratur erwerben.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
none

Frequency:	Recommended Semester:	Minimal Duration of the Module:
	1. - 4.	1 semester[s]

Contact Hours:	Repeat Exams Permitted:
6,00	any

Parts of the Module

Part of the Module: Kontrolltheorie
Language: German
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Dieses Modul führt in die mathematische Kontrolltheorie ein.

- Lineare Steuerungssysteme
- Steuerbarkeit und Beobachtbarkeit
- Rekonstruierbarkeit und Beobachtbarkeit
- Stabilität
- Stabilisierbarkeit und Entdeckbarkeit
- Polvorgabe
- Linear-quadratisches Optimierungsproblem

Voraussetzungen: Kenntnisse in Analysis auf endlich dimensionalen Räumen, gewöhnliche Differentialgleichungen, Numerik

Literature:
Knobloch, H.W., Kwakernaak, H. Lineare Kontrolltheorie. Springer, 1985

Sontag, E.: Mathematical Control Theory. Springer, 1998.

Hinrichsen, D., Pritchard, A.J.: Mathematical Systems Theory I. Springer, 2005.

Examination

Kontrolltheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1598: Numerical Analysis of Partial Differential Equations

Numerik partieller Differentialgleichungen

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Daniel Peterseim

Learning Outcomes / Competences:
Understanding of finite differences as well as the ideas of the finite element method generally as well as construction of Lagrange elements with respect to simplicial triangulations and a posteriori error estimation for elliptic problems; convergence results, connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.

Remarks:
Kann nicht mit MTH-1590 gemeinsam eingebracht werden

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Recommended: analysis (particularly functional analysis), introduction to numerical analysis, numerical analysis of ordinary differential equations

Frequency: each winter semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik partieller Differentialgleichungen

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Malte Peter
Language: English / alle Sprachen
Frequency: each winter semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Es werden die Grundlagen der Standardmethoden zur numerischen Lösung partieller Differentialgleichungen behandelt.

Finite-Differenzen-Methode auf rechteckigen und nicht rechteckigen Gebieten
Finite-Elemente-Methode inkl. Triangulierung
Lagrange-Elemente
Adaptivität für elliptische Probleme

Literature:
Grossmann, C., Ross, H.-G.: Numerische Behandlung partieller Differentialgleichungen. Teubner, 2005 .
Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen. Springer. 2010

Assigned Courses:

Numerik partieller Differentialgleichungen (lecture + exercise)

*(in attendance) *

Partial differential equations (PDEs) describe processes in continua, such as wave propagation, diffusion, and advection. They are used to construct models of the most basic theories underlying physics and engineering. However, in many interesting cases, PDEs are difficult to solve analytically and have to be approximated numerically. The course gives an introduction to some classes of PDEs and the corresponding finite element type methods for their numerical simulation. Among the target applications are heat conduction, viscous fluid flow and acoustic scattering. Depending on the particular problem, the lecture will discuss the algorithms and the mathematics that underlie the numerical methods as well as their practical implementation.

Examination

Numerik partieller Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

only in the winter semester

Module MTH-1608: Multiscale Methods

Multiskalenmethoden

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Malte Peter

Learning Outcomes / Competences:
Deeper understanding of the finite element method in its most important versions; connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; understanding of the problems arising from multiple scales as well as basic solution ideas; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:
none

Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Multiskalenmethoden
Mode of Instruction: lecture + exercise
Language: English / German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Aufbauend auf grundlegende Inhalte der Module Numerik partieller Differentialgleichungen bzw. Methoden der finiten Elemente werden weiterführende Aspekte der Finite-Elemente-Methode behandelt, insbesondere im Hinblick auf Multiskalenprobleme.
Finite-Elemente-Methode und parabolische Gleichungen
Discontinuous Galerkin Method
Einführung in Multiskalenprobleme
Multiskalen-Finite-Elemente-Methode
Voraussetzungen: Es wird empfohlen, die mit dem erfolgreichen Absolvieren einer der Module "Numerik partieller Differentialgleichungen" oder "Finite Elemente Methoden" einhergehenden Kompetenzen erworben zu haben.

Literature:
C. Grossmann, H.-G. Roos: Numerische Behandlung partieller Differentialgleichungen. Teubner.
Y. Efendiev, T. Y. Hou: Multiscale Finite Element Methods. Springer.

Examination

Multiskalenmethoden

module exam, mündliche Prüfung / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1618: Mathematical Modelling *Mathematische Modellierung*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Understanding of describing real-world processes in terms of mathematical objects; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Remarks: Kann nicht gemeinsam mit MTH-1610 eingebracht werden		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematische Modellierung
Mode of Instruction: lecture + exercise
Language: English / alle Sprachen
Frequency: irregular
Contact Hours: 6,00

Assigned Courses:

Mathematische Modellierung (lecture + exercise)
**(in attendance) **

Examination
Mathematische Modellierung
oral exam / length of examination: 25 minutes, graded
Test Frequency:
this semester

Module MTH-1628: Combinatorial Optimisation (Optimisation III) *Kombinatorische Optimierung (Optimierung III)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Mirjam Dür		
Remarks: Dieses Modul kann nicht gemeinsam mit MTH-1620		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Module Introduction to Optimisation (MTH-1140) - recommended Module Introduction to Nonlinear and Combinatorial Optimisation (MTH-1200) - recommended		
Frequency: each summer semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Kombinatorische Optimierung (Optimierung III)
Mode of Instruction: lecture
Language: German
Frequency: each summer semester
Contact Hours: 6,00

Contents:

In dieser Vorlesung geht es um folgende Themen der diskreten Optimierung:

- Komplexität und Algorithmen
- Matchings
- Flüsse und Netzwerke
- Kostenminimale Flüsse
- Approximationsalgoritmen

Examination

Kombinatorische Optimierung (Optimierung III)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

only in the summer semester

Module MTH-1658: Discrete Mathematics (Optimisation IV) *Diskrete Mathematik (Optimierung IV)*	8 ECTS/LP
Version 1.0.0 Person responsible for module: apl. Prof. Dr. Dirk Hachenberger	
Contents: Ergänzung zur Vorlesung Kombinatorische Optimierung aus dem Sommersemester, insbesondere sollen voraussichtlich folgende Themen behandelt werden: NP-Vollständigkeit, Matroide, Zirkulationen und Flüsse minimaler Kosten, Netzwerk-Simplex-Algorithmus	
Learning Outcomes / Competences: Die Studierenden sollen anhand fortgeschrittener Fragestellungen vertiefte Kenntnisse über diskrete Optimierungsprobleme erwerben. Insbesondere soll die Interaktion von allgemeinen theoretischen Ansätzen und konkreten Problemen auf einem höheren Abstraktionsniveau erfasst werden.	
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: Module Introduction to Optimisation (MTH-1140) - recommended Module Introduction to Nonlinear and Combinatorial Optimisation (MTH-1200) - recommended Module Combinatorial Optimisation (Optimisation III) (MTH-1620) - recommended	

Frequency: as needed	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Diskrete Mathematik (Optimierung IV)

Mode of Instruction: lecture
Language: German
Frequency: as needed
Contact Hours: 6,00

Learning Outcome:

Die Studierenden sollen anhand fortgeschrittener Fragestellungen vertiefte Kenntnisse über diskrete Optimierungsprobleme erwerben. Insbesondere soll die Interaktion von allgemeinen theoretischen Ansätzen und konkreten Problemen auf einem höheren Abstraktionsniveau erfasst werden.

Contents:

Ergänzung zur Vorlesung Kombinatorische Optimierung aus dem Sommersemester, insbesondere sollen voraussichtlich folgende Themen behandelt werden: NP-Vollständigkeit, Matroide, Zirkulationen und Flüsse minimaler Kosten, Netzwerk-Simplex-Algorithmus

Literature:

Jungnickel, D.: Graphs, Networks and Algorithms, 4th edition (English), Springer, 2013.

Examination

Diskrete Mathematik (Optimierung IV)

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1668: Mathematical Statistics

Mathematische Statistik (Stochastik III)

8 ECTS/LP

Version 1.1.0
Person responsible for module: Prof. Dr. Sarah Friedrich-Welz

Contents:
Auswahl aus fortgeschrittenen Themen der Statistik, z.B.

nichtparametrische Methoden (z.B. Kerndichteschätzer), lineare Modelle, Markov-Ketten,
Bayessche Statistik
oder
Zeitreihenmodelle, ARMA-Prozesse, Parameter-Schätzung bei abhängigen Daten, Zustandsraum-Modelle

Learning Outcomes / Competences:
Verständnis der mathematischen Grundlagen bei den unter „Inhalte“ genannten fortgeschrittenen Themen der Statistik; Fähigkeit, Daten mit Hilfe von geeigneten Modellen zu analysieren und zu interpretieren; Kenntnisse von wichtigen statistischen Modellen und Schätzverfahren

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Einführung in die Stochastik (Stochastik I) / Stochastik II

Lineare Algebra I und Analysis I und II

Frequency: each winter semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Statistische Modelle und Verfahren (Stochastik III)
Language: German
Frequency: each winter semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Learning Outcome:
Verständnis der mathematischen Grundlagen bei den unter „Inhalte“ genannten fortgeschrittenen Themen der Statistik; Fähigkeit, Daten mit Hilfe von geeigneten Modellen zu analysieren und zu interpretieren; Kenntnisse von wichtigen statistischen Modellen und Schätzverfahren

Contents:
Auswahl aus fortgeschrittenen Themen der Statistik, z.B.

nichtparametrische Methoden (z.B. Kerndichteschätzer), lineare Modelle, Markov-Ketten,
Bayessche Statistik
oder
Zeitreihenmodelle, ARMA-Prozesse, Parameter-Schätzung bei abhängigen Daten, Zustandsraum-Modelle

Literature:

Themenabhängig - wird in der Vorlesung bekanntgegeben

Assigned Courses:

Mathematische Statistik (Stochastik III) (lecture + exercise)

**(in attendance) **

Auswahl aus fortgeschrittenen Themen der Statistik, z.B. nichtparametrische Methoden (z.B. Kerndichteschätzer), lineare Modelle, Markov-Ketten, Bayessche Statistik oder Zeitreihenmodelle, ARMA-Prozesse, Parameter-Schätzung bei abhängigen Daten, Zustandsraum-Modelle

Examination

Statistische Modelle und Verfahren (Stochastik III)

written exam / length of examination: 90 minutes, graded

Test Frequency:

this semester

Module MTH-1678: Stochastic Processes

Stochastische Prozesse (Stochastik IV)

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Stefan Großkinsky

Learning Outcomes / Competences:
Die Studierenden sollen die nötigen mathematischen Konzepte zur Beschreibung zufälliger, zeitabhängiger Prozesse verstehen und mit ihnen umgehen können. Darüber hinaus sollen sie wichtige Beweiskonzepte und Konstruktionen aus dem Bereich der stochastischen Prozesse beherrschen.

Remarks:
Kann nicht gemeinsam mit MTH-1670 eingebracht werden

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:
Lineare Algebra I
Analysis I
Analysis II
Einführung in die Stochastik (Stochastik I)
Einführung in die mathematische Statistik (Stochastik II)

Frequency: each summer semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Prozesse (Heydenreich)

Lecturers: Prof. Dr. Markus Heydenreich
Language: English / German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:

Es werden folgende Kernthemen behandelt:

1. Strenge Einführung des Begriffs "Stochastischer Prozess" und "Stochastisches Feld" mit Beispielen.
2. Pfadeigenschaften der Stochastischen Prozesse.
3. Gaußsche Prozesse, Lévy-Prozesse.
4. Brownsche Bewegung und ihre Eigenschaften.
5. Poisson-Prozess.
6. Irrfahrten und Konvergenz gegen Brownsche Bewegung.

Literature:

Wird in der Vorlesung bekannt gegeben.

Part of the Module: Stochastische Prozesse (Großkinsky)
Lecturers: Prof. Dr. Stefan Großkinsky
Language: English / German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
- Prozesse in diskreter Zeit: Markov Ketten, Gaußsche Prozesse, Martingale
- Konstruktion stochastischer Prozesse nach Kolmogorov und Pfadeigenschaften
- Erneuerungsprozesse, Poisson Prozess, Markov Ketten in stetiger Zeit
- Diffusionsprozesse, Brownsche Bewegung
- Sprungprozesse, Lévy Prozesse

Literature:
Wird in der Vorlesung bekannt gegeben.

Examination
Stochastische Prozesse (Stochastik IV)
oral exam / length of examination: 30 minutes, graded
Test Frequency:
each semester

Module MTH-1688: Optimisation IV (Global Optimisation)

Optimierung IV (Globale Optimierung)

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Mirjam Dür

Learning Outcomes / Competences:
Nach der Teilnahme an diesem Modul verfügen die Studierenden über detailliertes und aktuelles Wissen auf dem Gebiet der Globalen Optimierung. Sie können Problemstellungen und Ergebnisse des Gebiets präzise beschreiben und diskutieren. Darüber hinaus verstehen die Studierenden grundlegende Konzepte, Methoden, Verfahren und Techniken aus dem genannten Gebiet und können diese in Entwicklungsprojekten anwenden und dort aktiv mitarbeiten. Außerdem verfügen sie über die Team- und Kommunikationsfähigkeit, um Problemstellungen auf dem Gebiet zu erörtern, Fragen und Zwischenergebnisse zu diskutieren und zu präsentieren.

Workload:
Total: 240 h

Conditions:
- Modul Einführung in die Optimierung (Optimierung I) (MTH-1140) - empfohlen
- Modul Nichtlineare und kombinatorische Optimierung (Optimierung II) (MTH-1200) - empfohlen
- Modul Kombinatorische Optimierung (Optimierung III) (MTH-1620) - empfohlen

Credit Requirements:
Bestehen der Modulprüfung

Frequency: irregular (usu. winter semester)	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Globale Optimierung (Optimierung IV)

Lecturers: Prof. Dr. Mirjam Dür
Language: German
Frequency: irregular (usu. winter semester)

Contents:
- Konvexe Relaxierungen und konvexe Hüllfunktionale
- D.C. Funktionen
- Quadratische Optimierungsprobleme
- Branch-and-Bound für boxrestringierte Probleme
- Branch-and-Bound für konvex restringierte Probleme
- Branch-and-Bound für nichtkonvexe Probleme
- Heuristiken

Literature:

- O.Stein: Grundzüge der Globalen Optimierung. Springer Verlag 2018
- M.Locatelli, F.Schoen: Global Optimization. SIAM 2013
- R.Horst, P.Pardalos, N.V.Thoai: Introduction to Global Optimization. Kluwer Academic Publishers 1995

Assigned Courses:

Globale Optimierung (Optimierung IV) (lecture + exercise)
**(in attendance) **

Examination

Globale Optimierung (Optimierung IV)

module exam, Der konkrete Typ der Modulprüfung (Klausur oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben., graded

Test Frequency:

this semester

Module MTH-1698: Parabolic Partial Differential Equations *Parabolische partielle Differentialgleichungen*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Dirk Blömker	
Contents: selected topics in parabolic PDEs, existence and uniqueness of solutions, energy estimates, dynamics	
Learning Outcomes / Competences: The students know modern approaches to selected example classes in the theory of parabolic partial differential equations. They are able to read research literature in these areas based on the contents of the lecture and to work independently on further aspects.	
Workload: Total: 240 h	
Conditions: Prerequisites: Solid knowledge of multidimensional differential and integral calculus, functional analysis. Knowledge of ordinary differential equations or the weak solution theory of linear elliptic equations is helpful.	**Credit Requirements:** oral exam

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Parabolische partielle Differentialgleichungen

Language: English
Frequency: irregular
Contact Hours: 6,00

Contents:

Voraussetzungen: Solide Kenntnisse der mehrdimensionalen Differential- und Integralrechnung, Funktionalanalysis. Hilfreich sind Kenntnisse in gewöhnlichen Differentialgleichungen oder der schwachen Lösungtheorie linearer elliptischer Gleichungen.

Examination

Parabolische partielle Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1788: Stochastic Modelling of Complex Systems

Stochastische Modellierung komplexer Systeme

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Stefan Großkinsky

Learning Outcomes / Competences:
Verständnis von mathematischen Konzepten in der stochastischen Modellierung, insbesondere für komplexe Systeme aus vielen wechselwirkenden Bestandteilen.

Studierende erlernen wie ein Anwendungsbeispiel mathematisch beschrieben werden kann, sowie wichtige Techniken für die deren theoretische und numerische Analyse.

Besonders wichtig ist das Verständnis von Skalenlimiten in großen Systemen, das asymptotische Verhalten und mögliche Phasenübergänge in komplexen Systemen.

Workload:
Total: 240 h

Conditions:		**Credit Requirements:**
Wahrscheinlichkeits- und Maßtheorie		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Modellierung komplexer Systeme
Language: English / German
Contact Hours: 6,00

Contents:

1. Kurze Wiederholung/Einführung von Markov Prozessen in stetiger Zeit als Zufallsvariablen auf dem Pfadraum.
2. Beschreibung von Feller Markov Prozessen durch Halbgruppen und Generatoren auf dem Raum der stetigen Testfunktionen. Beispiele: Markov-Ketten, Diffusionspozesse, Sprungprozesse, Lévy Prozesse.
3. Charakterisierung von Markov Prozessen durch Martingalprobleme, Formeln von Dynkin, Itô, Feynman-Kac und Girsanov.
4. Stochastische Interagierende Teilchensysteme (IPS) als Modelle komplexer Systeme und als Feller Prozesse: Spin-systeme, Votermodell, Kontaktprozess, Exklusions- und Inklusionspozess, Zero-range Prozess.
5. Charakterisierung von stationären Verteilungen, Reversibilität, Erhaltungssätze und Symmetrien. Theorie der Phasenübergänge. Als wichtige Tools führen wir Dualität und Kopplung ein.
6. Hydrodynamische Grenzwertsätze, die das Verhalten von IPS auf großen Skalen durch PDEs oder ODEs beschreiben im Sinne eines funktionalen GGZ.
7. Funktionaler ZGS zur Beschreibung der Fluktuationen, z.B. Donskers Invarianzprinzip für Brownsche Bewegung und Ornstein-Uhlenbeck Prozesse.
8. Große Abweichungen für Markov Prozesse.

Assigned Courses:

Stochastic modelling of complex systems (lecture + exercise)
**(in attendance) **
For all info see "Practical Info and Content"

Examination

Stochastische Modellierung komplexer Systeme

oral exam / length of examination: 30 minutes, graded

Test Frequency:

this semester

Module MTH-1860: Introduction to Projective Geometry *Einführung in die Projektive Geometrie*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger		
Contents: Die Projektive Geometrie ist eines der klassischen Teilgebiete der Reinen Mathematik. Dieses Gebiet ist ursprünglich aus Fragen der Perspektive entstanden und kann heutzutage kurz als "Lineare Algebra vom geometrischen Standpunkt aus gesehen" bezeichnet werden. Alle notwendigen geometrischen Begriffe werden in der Vorlesung entwickelt werden. Neben den klassischen Fragestellungen (Einführung von Koordinaten, Kollineationen, Projektivitäten, Kegelschnitte und Quadriken...) sollen insbesondere die endlichen projektiven Räume behandelt werden. Diese Strukturen haben durch Bezüge zu Designs, Codes und Kryptosystemen neuerdings auch eine gewisse Bedeutung in den Anwendungen erlangt. Einige derartige Aspekte sollen ebenfalls angesprochen werden.		
Learning Outcomes / Competences: Erkenntnis der engen Verflechtung von Algebra und Geometrie; Mathematische Allgemeinbildung (Einblick in eines der klassischen Gebiete der Mathematik, das derzeit im Studium fast immer zu kurz kommt.		
Workload: Total: 180 h 4 h lecture (attendance)		
Conditions: Module Linear Algebra I (MTH-1000) - recommended Module Linear Algebra II (MTH-1010) - recommended		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Projektive Geometrie
Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Learning Outcome:
Erkenntnis der engen Verflechtung von Algebra und Geometrie; Mathematische Allgemeinbildung (Einblick in eines der klassischen Gebiete der Mathematik, das derzeit im Studium fast immer zu kurz kommt.

Contents:

Die Projektive Geometrie ist eines der klassischen Teilgebiete der Reinen Mathematik. Dieses Gebiet ist ursprünglich aus Fragen der Perspektive entstanden und kann heutzutage kurz als "Lineare Algebra vom geometrischen Standpunkt aus gesehen" bezeichnet werden. Alle notwendigen geometrischen Begriffe werden in der Vorlesung entwickelt werden. Neben den klassischen Fragestellungen (Einführung von Koordinaten, Kollineationen, Projektivitäten, Kegelschnitte und Quadriken...) sollen insbesondere die endlichen projektiven Räume behandelt werden. Diese Strukturen haben durch Bezüge zu Designs, Codes und Kryptosystemen neuerdings auch eine gewisse Bedeutung in den Anwendungen erlangt. Einige derartige Aspekte sollen ebenfalls angesprochen werden.

Voraussetzungen: Lineare Algebra I

Lineare Algebra II

Literature:

Beutelspacher, A., Rosenbaum, U.: Projektive Geometrie. Von den Grundlagen bis zu den Anwendungen. Wiesbaden, 1992.

Lenz, H.: Vorlesungen über die projektive Geometrie. Leipzig, 1965.

Examination

Einführung in die Projektive Geometrie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1900: Introduction to Cryptography

Einführung in die Kryptographie

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Contents:
Die Kryptographie ist dasjenige Teilgebiet der Mathematik, das sich mit der sicheren Übermittlung geheim zu haltender Nachrichten bzw. umgekehrt mit der Analyse verschlüsselter Texte beschäftigt. Derartige Themenbereiche sind von zunehmender wirtschaftlicher Bedeutung (Electronic Banking). Dabei ergeben sich viele interessante Fragestellungen wie z.B. die Möglichkeit von elektronischen Unterschriften und Zeitstempeln sowie Fragen der Authentifikation und Zugangskontrolle. In der Vorlesung soll eine Einführung in die wichtigsten Probleme und Methoden der Kryptographie gegeben werden. Nach einer kurzen historischen Einleitung werden auch einige praktisch verwendete Systeme (DES, AES, RSA-System) behandelt.

Learning Outcomes / Competences:
Algebra, Zahlentheorie und Kombinatorik sind klassische Kerngebiete der Reinen Mathematik. Die Studenten sollen an einem konkreten Beispiel erkennen, dass auch diese Teile der Mathematik praktisch relevante Anwendungen hat.

Workload:
Total: 180 h
4 h lecture (attendance)

Conditions:
Als Voraussetzungen werden lediglich die Grundvorlesungen in Linearer Algebra I und II sowie elementare Wahrscheinlichkeitstheorie benötigt.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Kryptographie
Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Die Kryptographie ist dasjenige Teilgebiet der Mathematik, das sich mit der sicheren Übermittlung geheim zu haltender Nachrichten bzw. umgekehrt mit der Analyse verschlüsselter Texte beschäftigt. Derartige Themenbereiche sind von zunehmender wirtschaftlicher Bedeutung (Electronic Banking). Dabei ergeben sich viele interessante Fragestellungen wie z.B. die Möglichkeit von elektronischen Unterschriften und Zeitstempeln sowie Fragen der Authentifikation und Zugangskontrolle. In der Vorlesung soll eine Einführung in die wichtigsten Probleme und Methoden der Kryptographie gegeben werden. Nach einer kurzen historischen Einleitung werden auch einige praktisch verwendete Systeme (DES, AES, RSA-System) behandelt.
Voraussetzungen: Als Voraussetzungen werden lediglich die Grundvorlesungen in Linearer Algebra I und II sowie elementare Wahrscheinlichkeitstheorie benötigt. Auch wenn es sich um keine Pflichtvorlesung handelt, ist die Vorlesung insbesondere auch den Studenten der Wirtschaftsmathematik sehr zu empfehlen.

Literature:
Stinson, D.: Cryptography: Theory and Practice (Discrete Mathematics and its Applications).

Examination

Einführung in die Kryptographie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1928: Nonlinear Control Theory *Nichtlineare Kontrolltheorie*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Fritz Colonius		
Learning Outcomes / Competences: Vertiefte Einsicht in die geometrische Interpretation von kontrolltheoretischen Objekten und Konzepten, die hier nichtlinearen Charakter haben und differentialgeometrische Methoden erfordern. Die Studenten sollen in die Lage versetzt werden, diese Strukturen im Anwendungszusammenhang (hier. in der Regelungstheorie) selbständig zu erkennen und die in der Veranstaltung behandelten Methoden einzusetzen. Darüber hinaus sollen sie in die Lage versetzt werden., aktuelle Forschungsliteratur selbständig zu erarbeiten.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nichtlineare Kontrolltheorie

Language: German
Frequency: each semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Dieses Modul bietet eine Einführung in die Theorie Nichtlinearer Kontrollsysteme
Akzessibilität und Lie-algebraische Bedingungen
Kontrollmengen
Beziehungen zur Theorie dynamischer Systeme
Voraussetzungen:

Literature:
Sastry: Nonlinear Systems. Springer.
Jurdjevic: Geometric Control Theory. Cambridge.
Coron: Control and Nonlinearity. American Mathematical Society.

Examination

Nichtlineare Kontrolltheorie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-1950: Coding Theory

Codierungstheorie

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Contents:
Die Codierungstheorie ist eine relativ junge mathematische Disziplin, die sich mit dem Entwurf von optimalen fehlererkennenden und fehlerkorrigierenden Codes beschäftigt.
Solche Codes werden überall dort verwendet, wo Informationen (bildlich gesprochen) über einen gestörten Nachrichtenkanal übertragen werden: Durch eine geeignete Codierung der Information vor der Sendung, ist es möglich auch bei Verfälschung die ursprüngliche Nachricht zu rekonstruieren.
Zu den wichtigsten Anwendungen gehören die Übertragung von Satellitenbildern sowie die Verbesserung der Qualität beim Abspielen von Compact Discs. Der mathematische Reiz der Codierungstheorie liegt im Zusammenspiel von Algebra, Kombinatorik und Zahlentheorie, zumal die sog. linearen Codes über endlichen Körpern sehr erfolgreich in der Praxis eingesetzt werden.

Nach einer Einführung und der Formulierung der Hauptproblemstellung verfolgen wir in dieser Vorlesung das Ziel, einige der wichtigsten Klassen von (optimalen) Codes zu beschreiben:

- Dazu zählen zunächst die *Hamming-Codes* und die *Reed-Solomon Codes*, die zur allgemeineren Familie der *zyklische Codes*, insbesondere den BCH-Codes gehören.
- Die *Reed-Muller-Codes* dienen als Ausgangspunkt für die Konstruktion der (optimalen) *Kerdock-* und *Preparata-Codes.*
- Die grundlegenden *Goppa-Codes* sind im Rahmen der *Funktionenkörper-Codes* mittlerweile vielfach verallgemeinert worden.

Learning Outcomes / Competences:
Algebra, Kombinatorik und Zahlentheorie sind klassische Kerngebiete der Mathematik. An dem konkreten Beispiel der Codierungstheorie sollen die Studierenden erkennen, dass durch das Zusammenspiel sehr interessante praktische Problemstellungen adäquat modelliert und gelöst werden können.

Workload:
Total: 180 h
4 h lecture (attendance)

Conditions:
Lineare Algebra I und II, Grundlagen der Algebra, der Kombinatorik und der elementare Zahlentheorie.I

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Codierungstheorie
Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Learning Outcome:

Algebra, Kombinatorik und Zahlentheorie sind klassische Kerngebiete der Mathematik. An dem konkreten Beispiel der Codierungstheorie sollen die Studierenden erkennen, dass durch das Zusammenspiel sehr interessante praktische Problemstellungen adäquat modelliert und gelöst werden können.

Contents:

Die Codierungstheorie ist eine relativ junge mathematische Disziplin, die sich mit dem Entwurf von optimalen fehlererkennenden und fehlerkorrigierenden Codes beschäftigt.
Solche Codes werden überall dort verwendet, wo Informationen (bildlich gesprochen) über einen gestörten Nachrichtenkanal übertragen werden: Durch eine geeignete Codierung der Information vor der Sendung, ist es möglich auch bei Verfälschung die ursprüngliche Nachricht zu rekonstruieren.
Zu den wichtigsten Anwendungen gehören die Übertragung von Satellitenbildern sowie die Verbesserung der Qualität beim Abspielen von Compact Discs. Der mathematische Reiz der Codierungstheorie liegt im Zusammenspiel von Algebra, Kombinatorik und Zahlentheorie, zumal die sog. linearen Codes über endlichen Körpern sehr erfolgreich in der Praxis eingesetzt werden.

Nach einer Einführung und der Formulierung der Hauptproblemstellung verfolgen wir in dieser Vorlesung das Ziel, einige der wichtigsten Klassen von (optimalen) Codes zu beschreiben:

- Dazu zählen zunächst die *Hamming-Codes* und die *Reed-Solomon Codes*, die zur allgemeineren Familie der *zyklische Codes*, insbesondere den BCH-Codes gehören.
- Die *Reed-Muller-Codes* dienen als Ausgangspunkt für die Konstruktion der (optimalen) *Kerdock*- und *Preparata-Codes.*
- Die grundlegenden *Goppa-Codes* sind im Rahmen der *Funktionenkörper-Codes* mittlerweile vielfach verallgemeinert worden.

Literature:

Folgende Liste ist lediglich eine kleine Auswahl. Wir werden zusammen mit dem Vorlesungsskript eine umfassendere Literaturliste ausgeben.

- *Lidl, R., Niederreiter, H.*: Introduction to Finite Fields and their Applications (revised edition). Cambridge University Press, 1994.
- *Pretzel, O.*: Error-Correcting Codes and Finite Fields. Clarendon Press, Oxford, 1992.

Examination

Codierungstheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1978: Lie Groups and Their Representations *Liegruppen und ihre Darstellungen*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Jost-Hinrich Eschenburg		
Learning Outcomes / Competences: Ziel der Vorlesung ist es, die Kompakten Liegruppen und ihre Darstellungen (Stichwort: Weylsche Charakterformel) zu verstehen.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Liegruppen und ihre Darstellungen

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6,00

Contents:

Symmetrien werden in der Mathematik durch Gruppen beschrieben. Für den Würfel zum Beispiel gibt es 24 nicht unterscheidbare (achsenparallele) Positionen, deren Übergänge durch eine Gruppe von 24 Drehungen beschrieben werden. Neben solchen diskreten Symmetrien gibt es auch kontinuierliche, wie zum Beispiel bei der Kugel: Sie lässt sich durch beliebige Drehungen um ihr Zentrum in eine andere, ununterscheidbare Lage bringen. Solche Symmetrien werden durch kontinuierliche Gruppen, sog. Lie-Gruppen beschrieben (nach dem norwegischen Mathematiker Sophus Lie benannt). Das einfachste nichttriviale Beispiel ist die Gruppe aller Drehungen um den Ursprung im euklidischen Raum, die Drehgruppe SO(3). Sie ist nicht nur eine Gruppe, sondern gleichzeitig eine differenzierbare Mannigfaltigkeit (eine Untermannigfaltigkeit im Vektorraum aller reellen 3x3-Matrizen), und die Gruppenoperationen sind differenzierbare Abbildungen. Die Drehgruppe wirkt durch Transformationen auf der Kugel und kennzeichnet damit die Symmetrien der Kugel. Mit jeder abstrakten Gruppe ist also auch ihre Wirkung durch Transformationen auf bestimmten Räumen (anderen Mannigfaltigkeiten) von Bedeutung. Die einfachsten Wirkungen sind die linearen: das sind differenzierbare Gruppenhomomorphismen von eine Gruppe G in eine Matrizengruppe, d.h. in die Gruppe der invertierbaren linearen Abbildungen auf einem Vektorraum. Die Gruppe SO(3) wirkt linear auf dem dreidimensionalen euklidischen Raum, aber sie kann auch noch auf andere Arten als Matrizengruppe dargestellt werden: Eine Drehmatrix A konjugiert eine symmetrische spurfreie 3x3-Matrix S zu einer anderen solchen Matrix S' = ASA* ; damit bewirkt A eine lineare Transformation S nach S' auf dem 5-dimensionalen Vektorraum der spurfreien symmetrischen reellen 3x3-Matrize n. Damit haben wir eine 5-dimensionale Darstellung der Gruppe SO(3). Ziel der Vorlesung ist es, die Kompakten Liegruppen und ihre Darstellungen (Stichwort: Weylsche Charakterformel) zu verstehen.

Voraussetzungen:

Literature:

Adams, F. A.: Lectures on Lie Groups. Benjamin, New York, 1969.
Hsiang, W.Y.: Lectures on Lie Groups. World Scientific, 2000.

Examination

Liegruppen und ihre Darstellungen

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-1998: Graph Theory

Graphentheorie

8 ECTS/LP

Version 1.0.0
Person responsible for module: apl. Prof. Dr. Dirk Hachenberger

Learning Outcomes / Competences:
Graphen dienen praktisch als Standardmodell für jede Art von Objekten, die mit einer binären Relation versehen sind. Anhand ausgewählter Themengebiete erwerben Studierende anhand des Studiums grundlegender Problemstellungen ein tieferes Verständnis für diskrete Strukturen. Dabei wird insbesondere die algebraische, kombinatorisch und zahlentheoretische Denkweise geschult.

Remarks:
Die Module MTH-1990 und MTH-1991 unterscheiden sich im Aufwand (SWS und LP), sind aber inhaltlich nahezu identisch. Daher dürfen Studierende nur eines dieser beiden Module einbringen.

Workload:
Total: 240 h

Conditions:	**Credit Requirements:**
Lineare Algebra I und II, Grundlagen der Algebra, der Kombinatorik und der elementaren Zahlentheorie	Bestehen der Modulprüfung Ausschluss-Bedingung: Dieses Modul darf nicht eingebracht werden, wenn das Modul MTH-1990 bereits eingebracht wurde!

Frequency: Wintersemester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Graphentheorie
Mode of Instruction: lecture + exercise
Language: German
Frequency: Wintersemester

Learning Outcome:
Die Studierenden werden anhand des Studiums einer diskreten algebraischen Struktur ein vertieftes Verständnis von algebraischer, kombinatorischer und zahlentheoretischer Denkweise erwerben.

Assigned Courses:

Graphentheorie (lecture + exercise)
**(in attendance) **
Graphen dienen praktisch als Standardmodell für jede Art von Objekten, die mit einer binären Relation versehen sind. Anhand ausgewählter Themenbereiche erwerben Studierende in dieser Vorlesung ein tieferes Verständnis für diskrete Strukturen. Dabei wird insbesondere die algebraische, kombinatorisch und zahlentheoretische Denkweise geschult. In der Vorlesung werden alle nötigen Grundlagen über Graphen bereitgestellt. Inhaltlich wollen wir uns mit den wichtigsten Bereichen der Graphentheorie auseinadersetzen, wobei der algorithmische Aspekt weitestgehend ausgeblendet wird, weil dies Gegenstand der Vorlesungen Optimierung II und (die ebenfalls in diesem Sommer stattfindende) Kombinatorische Optimierung ist. Zu den uns interessierendenThemen gehören: - Bäume und Kreise - Zusammenhang - Färbungen - Zuordnungen - Planarität - Grundlagen der algebraischen Graphentheorie - spezielle Klassen von Graphen, wie z.B. stark reguläre, sowie perfekte Graphen....

Examination

Graphentheorie

oral exam / length of examination: 30 minutes, graded

Test Frequency:

only in the winter semester

Module MTH-2000: Financial Optimisation *Financial Optimization*		3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ralf Werner		
Learning Outcomes / Competences: Erarbeitung der mathematischen Grundlagen, Qualifizierung zur Anwendung in der industriellen Praxis, Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur		
Workload: Total: 90 h 2 h lecture (attendance)		
Conditions: Lineare und Nichtlineare Optimierung, Stochastik		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Financial Optimization

Mode of Instruction: lecture
Lecturers: Prof. Dr. Ralf Werner
Language: German
Frequency: irregular
Workload:
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
Markowitz-Portfoliooptimierung, Indextracking & Portfolioreplikation, Cash-Flow-Matching & Portfolio Immunisierung, Szenariooptimierung & Stochastische Optimierung, Robuste Optimierung im Asset Management, Semi-infinite Optimierung für Bewertungsprobleme, Dynamische Optimierung für Stoppprobleme

Examination

Financial Optimization
written exam, Mündliche Prüfung à 30 Minuten oder Klausur à 120 Minuten, graded
Test Frequency:
this semester
Description:
Mündliche Prüfung à 30 Minuten

Module MTH-2010: Numerics of Stochastic Differential Equations

Numerik Stochastischer Differentialgleichungen

6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
numerical method for stochastic differential equations, Euler-Maruyama, weak and strong convergence, error estimates

Learning Outcomes / Competences:
The students know the basic terms, concepts and phenomena of the numerical treatment of stochastic differential equations.
of the numerical treatment of stochastic differential equations, can implement the corresponding algorithms and are familiar with the basics of stochastic analysis.
Ability to work independently on further literature.
Competences in the independent processing and implementation of numerical algorithms,
Skills in formulating and working on theoretical and applied problems using the
and applied questions with the help of the methods learnt.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
working with scientific computers,
in-depth competences in the independent processing of problems,
Skills in formulating and working on applied questions.

Workload:
Total: 180 h
2 h exercise course (attendance)
2 h lecture (attendance)

Conditions:	**Credit Requirements:**
knowledge in stochastic differential equations and numerical methods for ordinary differential equations are helpful	oral exam

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik Stochastischer Differentialgleichungen
Language: German / English
Frequency: irregular
Workload:
2 Std. Übung (Präsenzstudium)
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:

Dieses Modul führt in die Theorie der numerischen Behandlung stochastischer Differentialgleichungen ein.
Stochastische Differentialgleichungen
Zeitdiskretisierung
Fehlerabschätzungen
Implementierung numerischer Verfahren
Spektrales Galerkinverfahren für stochastische partielle DGL
Voraussetzungen: Die Vorlesung verwendet die grundlegende Theorie stochastischer Differentialgleichungen.
Zwingend notwendig ist ein gutes Grundwissen in der Wahrscheinlichkeitstheorie,
stochastischen Prozessen und der Analysis.
Hilfreich, aber nicht zwingend notwendig, sind Vorkenntnisse
in gewöhnlichen Differentialgleichungen und Numerik gewöhnlicher Differentialgleichungen,
sowie Programmiererfahrung.

Examination

Numerik Stochastischer Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

Module MTH-2030: Parametric Optimisation

Parametrische Optimierung

5 ECTS/LP

Version 1.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Ralf Werner

Contents:
- Parametrische lineare Optimierung
- Parametrische unrestringierte nicht-lineare Optimierung
- Parametrische restringierte nicht-lineare Optimierung
- Anwendungen

Learning Outcomes / Competences:
- Erarbeitung der mathematischen Grundlagen der parametrischen Optimierung
- Qualifizierung zur Anwendung in Theorie und Praxis
- Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Remarks:
Die Veranstaltung wird vorzugsweise als Blockveranstaltung angeboten.

Workload:
Total: 150 h
3 h lecture and exercise course (attendance)

Conditions:
- Kenntnisse in Optimierung (etwa im Umfang von Optimierung I und II)
- Kenntnisse in numerischen Optimierungsverfahren (etwa Numerische Verfahren der nicht-linearen Optimierung)
- Grundkenntnisse in Funktionalanalysis

Credit Requirements:
Bestehen der Modulprüfung

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 3,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Parametrische Optimierung
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Ralf Werner
Language: German
Frequency: irregular
Contact Hours: 3,00
ECTS Credits: 5.0

Learning Outcome:
- Erarbeitung der mathematischen Grundlagen der parametrischen Optimierung
- Qualifizierung zur Anwendung in Theorie und Praxis
- Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Contents:
- Parametrische lineare Optimierung
- Parametrische unrestringierte nicht-lineare Optimierung
- Parametrische restringierte nicht-lineare Optimierung
- Anwendungen

Literature:

wird am Anfang der Vorlesung bekannt gegeben

Assigned Courses:

Parametrische Optimierung (lecture + exercise)

*(in attendance) *

Erarbeitung der mathematischen Grundlagen der parametrischen Optimierung; Qualifizierung zur Anwendung in Theorie und Praxis; Befähigung zum selbständigen Erarbeiten weiterfu#hrender Fachliteratur

Examination

Parametrische Optimierung

oral exam / length of examination: 15 minutes, graded

Test Frequency:

this semester

Module MTH-2058: Numerical Optimisation Methods for Business Mathematics (Numerical Methods for Business Mathematics I) *Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)*	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Tatjana Stykel

Contents:
Numerische Optimierungsverfahren

Learning Outcomes / Competences:
Verständnis der grundlegenden Fragestellungen der linearen und quadratischen Programmierung sowie allgemeiner Minimierungsprobleme inkl. Algorithmik und Konvergenzanalyse; Kenntnisse der einfachsten Verfahren zur Lösung endlichdimensionaler Optimierungsprobleme, insbesondere mit Nebenbedingungen; integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen in Kleingruppen, Problemstellungen präzise zu definieren, numerische Lösungsstrategien zu entwickeln und deren Tauglichkeit abzuschätzen, dabei wird die soziale Kompetenz zur Zusammenarbeit im Team weiterentwickelt.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Programmierkenntnisse, grundlegende Kenntnisse der Numerik

Frequency: jedes 3. Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)
Mode of Instruction: lecture + exercise
Language: German
Frequency: jedes 3. Semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Numerische Verfahren der linearen und nichtlinearen Optimierung, insbesondere Optimierung ohne und mit Nebenbedingungen, quadratische und sequentielle quadratische Optimierung

Examination
Numerische Optimierungsverfahren der Wirtschaftsmathematik (Numerische Verfahren der Wirtschaftsmathematik I)
portfolio exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2068: Numerical Methods of Financial Mathematics *Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)*	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Malte Peter

Contents:
Finanzmathematik und zugehörige numerische Verfahren

Learning Outcomes / Competences:
Verständnis der grundlegenden Fragestellungen der Finanzmathematik und der einfachsten numerischen Verfahren zur Lösung der zugrundeliegenden Probleme inkl. Algorithmik und Konvergenzanalyse; Kenntnisse der Grundlagen der Optionspreisbewertung inkl. Black-Scholes-Modell, der Monte-Carlo-Methoden, der stochastischen Differentialgleichungen und deren numerischer Lösung sowie der Finite-Differenzen-Approximationen zur Lösung parabolischer Probleme; integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen in Kleingruppen, Problemstellungen präzise zu definieren, numerische Lösungsstrategien zu entwickeln und deren Tauglichkeit abzuschätzen, dabei wird die soziale Kompetenz zur Zusammenarbeit im Team weiterentwickelt.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Grundlegende Kenntnisse der Numerik und der Stochastik

Frequency: each semester 24/25	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)
Mode of Instruction: lecture + exercise
Language: German
Frequency: every 4th semester
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6,00

Contents:
Bewertung von Optionen, insbesondere Grundlagen der Optionsbewertung, Ito-Kalkül, Black-Scholes-Formel und Black-Scholes-Gleichungen, Monte-Carlo-Methoden und Finite-Differenzen-Verfahren

Examination
Numerische Verfahren der Finanzmathematik (Numerische Verfahren der Wirtschaftsmathematik II)
oral exam, mündliche Einzelprüfung / length of examination: 30 minutes, graded
Test Frequency:
this semester

Module MTH-2100: Design Theory *Design Theorie*		3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger		
Contents: Es handelt sich um eine Einführung in die Design Theorie (Blockpläne) unter Betonung der algebraischen Aspekte (Symmetriegruppen) oder Auflistung von Themen.		
Learning Outcomes / Competences: Anwendbarkeit algebraischer Denkweisen in einem kombinatorischen Zusammenhang.		
Workload: Total: 90 h 2 h lecture (attendance)		
Conditions: Gründliche Kenntnis der Linearen Algebra (insbesondere Eigenwerte, Determinanten und symmetrische Bilinearformen). Grundlagen aus der Algebra (Gruppen, Ringe, Körper).		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Design Theorie

Mode of Instruction: lecture
Language: German
Frequency: irregular
Workload:
2 Std. Vorlesung (Präsenzstudium)
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
Es handelt sich um eine Einführung in die Design Theorie (Blockpläne) unter Betonung der algebraischen Aspekte (Symmetriegruppen) oder Auflistung von Themen
Voraussetzungen: Gründliche Kenntnis der Linearen Algebra (insbesondere Eigenwerte, Determinanten und symmetrische Bilinearformen). Grundlagen aus der Algebra (Gruppen, Ringe, Körper).

Literature:
Jacobs K., Jungnickel D., Einführung in die Kombinatorik, 2004, 2. Auflage, Verlag: de Gruyter

Examination

Design Theorie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2118: Continuous Time Finance

Zeitstetige Finanzmathematik

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Ralf Werner

Contents:

Brownsche Bewegung und stochastische Integration (Ito Formel)
Finanzmarktmodelle in stetiger Zeit (Semimartingalmodelle)
Arbitrage
Vollständigkeit
Hauptsatz der Finanzmathematik
Black-Scholes Modell
Bewertung und Hedging in unvollständigen Märkten

Learning Outcomes / Competences:

Erarbeitung der mathematischen Grundlagen für die Bewertung und das Hedgen von Derivaten
Qualifizierung zur Anwendung in Banken, Versicherungen und Asset Management
Befähigung zum selbständigen Erarbeiten weiterführender Fachliteratur

Workload:

Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:		**Credit Requirements:**
Diskrete Finanzmathematik Stochastik IV		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Zeitstetige Finanzmathematik

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Ralf Werner
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Contents:

Brownsche Bewegung und stochastische Integration (Ito Formel)
Finanzmarktmodelle in stetiger Zeit (Semimartingalmodelle)
Arbitrage
Vollständigkeit
Hauptsatz der Finanzmathematik
Black-Scholes Modell
Bewertung und Hedging in unvollständigen Märkten

Literature:

Literatur wird in der Vorlesung bekannt gegeben.

Examination

Zeitstetige Finanzmathematik

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2178: Time Series Analysis *Zeitreihenanalyse (Stochastik IV)*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Gernot Müller		
Learning Outcomes / Competences: Fähigkeit, mit Hilfe statistischer Methoden zeitliche Abhängigkeiten in Daten aufzudecken, zu beschreiben, und für die Zustandsschätzung und Vorhersage zu nutzen.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Stochastik I, Stochastik II		
Frequency: jedes 3. Semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Zeitreihenanalyse

Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: jedes 3. Semester
Contact Hours: 6,00

Contents:

stationäre stochastische Prozesse, Autokovarianzfunktion, WN- und ARMA-Prozesse, Analyse im Zeitbereich, Analyse im Frequenzbereich, Periodogramm, Schätzen von Modellparametern, Vorhersage, rekursive Algorithmen, Zustandsraum-Modelle

Literature:

Brockwell, P.J., Davis, R.A. (1991 / 2009). Time Series - Theory and Methods. Springer

Examination

Zeitreihenanalyse

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2218: Stochastic Evolution Equations

Stochastische Evolutionsgleichungen

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Dirk Blömker

Contents:

Infinite dimensional spaces
Fourier series and transforms
cylindrical Wiener processes
analytic semigroups
stochastic evolution equations
stochastic dynamical systems

Learning Outcomes / Competences:

The students know the basic terms, concepts and phenomena in the field of stochastic evolution equations and stochastic dynamic systems.
Ability to work independently on further research literature, competences in the independent processing of problems, skills in the formulation and processing of theoretical questions with the help of the methods learned.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature, scientific thinking,
deepened competences in the independent processing of problems.

Workload:

Total: 240 h

Conditions:

Knowledge of calculus on infinite dimensional spaces and basic knowledge of stochastics.

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Stochastic Evolution Equations

Language: German
Frequency: irregular
Contact Hours: 6,00

Contents:

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Examination

Stochastic Evolution Equations

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2228: Adaptive Finite Element Methods

Adaptive Finite Elemente-Verfahren

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Daniel Peterseim

Contents:
Diese Vorlesung betrachtet fortgeschrittene Finite-Elemente-Verfahren mit folgenden Inhalten:

In dieser Vorlesung werden Theorie und Implementierung fortgeschrittener Finite-Elemente-Verfahren betrachtet. Dies beinhaltet die folgenden Themengebiete:
1. Residuenbasierte und hierarchische Fehlerschätzer
2. Effizienz und Zuverlässigkeit von Fehlerschätzern
3. Implementierung adaptiver finiter Elemente mit hängenden Knoten
4. Dual gewichtete Residuen
5. Unstetige Galerkin-Verfahren (discontinuous Galerkin, DG) für Transportprobleme
6. DG-Verfahren für Erhaltungsgleichungen

Learning Outcomes / Competences:
In dieser Vorlesung werden Theorie, Anwendung und Implementierung fortgeschrittener Finite-Elemente-Verfahren erlernt, mit einem Schwerpunkt auf A-Posteriori-Fehlerschätzer für Finite Elemente-Approximationen partieller Differentialgleichungen sowie nicht-konforme Finite-Elemente-Verfahren.

Workload:
Total: 240 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Numerik partieller Differentialgleichungen

Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Adaptive Finite Elemente-Verfahren
Language: German
Frequency: irregular
Contact Hours: 6,00

Learning Outcome:
In dieser Vorlesung werden Theorie, Anwendung und Implementierung fortgeschrittener Finite-Elemente-Verfahren erlernt, mit einem Schwerpunkt auf A-Posteriori-Fehlerschätzer für Finite Elemente-Approximationen partieller Differentialgleichungen sowie nicht-konforme Finite-Elemente-Verfahren.

Contents:
In dieser Vorlesung werden Theorie und Implementierung fortgeschrittener Finite-Elemente-Verfahren betrachtet. Dies beinhaltet die folgenden Themengebiete:
1. Residuenbasierte und hierarchische Fehlerschätzer
2. Effizienz und Zuverlässigkeit von Fehlerschätzern
3. Implementierung adaptiver finiter Elemente mit hängenden Knoten
4. Dual gewichtete Residuen
5. Unstetige Galerkin-Verfahren (discontinuous Galerkin, DG) für Transportprobleme
6. DG-Verfahren für Erhaltungsgleichungen

Literature:

R. Verfuerth; A Posteriori Error Estimation Techniques for Finite Element Methods. Oxford University Press, Oxford, 2013

J. Hesthaven, T. Warburton; Nodal Discontinuous Galerkin Methods: Algorithms, Analysis, and Applications. Springer, New York, 2008

Examination

Adaptive Finite Elemente-Verfahren

module exam, Der konkrete Typ der Modulprüfung (Klausur oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben., graded

Test Frequency:

not this semester

Module MTH-2257: Symplectic Geometry *Symplectic Geometry*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Kai Cieliebak		
Learning Outcomes / Competences: Learning about techniques of symplectic geometry and their applications in the theory of classical mechanical systems.		
Remarks: Cannot be combined together with MTH-2250.		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Symplectic Geometry and Hamiltonian Dynamics

Language: English / German
Frequency: every 4th semester
Contact Hours: 6,00

Contents:

This course is an introduction to symplectic techniques in the theory of Hamiltonian systems. It covers the following topics: Hamilton's equations, symplectic manifolds, symmetries and Noether's theorem, symplectic reduction, rigid bodies, integrable systems, stability and the KAM theorem, chaos, applications to celestial mechanics, fluid dynamics, and quantum mechanics.

Voraussetzungen: Basic differential geometry (manifolds, differential forms)

Literature:

V.I.Arnold, Mathematical Methods of Classical Mechanics (Springer)

H.Hofer and E.Zehnder, Symplectic Invariants and Hamiltonian Dynamics (Birkhaeuser)

Examination

Symplectic Geometry and Hamiltonian Dynamics

oral exam / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2280: Stochastic Models for Financial and Energy Markets *Stochastische Modelle für Finanz- und Energiemärkte*	3 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Gernot Müller	
Learning Outcomes / Competences: Kenntnisse über die Funktionsweise und die theoretischen Eigenschaften von Modellen, die zur Beschreibung von Preisen an Finanz- und Energiemärkten geeignet sind; Fähigkeit, die Modelle auf Daten anzuwenden.	
Workload: Total: 90 h 2 h lecture (attendance)	
Conditions: Stochastik I / II, empfohlen: Zeitreihenanalyse	

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Stochastische Modelle für Finanz- und Energiemärkte

Mode of Instruction: lecture
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: irregular
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:

Levy-Prozesse, alpha-stabile Zufallsvariablen, alpha-stabile Prozesse, ARMA-Modelle, SV-Modelle, CARMA-Modelle, zeitstetige SV-Modelle, COGARCH-Modelle, Schätzverfahren; Anwendungen auf Finanz- und Energiemarkt-Daten.

Literature:

neuere wissenschaftliche Veröffentlichungen

Examination

Stochastische Modelle für Finanz- und Energiemärkte

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2328: Markov Chains and Monte-Carlo-Simulation *Markov-Ketten und Monte-Carlo-Simulation*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Gernot Müller		
Learning Outcomes / Competences: Verständnis der mathematischen Konzepte für Markov-Ketten, Verständnis der Funktionsweise von Markov-Chain-Monte-Carlo-Algorithmen, Fähigkeit, solche Algorithmen selbstständig an Modelle zu adaptieren.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Stochastik I / Stochastik II		
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Markov-Ketten und Monte-Carlo-Simulation

Mode of Instruction: lecture + exercise

Lecturers: Prof. Dr. Gernot Müller

Language: German

Frequency: every 4th semester

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6,00

Contents:

Markov-Ketten in diskreter / stetiger Zeit und mit diskretem / stetigem Zustandsraum, Stationarität, Ergodizität, Reversibilität, Markov-Chain-Monte-Carlo-Algorithmen

Literature:

Bremaud, P. (2008). Markov Chains, Gibbs Fields, Monte Carlo Simulation, and Queues. Springer.

Meyn, S.P., Tweedie, R.L. (1993). Markov Chains and Stochastic Stability. Springer.

Robert, C.P., Casella, G. (2004). Monte Carlo Statistical Methods. Springer

Examination

Markov-Ketten und Monte-Carlo-Simulation

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 90 Minuten, graded

Test Frequency:

not this semester

Description:

Die Prüfungsform wird rechtzeitig bekannt gegeben.

Module MTH-2380: Bayesian Statistics and Econometrics

Bayessche Statistik und Ökonometrie

6 ECTS/LP

Version 2.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Gernot Müller

Learning Outcomes / Competences:
Verständnis der mathematischen Konzepte in der Bayesschen Statistik, Kenntnisse über Vor- und Nachteile der Bayesschen Statistik gegenüber der frequentistischen Statistik, Kenntnisse über Einsatzmöglichkeiten der Bayesschen Statistik in der Ökonometrie,
Fähigkeit, Bayessche Verfahren bei praktischen Problemen selbstständig einzusetzen.

Workload:
Total: 180 h
3 h lecture (attendance)
1 h exercise course (attendance)

Conditions:
Stochastik I, Stochastik II

Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Bayessche Statistik und Ökonometrie
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German
Frequency: every 4th semester
Contact Hours: 4,00
ECTS Credits: 6.0

Contents:
Grundlagen der Bayesschen Statistik, Prior-Verteilungen (konjugierte, nichtinformative), Posterior-Verteilungen, Optimalität von Bayesschätzern, Bayes-Tests, Schätzungen der Posterior-Verteilung über MCMC Methoden, Bayessche Netzwerke, Anwendungen der Bayesschen Statistik in der Ökonometrie.
Voraussetzungen: Stochastik 1 und 2

Literature:
Blake, A., and Mumtaz, H. (2012). Applied Bayesian Econometrics for Central Bankers. Bank of England / CCBS Technical Handbook No. 4.
Carlin, B.P., and Louis, Th.A. (2009). Bayesian Methods for Data Analysis. Chapman and Hall.
Efron, B. (1986). Why Isn't Everyone a Bayesian? The American Statistician 40 (1) 1-5
Gelman, A., Carlin, J.B., Stern, H.S., and Rubin, D.R. (1995). Bayesian Data Analysis. Chapman and Hall.
Geweke, J. (2005). Contemporary Bayesian Econometrics and Statistics., Wiley.
Geweke, J., Koop, G., and van Dijk, H. (Eds.) (2011). The Oxford Handbook of Bayesian Econometrics. Oxford.
Koop, G. (2003). Bayesian Econometrics. Wiley.
Robert, Ch. (2007). The Bayesian Choice. Springer.

Examination

Bayessche Statistik und Ökonometrie

module exam, Mündliche Prüfung / length of examination: 30 minutes, graded

Test Frequency:

not this semester

Module MTH-2510: Advanced Methods in Machine Learning *Advanced Methods in Machine Learning*	3 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Gernot Müller	
Contents: basics of machine learning, learnability, bias-complexity tradeoff, VC-dimension, deep feedforward networks, several case studies	
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results	
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)	
Conditions: Stochastik I, Stochastik II	**Credit Requirements:** Passing the module exam

Frequency: irregular / 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Methods in Machine Learning
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German / English
Frequency: irregular every 4th semester
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
-

Literature:
recent publications about machine learning (depending on the current semester)

Examination
Advanced Methods in Machine Learning
module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 60 Minuten / length of examination: 60 minutes, graded
Test Frequency:
not this semester

Module MTH-2511: Advanced Methods in Machine Learning II *Advanced Methods in Machine Learning II*		3 ECTS/LP
Version 1.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Gernot Müller		
Contents: linear predictors, half-spaces, Perceptron algorithm, boosting, AdaBoost, support vector machines		
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results		
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II, AMML (MTH-2510)		**Credit Requirements:** Passing the module exam
Frequency: irregular / 4h semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Methods in Machine Learning II
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German / English
Frequency: irregular / 4h semester
Contact Hours: 2,00
ECTS Credits: 3.0

Contents:
-

Literature:
recent publications about machine learning (depending on the semester)

Examination
Advanced Methods in Machine Learning II
module exam, - / length of examination: 60 minutes, graded
Test Frequency:
not this semester

Module MTH-2548: Floer Homology *Floer Homologie*		8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Urs Frauenfelder		
Contents: Arnold conjecture, Analysis of pseudoholomorphic curves, Rabinowitz action functional		
Remarks: Cannot be combined together with MTH-2540.		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Floer Homologie
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Contents:
Arnold conjecture, Analysis of pseudoholomorphic curves, Rabinowitz action functional

Examination
Floer Homologie
oral exam / length of examination: 30 minutes, graded
Test Frequency:
this semester

Module MTH-2581: Advanced Survival Analysis

Advanced Survival Analysis

8 ECTS/LP

Version 1.3.0 (since WS22/23)
Person responsible for module: Prof. Dr. Sarah Friedrich-Welz

Contents:

- Besonderheiten von Überlebenszeitdaten: Zensierung/Trunkierung
- Martingale, Zählprozesse, stochastische Integrale
- Nelson-Aalen, Kaplan-Meier und Aalen-Johansen Schätzer
- Konkurrierende Risiken und Mehrstadienmodelle
- Cox Regression
- Asymptotik (schwache Konvergenz, gleichmäßige Konsistenz), Martingaltheorie

Learning Outcomes / Competences:
Nach der Teilnahme an diesem Modul verfügen die Studierenden über detailliertes und aktuelles Wissen auf dem Gebiet der Überlebenszeitanalyse (Survival Analysis). Sie können Problemstellungen und Ergebnisse des Gebiets präzise beschreiben und diskutieren. Darüber hinaus verstehen die Studierenden mathematische Konzepte, Methoden, Verfahren und Techniken, um Ereigniszeitdaten zu analysieren.

Workload:
Total: 240 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions: Stochastik I + II		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Survival Analysis

Mode of Instruction: lecture + exercise
Language: German / English
Frequency: irregular
Contact Hours: 6,00
ECTS Credits: 8.0

Literature:

- Andersen, Borgan, Gill, Keiding: Statistical Models Based on Counting Processes, Springer 1993
- Aalen, Borgan, Gjessing: Survival and Event History Analysis, Springer 2008
- Beyersmann, Allignol, Schumacher: Competing Risks and Multistate Models with R, Springer 2012

Examination

Advanced Survival Analysis
written exam, Die genauer Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
not this semester

Module MTH-2600: Nonparametric Statistics

Nichtparametrische Statistik

6 ECTS/LP

Version 1.0.0 (since WS22/23)
Person responsible for module: Prof. Dr. Sarah Friedrich-Welz

Contents:

- Besonderheiten der nichtparametrischen Statistik: Nichtparametrische Effekte und Hypothesen im Vergleich zur parametrischen und semi-parametrischen Statistik
- Empirische Verteilungen und Ränge
- Relative Effekte und deren Schätzer
- Einfaktorielle Versuchspläne: Wilcoxon-Mann-Whitney-Test, das nichtparametrische Behrens-Fischer-Problem, Kruskal-Wallis-Test
- Mehrfaktorielle Versuchspläne

Learning Outcomes / Competences:

Nach der Teilnahme an diesem Modul kennen die Studierenden den Unterschied zwischen der nichtparametrischen und der parametrischen Datenanalyse. Sie erkennen, wann eine nichtparametrische Datenanalyse notwendig ist, sind mit den Grundbegriffen der Rangstatistiken vertraut, können Rangverfahren für ausgewählte faktorielle Versuchspläne durchführen und kennen deren theoretische, mathematische Grundlagen.

Workload:

Total: 180 h
2 h exercise course (attendance)
2 h lecture (attendance)

Conditions: Stochastik I und II		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular (usu. winter semester)	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Übung Nichtparametrische Statistik

Mode of Instruction: lecture + exercise
Language: German / English

Literature:

Brunner, Konietschke, Bathke: *Rank and Pseudo-Rank Procedures for Independent Observations in Factorial Designs,* Springer 2018
Brunner, Munzel: *Nichtparametrische Datenanalyse,* Springer 2013

Examination

Nichtparametrische Statistik

portfolio exam, Die genauer Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded

Test Frequency:

not this semester

Module MTH-2670: Computational Algebraic Geometry *Computational Algebraic Geometry*	6 ECTS/LP
Version 1.0.0 (since SoSe24) Person responsible for module: Prof. Dr. André Uschmajew	

Contents:
1. Polynomial Rings
2. Gröbner Bases
3. Elimination Theory
4. Computer Algebra Systems
5. Applications

Learning Outcomes / Competences:
In this lecture we will learn about the algebra and the geometry of nonlinear polynomial equations. We will develop the theory of polynomial algebra and we will discuss how to solve these systems algorithmically using computer algebra. Depending on time and interest of the participants, we will see selected applications in statistics and data science.

Workload:
Total: 180 h

Conditions:		**Credit Requirements:**
Linear Algebra. A course in abstract algebra is useful but not necessary.		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Computational Algebraic Geometry
Language: English / German
Frequency: einmalig SoSe
Contact Hours: 4,00
ECTS Credits: 6.0

Literature:
David A. Cox, John Little, and Donal O'Shea. Ideals, Varieties, and Algorithms: An Introduction to Computational Algebraic Geometry and Commutative Algebra. Springer, 2007.
Viviana Ene and Jurgen Herzog. Gröbner Bases in Commutative Algebra. American Mathematical Society, 2012.

Examination
Computational Algebraic Geometry
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-2698: Inverse Problems

Inverse Probleme

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Jan-Frederik Pietschmann

Contents:

* Charakterisierung inverser Aufgaben anhand von angewandten Beispielen aus der Mathematik, den Naturwissenschaften und dem Ingenieurwesen
* die Hadamard'sche Korrektheitsdefinition und das Phänomen der Inkorrektheit
* Inverse Probleme als lineare und nichtlineare Operatorgleichungen in Banach- und Hilberträumen mit Schwerpunkt auf linearen Problemen
* Singulärwertzerlegung kompakter Operatoren und Grad der Inkorrektheit
* Theorie und Praxis der Regularisierung inkorrekter Aufgaben mit Mitteln der Analysis, Numerik, Optimierung und Stochastik
* Konvergenzraten und Quelldarstellungen
* Statistische Inverse Probleme

Learning Outcomes / Competences:

Ziel dieses Moduls ist die Einführung in die Mathematik inverser Probleme, wobei sowohl die angewandte Komponente (naturwissenschaftlich-technische und ökonomische Probleme inverser Natur) als auch die theoretische Komponente (funktionalanalytische Behandlung, Nutzung von Techniken der Analysis, Numerik, Optimierung und Stochastik) eine unverzichtbare Rolle spielen. Die Studenten erwerben die Kompetenz zum Erkennen inverser Problemstellungen und ihrer Instabilität und zum Überwinden der spezifischen Probleme durch angepasste Techniken der Regularisierung mittels objektiver und subjektiver Apriori-Informationen im Rahmen mathematischer Handwerkszeuge.

Remarks:

Kann nicht gemeinsam mit MTH-2690 eingebracht werden

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
Funktionalanalysis		Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Inverse Probleme

Language: German / English

Examination

Inverse Probleme

portfolio exam, graded

Test Frequency:

not this semester

Module MTH-2708: Advanced Discrete Probability

Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie

8 ECTS/LP

Version 1.0.0 (since SoSe25)
Person responsible for module: Prof. Dr. Markus Heydenreich

Learning Outcomes / Competences:
Studierende lernen in diesem Kurs aktive Forschungsgebiete der diskreten Wahrscheinlichkeitstheorie kennen. Sie kennen wesentliche Theorielinien und können den Beweis zentraler Resultate skizzieren. Sie sind in der Lage mit den erlernten Techniken eigene Beweise zu erarbeiten.
Integrierter Erwerb von Schlüsselqualifikationen: Eigenständiges Arbeiten mit (englischsprachiger) wissenschaftlicher Literatur, wissenschaftliches Denken, vertiefte Kompetenzen in der selbständigen Bearbeitung von Problemstellungen

Workload:
Total: 240 h

Conditions:
Lineare Algebra I
Analysis I
Analysis II
Stochastik I
Stochastik II (kann parallel gehört werden)

Credit Requirements:
Bestehen der Modulprüfung

Frequency: irregular

Recommended Semester:
1. - 4.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie
Language: English / German
Contact Hours: 6,00

Contents:
Im Kurs werden Studierende anhand ausgewählter Themen in aktuelle Forschungsthemen aus der diskreten Wahrscheinlichkeitstheorie eingeführt. Dabei werden sowohl grundlegende Beweistechniken erarbeitet also auch einige der neuesten Resultate präsentiert.
Themen und Format variieren, im Sommersemester 2025 findet ein Lesekurs zur Mathematischen Statistischen Physik statt.

Examination
Fortgeschrittene Themen der diskreten Wahrscheinlichkeitstheorie
portfolio exam, Die genaue Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
not this semester

Module MTH-2738: Homotopy Theory

Homotopietheorie

8 ECTS/LP

Version 1.0.0

Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:

Die Studierenden lernen grundlegende Konzepte, Techniken und Resultate der modernen Homotopietheorie und wissen, wie man sie in verschiedenen Bereichen der Geometrie und Algebra anwenden kann.

Workload:

Total: 240 h

Conditions:

keine

Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:**	

Parts of the Module

Part of the Module: Modulteil: Homotopietheorie

Language: German / English

Frequency: irregular (usu. winter semester)

Contact Hours: 6,00

Contents:

Die moderne Homotopietheorie ist eine axiomatische Theorie, die auf so unterschiedliche Bereichen der Mathematik wie Topologie, algebraischer Geometrie, Operatortheorie und Darstellungstheorie gleichermaßen anwendbar ist, und in deren Zentrum der Begriff von unendlich-Kategorien steht. Die Vorlesung bietet einen Einstieg in die moderne Homotopietheorie aus praxisorientierter Sicht, d. h. im Vordergrund steht nicht der systematische Aufbau der Theorie, sondern ein möglichst schneller Weg zu den zentralen Konzepten. Im Vordergrund steht dabei das Erlernen der kategoriellen Sprache und Techniken und der Überblick über verschiedene Anwendungen in unterschiedlichen Bereichen der Mathematik.

Assigned Courses:

Vorlesung und Übung: Homotopietheorie (lecture + exercise)

**(in attendance) **

Examination

Prüfung

oral exam / length of examination: 45 minutes, graded

Test Frequency:

this semester

Module MTH-2758: High-Dimensional Probability with Applications to Data Science

Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science

8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Stefan Großkinsky

Contents:
1. Preliminaries on random variables
2. Concentration of sums of independent random variables
3. Random vectors in high dimensions
4. Random matrices
5. Concentration without independence
6. Quadratic forms, symmetrization and contraction
7. Random processes

Learning Outcomes / Competences:
Erlernen der wahrscheinlichkeitstheorietischen Grundlagen des Data Science. Studierende können Fragestellungen in Data Science mathematisch-präzise formulieren und rigorose Lösungen erarbeiten.

Workload:
Total: 240 h

Conditions: Probability Theory (e.g. Stochastik I), Analysis I+II. Linear Algebra I+II		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: every 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science
Language: English
Frequency: every 4th semester
Contact Hours: 6,00

Examination
Hochdimensionale Wahrscheinlichkeitstheorie mit Anwendungen in Data Science
portfolio exam, Die genaue Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben., graded
Test Frequency:
only in the summer semester

Module MTH-3258: Complex Geometry I *Complex Geometry I*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Workload: Total: 240 h		
Conditions: • Grundvorlesungen in linearer Algebra • Grundvorlesungen in Analysis • Funktionentheorie		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Complex Geometry I **Language:** German

Examination

MTH-3258 Complex Geometry I

oral exam, graded

Test Frequency:

each semester

Module MTH-3269: Lie Groups and Homogeneous Spaces *Lie-Gruppen und homogene Räume*		8 ECTS/LP
Version 1.0.0 Person responsible for module: Dr. Peter Quast		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency:	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Lie-Gruppen und homogene Räume
Language: German
Contact Hours: 6,00

Examination
Lie-Gruppen und homogene Räume
module exam, schriftliche Prüfung oder mündliche Prüfung oder Portfolioprüfung, graded
Test Frequency:
not this semester

Module MTH-3308: Mathematical Physics *Mathematische Physik*	8 ECTS/LP
Version 1.0.0 (since SoSe25) Person responsible for module: Prof. Dr. Urs Frauenfelder	
Contents: In this course several topics of mathematical physics are discussed like the question about the quantization of a classical mechanical system and the connection between its geometry and dynamics.	
Remarks: Cannot be combined together with MTH-3300.	
Workload: Total: 240 h	

Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematische Physik
Language: German / English
Frequency: irregular
Contact Hours: 6,00

Examination
Mathematische Physik
portfolio exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module MTH-3668: Selected Topics in Numerics *Ausgewählte Themen der Numerik*	8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Daniel Peterseim Stykel, Tatjana, Prof. Dr.	
Contents: Die konkrete Themenauswahl wird regelmäßig aktualisiert und orientiert sich an aktuellen Fragestellungen und Trends in Forschung und Anwendung.	
Learning Outcomes / Competences: Deeper understanding of the finite element method in its most important versions; connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; understanding of the problems arising from multiple scales as well as basic solution ideas; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.	
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)	
Conditions: Empfohlen: Einführung in die Numerik, Numerik gewöhnlicher DIfferentialgleichungen, Numerik partieller Differentialgleichungen	

Frequency: irregular	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Ausgewählte Themen der Numerik
Language: English / German
Contact Hours: 6,00
ECTS Credits: 9.0

Learning Outcome:

Die Studierenden entwickeln ein vertieftes Verständnis für moderne Verfahren der numerischen Mathematik und ihrer theoretischen Grundlagen. Sie lernen, komplexe numerische Algorithmen selbstständig zu entwerfen, zu analysieren und hinsichtlich Stabilität, Konvergenz, Effizienz und Robustheit zu bewerten. Zudem erlangen sie die Kompetenz, anspruchsvolle numerische Methoden zur Lösung wissenschaftlicher und praxisrelevanter Probleme zu konzipieren und in geeigneten Programmiersprachen umzusetzen. Schließlich lernen sie, numerische Ergebnisse kritisch zu beurteilen, Fehlerquellen zu identifizieren und angemessene Methoden für spezifische Anwendungen oder Forschungsfragen auszuwählen.

Contents:

Die konkrete Themenauswahl wird regelmäßig aktualisiert und orientiert sich an aktuellen Fragestellungen und Trends in Forschung und Anwendung.

Examination

Ausgewählte Themen der Numerik

module exam, mündliche Prüfung / length of examination: 30 minutes, graded

Test Frequency:

when a course is offered

Module MTH-4290: Selected Topics in Mathematical Data Science *Spezielle Kapitel der Mathematical Data Science*		3 ECTS/LP
Version 1.0.0 (since WS25/26) Person responsible for module: Prof. Dr. André Uschmajew		
Learning Outcomes / Competences: Die Studierenden vertiefen ihre Kenntnisse in speziell ausgewählten Kapiteln der Mathematical Data Science.		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Spezielle Kapitel der Mathematical Data Science
Language: German / English

Examination
MTH-4290 Spezielle Kapitel der Mathematical Data Science
oral exam / length of examination: 30 minutes, graded
Test Frequency:
not this semester

Module INF-0227: Seminar Database Systems (Master)

Seminar Datenbanksysteme für Master

4 ECTS/LP

Version 1.0.0 (since SoSe16)
Person responsible for module: Prof. Dr. Peter Michael Fischer

Learning Outcomes / Competences:
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.
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.
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.
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.

Remarks:
language (D/E) as requested by the students

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: Module Database Systems (INF-0073) - recommended		**Credit Requirements:** Passing the module exam
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Datenbanksysteme für Master
Mode of Instruction: seminar
Language: German / English
Frequency: irregular (usu. summer semester)
Contact Hours: 2,00

Contents:
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

Module INF-0344: Seminar Software Engineering of Distributed Systems (Master)

Seminar Software Engineering verteilter Systeme (MA)

4 ECTS/LP

Version 1.0.0 (since SoSe20)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
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.

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 www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions:
The previous course "Seminar on Software Engineering of Distributed Systems (MA)" (INF-0039) must not have been taken due to overlaps.

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering verteilter Systeme (MA)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 2,00

Contents:
Current software engineering topics from industry and research.

Literature:
Will be presented in the respective kick-off event.

Assigned Courses:

Seminar Software Engineering verteilter Systeme (Master) (seminar)

*(in attendance) *

Bestandteil dieses Seminars sind fortgeschrittene Ansätze und Techniken im Bereich Software Engineering. Dies betrifft alle Phasen des Softwareentwicklungszyklus von der Anforderungsanalyse bis hin zum Testen. Modellierungstechniken sowie domänenspezifische Sprachen bilden einen Schwerpunkt des Seminars.

Examination

Seminar Software Engineering verteilter Systeme (MA)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0364: Seminar Software Engineering in Safety- and Security-Critical Systems (Master) *Seminar Software Engineering in sicherheitskritischen Systemen (MA)*	4 ECTS/LP

Version 1.0.0 (since WS20/21)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
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.

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 www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions:
none

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering in sicherheitskritischen Systemen (MA)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 2,00

Contents:
Current software engineering topics from industry and research.

Literature:
Will be presented in the respective kick-off event.

Assigned Courses:

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

*(in attendance) *

Bestandteil dieses Seminars sind fortgeschrittene Ansätze und Techniken im Bereich Software Engineering. Dies betrifft alle Phasen des Softwareentwicklungszyklus von der Anforderungsanalyse bis hin zum Testen. Modellierungstechniken sowie domänenspezifische Sprachen bilden einen Schwerpunkt des Seminars.

Examination

Seminar Software Engineering in sicherheitskritischen Systemen (MA)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0385: Seminar Resource Aware Algorithmics (Master)

Seminar Resource Aware Algorithmics (Master)

4 ECTS/LP

Version 1.0.0 (since SoSe21)
Person responsible for module: Prof. Dr. Tobias Mömke

Learning Outcomes / Competences:
After attending the seminar, the students are able to understand basic algorithmic concepts, methods, tools and techniques in a self-sufficient manner.

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 writte form.

The participants have learned to express techical contents in a sturctured, 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.

Key Qualifications: Literature research; work with scientific literature in English language; analytic copetences; clean scientific practice; ability to present techincal 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.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions:	**Credit Requirements:**
Good knowledge of content taught in mathematical Bachelor classes such as "Mathematik für Informatiker 1" and "Diskrete Strukturen und Logik." Knowledge about algorithms and data structures (Informatik 3) is useful.	Passing of the module exam

Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Resource Aware Algorithmics (Master)
Mode of Instruction: seminar
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:
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.

Literature:
Depending on the topic of the seminar.

Assigned Courses:

Seminar Resource Aware Algorithmics (Master) (seminar)
**(in attendance) **

Examination

Seminar Resource Aware Algorithmics (Master)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0439: Seminar Quantum Algorithms (Master) *Seminar Quantum Algorithms (Master)*	4 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Jakob Siegfried Kottmann

Contents:
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.

Learning Outcomes / Competences:
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.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Quantum Algorithms (Master)
Mode of Instruction: seminar
Language: English / German
Frequency: each summer semester
Contact Hours: 2,00

Contents:
The topics of the seminar are redefined each time and adapted to current developments.

Literature:
Depends on chosen topic

Assigned Courses:

Seminar Quantenalgorithmen (Bachelor & Master) (seminar)

*(hybrid/mixed) *
Im Seminar werden die Inhalte aus der Vorlesung "Grundlagen der Quanteninformationsverarbeitung" vertieft. Spezifische Themen orientieren sich an aktueller Forschung. Hierbei werden in der Vorlesung aufgegriffene Anwendungsbeispiele und Themenfelder vertieft oder neue Themenfelder erschlossen. Das Seminar eignet sich als Vorbereitung einer Abschlussarbeit im Bereicht der Quantenalgorithmik. Eine kleine Auswahl:
- Differenzierbare Quantenalgorithmen - Quantensimulation fermionischer Systeme (e.g. Elektronen in Molekülen) - Komplexität von Quantenalgorithmen - Funktionalität und Limitierungen von aktuell existierenden Quantencomputern

Examination

Seminar Quantum Algorithms (Master)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0444: Seminar Generative Artificial Intelligence *Seminar Generative Künstliche Intelligenz*	4 ECTS/LP

Version 1.0.0 (since SoSe23)
Person responsible for module: Prof. Dr. Elisabeth André

Learning Outcomes / Competences:
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.

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.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions:
none

Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Generative Artificial Intelligence
Mode of Instruction: seminar
Language: German / English
Frequency: each summer semester
Contact Hours: 2,00

Contents:
Topics in the field of "Generative Artificial Intelligence"

Literature:
References will be announced at the preliminary meeting.

Assigned Courses:

Seminar Generative Künstliche Intelligenz (seminar)

*(in attendance) *
Das Seminar „Generative Künstliche Intelligenz“ richtet sich an Studierende im Masterstudiengang. Die einzelnen Themen für dieses Seminar werden unter Berücksichtigung aktueller Trends im Bereich generativer KI-Systeme festgelegt.

Examination

Seminar Generative Artificial Intelligence

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0468: Seminar Natural Language Understanding (Master)

Seminar Natural Language Understanding (Master)

4 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Annemarie Friedrich

Learning Outcomes / Competences:
Natural Language Understanding (NLU) is a subfield of Natural Language Processing (NLP) that aims to enable machines to understand the meaning, intent, and context of human language. It uses AI methods such as rule-based approaches, machine learning, deep learning, and modern architectures like transformers, generative AI, and large language models (LLMs) to interpret and reason over text and speech. Students will acquire core knowledge of the related concepts and technology. They have the working techniques, communication skills and ability to use appropriate media to present a special 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. 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. Key qualifications: Literature research; Independent work with English-language specialist literature; Analyticalmethodical 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.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Presentation and term paper
Frequency: irregular	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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 natural language processing, with a focus on computational semantics, 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 Natural Language Understanding (Master) (seminar)

*(in attendance) *

Examination

Seminar Natural Language Understanding (Master)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0471: Seminar Networked Systems and Communication Networks (Master) *Seminar Vernetzte Systeme und Kommunikationsnetze (Master)*	4 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module:
Prof. Dr. Michael Seufert

Learning Outcomes / Competences:
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.

Schlüsselqualifikationen: 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

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Vernetzte Systeme und Kommunikationsnetze (Master)
Mode of Instruction: seminar
Language: German
Frequency: irregular
Contact Hours: 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) **

Restplätze verfügbar

Examination

Seminar Vernetzte Systeme und Kommunikationsnetze (Master)

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-0474: Project Module Networked Systems and Communication Networks

Projektmodul Vernetzte Systeme und Kommunikationsnetze

10 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module:
Prof. Dr. Michael Seufert

Learning Outcomes / Competences:
Nach der Teilnahme am Projektmodul verstehen die Studierenden Problemstellungen höherer Komplexität auf dem Gebiet der vernetzten Systeme und Kommunikationsnetze 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.

Schlüsselqualifikationen: 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

Workload:
Total: 300 h
285 h internship / practical course (self-study)
15 h seminar (attendance)

Conditions:	Credit Requirements:
none	Bestehen der Modulprüfung

Frequency:	Recommended Semester:	Minimal Duration of the Module:
each semester	from 1.	1 semester[s]

Contact Hours:	Repeat Exams Permitted:
1,00	according to the examination regulations of the study program

Parts of the Module

Part of the Module: Projektmodul Vernetzte Systeme und Kommunikationsnetze
Mode of Instruction: internship
Language: English / German
Frequency: each semester
Contact Hours: 1,00

Contents:
Autonome Mitarbeit an aktuelle Forschungsthemen.

Literature:
wissenschaftliche Papiere, Handbücher

Assigned Courses:

Oberseminar Vernetzte Systeme und Kommunikationsnetze
**(online/digital) **

Das Oberseminar fasst Vorträge von Abschlussarbeiten und Praxis-/Forschungs-/Projektmodulen zusammen. Wenn Sie ein solches Modul belegen wollen, schauen Sie sich auf unserer Lehrstuhlhomepage unsere Forschungsthemen bzw. Themenvorschläge für studentische Arbeiten an und kontaktieren direkt einen Mitarbeiter, dessen Forschung Sie interessiert: https://www.uni-augsburg.de/de/fakultaet/fai/informatik/prof/netcom/ Die alleinige Teilnahme am Oberseminar ist freiwillig und gibt keine ECTS-Punkte.

Examination

Projektmodul Vernetzte Systeme und Kommunikationsnetze

practical exam, graded

Test Frequency:

when a course is offered

Module INF-0479: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision *Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision*	4 ECTS/LP

Version 1.0.0 (since WS23/24)
Person responsible for module: Prof. Dr. Jörg-Dieter Stückler

Learning Outcomes / Competences:
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.

Key qualifications: 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.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Current Topics in Embodied Artificial Intelligence and Computer Vision
Mode of Instruction: seminar
Language: English / German
Frequency: irregular
Contact Hours: 2,00

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

Module INF-3019: Seminar Data Engineering (Master)

Seminar Data Engineering Master

4 ECTS/LP

Version 1.0.0 (since WS24/25)
Person responsible for module: Prof. Dr. Fabian Panse

Learning Outcomes / Competences:
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.
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.
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.
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.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Data Engineering Master
Language: German / English
Frequency: irregular (usu. winter semester)
Contact Hours: 2,00

Contents:
Current research topics from the field of data engineering, such as data cleaning, schema matching, or entity matching.

Literature:
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) **

In this seminar, three scientific papers will first be jointly reviewed and discussed at two-week intervals. Each participant will then focus on the topic assigned to them at the beginning. These topics will be presented and discussed at the end of the lecture period.

Examination

Seminar Data Engineering Master

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-3023: Seminar Software Engineering for Artificial Intelligence Systems (Master)

Seminar Software Engineering for Artificial Intelligence Systems Master

4 ECTS/LP

Version 1.0.0 (since WS24/25)
Person responsible for module: Prof. Dr. Bernhard Bauer

Learning Outcomes / Competences:
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 www.DeepL.com/Translator (free version)

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Software Engineering for Artificial Intelligence Systems Master
Mode of Instruction: seminar
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:
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.

Literature:
Will be presented at the respective kick-off event.

Assigned Courses:

Seminar Software Engineering for Artificial Intelligence Systems Master (seminar)

**(in attendance) **

Bestandteil dieses Seminars sind fortgeschrittene Ansätze und Techniken im Bereich des Software Engineerings, speziell für Systeme der Künstlichen Intelligenz. Dies betrifft alle Phasen des Softwareentwicklungszyklus, von der Anforderungsanalyse bis hin zum Testen und Deployment von KI-Systemen. Darüber hinaus werden spezifische Herausforderungen und Best Practices bei der Entwicklung von KI-Systemen behandelt, wie z.B Datenmanagement, Algorithmen, Model-Architekturen und die Gewährleistung von Transparenz und Fairness in KI-Modellen.

Examination

Presentation and written paper

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-3029: Seminar Theoretical Computer Science (Master) *Seminar Theoretical Computer Science - Master*	4 ECTS/LP

Version 1.0.0 (since WS24/25)
Person responsible for module: Prof. Dr. Pascal Lenzner

Learning Outcomes / Competences:
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.
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.
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.
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.

Key skills: 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

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of written term papers (self-study)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar Theoretical Computer Science - Master
Mode of Instruction: seminar
Language: German / English
Frequency: irregular
Contact Hours: 2,00

Contents:
There are new topics every semester

Literature:
Scientific papers

Assigned Courses:

Seminar zu Logik (seminar)
*(in attendance) *

Examination

Seminar Theoretical Computer Science - Master
written/oral exam, graded

Test Frequency:
when a course is offered

Module INF-3057: Seminar on Machine Learning and Computer Vision Master

Seminar on Machine Learning and Computer Vision Master

4 ECTS/LP

Version 1.0.0 (since SoSe26)
Person responsible for module: Prof. Dr. Rainer Lienhart

Learning Outcomes / Competences:
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.

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.

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.

Key Qualifications: 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.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions: none		**Credit Requirements:** Passing the module exam
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2,00	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar on Machine Learning and Computer Vision Master
Language: German / English
Frequency: each semester
Contact Hours: 2,00

Contents:
The specific topic of the seminar within the broad field of Multimedia is defined annually and adapted to current topics.

Literature:
Current research literature

Assigned Courses:

Seminar on Machine Learning and Computer Vision Master (seminar)

*(in attendance) *

Examination

Seminar on Machine Learning and Computer Vision Master

written/oral exam, graded

Test Frequency:

when a course is offered

Module INF-3061: Seminar Intelligent Energy Systems Master

Seminar Intelligent Energy Systems

4 ECTS/LP

Version 1.0.0 (since SoSe26)
Person responsible for module: Prof. Dr. Nicole Ludwig

Learning Outcomes / Competences:
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.

Key Qualifications: 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.

Workload:
Total: 120 h
90 h preparation of written term papers (self-study)
30 h seminar (attendance)

Conditions:
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.

Credit Requirements:
Passing the module exam

Frequency: each summer semester

Recommended Semester:
1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
2,00

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Seminar Intelligent Energy Systems
Mode of Instruction: seminar
Language: English
Frequency: each summer semester
Contact Hours: 2,00

Contents:
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.

Literature:
dependent on individual topic

Assigned Courses:

Seminar Intelligent Energy Systems (Master) (seminar)

**(in attendance) **

Climate projections guide long-term decisions on the energy system, from the expansion of solar and wind power to the adaptation of infrastructure. However, the models behind these projections are expensive to run. Their largest uncertainties come from processes smaller than the model grid, such as clouds and convection. Machine learning (ML) parameterizations can represent these processes at a fraction of the computational cost. For this reason, they have received much interest in recent years. In this seminar, we explore ClimSim [1], a large benchmark for ML parameterizations in climate models, which was also the basis of a Kaggle competition [2]. You will receive a working data pipeline, a training framework and a test suite. For your own project, you will study one of the baseline models from the paper [1], which include methods such as multilayer perceptrons, convolutional networks, encoder-decoders and probabilistic models. You will also have the chance to explore extensions such...

Examination

Seminar Intelligent Energy Systems

written/oral exam, graded

Test Frequency:

when a course is offered